



National Aeronautics and Space Administration

The Apollo Spacecraft - A Chronology.

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Foreword

The chronology of the development of the Apollo spacecraft and the lunar mission provides specific documented information covering a wide range of happenings both directly and indirectly related to the program. This wealth of material should be of value to historians and others interested in the events of the great adventure. The foreword presents a synopsis of the first several years of the program as seen from the vantage point of the first Apollo Project Office Manager. It is hoped that it will aid the user of the chronology by providing context for some of the material presented.

A discussion of the Apollo Spacecraft Program must include reference to the Mercury and Gemini Programs, not because they are manned space programs but because of the interrelationship between the programs in time, in people, and in organizations, and the differences and similarities in the requirements of the programs. The Mercury Program had a very specific objective, namely to place a man in orbit and return him to earth. The Gemini Program was somewhat different. It was operating in the same earth orbital environment as Mercury but had as its goal a number of objectives which were intended to explore and develop our capabilities to work in this environment. In doing this, the Gemini Program had more resources than Mercury, in terms of increased payload weight in orbit. Apollo is more like Mercury. It has a well-defined objective that involves moving into a new environment deep space - and resources that offer little if any payload capability beyond that required to achieve the objective. Perhaps the Apollo Applications Program will be to Apollo what Gemini has been to Mercury, establishing an operational capability in an environment which has been first explored in a prior program.

The Mercury project was formally initiated in October 1958 and at that time the Space Task Group was formed to manage the project. This group and others had been studying the specifics of the program for over a year at Langley and other NACA Centers. During 1959, the requirements of the Mercury Program left no time for advanced program study by the Space Task Group. In 1960, the first organized activity related to advanced mission study began. Committee studies, such as that carried out by the Goett Committee, had indicated that the lunar mission should be the next major manned objective. With this in mind, a series of technical guidelines was developed to guide the spacecraft studies. These guidelines were based on assumptions that launch vehicles then planned were capable only of circumlunar flight rather than lunar landing and that there were enough unknowns related to the lunar mission that the hardware should be equally capable of advanced earth orbital missions as an alternative.

Based on the technical guidelines, three efforts were undertaken. A formal liaison activity was set up with other NASA Centers to stimulate and encourage their research and studies toward the lunar mission, using the guidelines as a general reference. Three system study contracts were let to industry and a preliminary design study was conducted by Space Task Group personnel. This total effort took approximately one year and culminated in a conference held in Washington in June 1961. These studies were primarily based on a circumlunar mission with the intent that the hardware elements developed

would have application to a later lunar mission.

Concurrent with the completion of this year of study effort in the Spring of 1961, two events of utmost significance to the program took place. The first U.S. manned suborbital flight, of Lt. Cdr. Alan B. Shepard, Jr., was successful. Shortly thereafter, President John F. Kennedy announced the national objective of a manned lunar landing mission within the decade.

As a follow-on to the study effort of the previous year, specifications were being prepared for the command and service modules so a contract could be let to industry. These specifications were changed to acknowledge the requirement for a lunar landing rather than a circumlunar mission. Since the lunar-mission launch vehicle had not been determined, it was assumed that a single launch vehicle would insert a spacecraft into the lunar trajectory and that the command and service modules would land on the lunar surface with the aid of a third module which would decelerate the total spacecraft as it approached the surface. The launch vehicle required for this approach was never fully defined but was of the class referred to as the Nova.

During the Spring and Summer of 1961, work statements and specifications were completed and issued to industry for the command and service modules. During the Fall, proposals were evaluated and a contractor was selected in November 1961. Throughout this period, practically all Space Task Group activity had been directed toward the command and service modules; launch vehicle studies by Marshall Space Flight Center and others had led to a selection of the Saturn C-5 as the lunar launch vehicle in the Fall of 1961.

This decision eliminated the lunar mission approach previously described, involving the Nova class vehicle, and offered two alternatives. The first involved the use of two Saturn C-5's and an earth orbit rendezvous to mate the spacecraft module, plus an earth-to-moon rocket stage. This would allow a landing of the entire spacecraft, employing a third module to decelerate the command and service modules to the lunar surface; then a launch from the lunar surface would use the servicemodule propulsion. The other alternative was to use a single Saturn C-5 launch vehicle carrying the entire spacecraft, consisting of three modules. The third module, instead of being an unmanned module whose purpose was to decelerate the other two modules to the lunar surface, would be a manned module which would go to the lunar surface from lunar orbit and return, while the command and service modules waited in lunar orbit to rendezvous with the third module.

This latter approach had been studied by the Langley Research Center and others during 1960 and 1961. At first it was not received enthusiastically by the Space Task Group in comparison with the Nova direct approach previously described.

In late 1961, the Space Task Group (redesignated Manned Spacecraft Center, November 1, 1961) personnel moved to Houston and initiated studies of the two remaining approaches offered by the C-5 vehicle. Studies were also being conducted by Marshall, Headquarters, and other groups. The Manned Spacecraft Center study concentrated on the feasibility of the lunar orbit rendezvous method and the

definition of the lunar module, then known as the LEM (Lunar Excursion Module). In the Spring of 1962, the Manned Spacecraft Center studies indicated the desirability of the lunar orbit rendezvous approach as opposed to the earth orbit rendezvous approach. Discussions were held with Headquarters and Marshall. It was decided to complete preparation of the work statement and specifications for the LEM and to issue them to industry. This was done in the Summer and contractors' proposals were evaluated. In early November, the final decision was made to go the lunar orbit rendezvous approach. A contractor was selected and negotiations were completed by the end of 1962.

Parallel to the effort related to mission selection, specifications preparation, and contractor selection for the major modules, additional work was being done on the navigation and guidance system. During this 1960 study phase previously described, Massachusetts Institute of Technology (MIT) was conducting a study of concepts for the Apollo system. It was subsequently decided that MIT would be given the navigation and guidance system task, with support from appropriate industrial contractors. The contract with MIT was signed in August 1961, the support contractor work statements and specifications were prepared and issued in early 1962, and three contractors were selected in the Spring of that year.

In summary, the period through 1962 was one of mission definition and major contractor selection. With the selection of the lunar orbit rendezvous mission mode and the LEM contractor, the program was in a position to move into specific design efforts.

Robert O. Piland

Science and Applications Directorate

Manned Spacecraft Center

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The Key Events

1955

March: The feasibility of a million-pound-thrust liquid-fueled rocket engine established by the Rocketdyne Division of North American Aviation, Inc.

1957

April: Studies of a large clustered-engine booster to generate 1.5 million pounds of thrust begun by the Army Ballistic Missile Agency (ABMA).

October 4: Sputnik I, the first man-made satellite, successfully launched by the Soviet Union.

1958

January 31: Explorer I, the first U.S. satellite, launched successfully.

June 23: Preliminary design begun by Rocketdyne Division on a single-chamber liquid-fueled rocket engine (the F-1) of 1.5 million pounds of thrust.

July 29: The National Aeronautics and Space Act signed, authorizing the establishment of the National Aeronautics and Space Administration (NASA).

August 15: Development begun of the Juno V (later named Saturn) booster under Advanced Research Projects Agency Order 14.

October 1: NASA officially constituted and charged with responsibility for the U.S. civilian space program.

October 11: Letter contract signed by NASA with Rocketdyne Division for development of the H-1 engine designed for use in the clustered-engine booster.

November 5: Space Task Group (STG) officially organized to implement the manned satellite project.

1959

January 19: Contract signed by NASA with Rocketdyne Division for design and development of the F-1 engine.

April 9: First group of astronauts selected for the manned space flight program.

April-December: Detailed study of advanced manned space flight missions by the Research Steering Committee on Manned Space Flight (Goett Committee).

August-September: Meetings of the STG New Projects Panel to discuss an advanced manned space flight program.

September 12: Launching by the Soviet Union of Lunik II, which crash-landed on the moon about 35 hours later.

October 4: Launching by the Soviet Union of Lunik III, which photographed the far side of the moon three days later.

December 31: NASA approval of the Saturn C-1 configuration and the long-range Saturn development program.

1960

January 28: NASA's Ten-Year Plan presented to Congress during testimony before the House Committee on Science and Astronautics.

March 15: ABMA's Development Operations Division and the Saturn program transferred to NASA cognizance.

April-May: Presentation by STG members of the guidelines for an advanced manned spacecraft program to NASA Centers.

April 26: NASA selection of the Douglas Aircraft Company to build the second stage (S-IV) of the Saturn C-1.

April 29: All eight H-1 engines of the Saturn C-1 first stage ground-tested simultaneously for the first time.

May 25: STG Advanced Vehicle Team formed to conduct research and make preliminary design studies leading to the definition of requirements for an advanced multiman spacecraft.

May 31: Selection of Rocketdyne Division by NASA to develop the 200,000-pound-thrust J-2 rocket

engine.

July 28-29: The announcement of the Apollo program to representatives of American industry.

1960

August 30: Industry briefing by Goddard Space Flight Center on feasibility studies for the Apollo spacecraft.

September 1: The Apollo Project Office formed under the Space Task Group (STG) Flight Systems Division.

September 13: STG briefing for prospective bidders on the feasibility studies for the Apollo spacecraft.

October 21: STG selection of the Apollo command module design.

October 25: Selection by NASA of Convair/Astronautics Division of General Dynamics Corporation, the General Electric Company, and The Martin Company to prepare feasibility studies for the Apollo spacecraft.

1961

January 6-12: First meetings of the Apollo Technical Liaison Groups, formed to coordinate NASA inter-Center information exchange.

February 7: Six-month study contract for Apollo guidance and navigation support signed by NASA with the Massachusetts Institute of Technology (MIT) Instrumentation Laboratory.

February 7: Final report of the Low Committee outlining a manned lunar landing within the decade using either the earth orbit rendezvous or direct ascent technique.

April 12: First successful manned orbital flight, by Cosmonaut Yuri A. Gagarin of the Soviet Union.

May 5: First successful American suborbital flight, by Astronaut Alan B. Shepard, Jr.

May 5: Completion of the first draft of the Apollo spacecraft specifications by STG.

May 15-17: Submission of final reports by contractors on the feasibility studies on the Apollo spacecraft.

May 22: Completion of the second draft of the Apollo spacecraft specifications by STG.

May 25: President John F. Kennedy's proposal to Congress and the nation of an accelerated space program including a manned lunar landing within the decade.

June 10: Report of the Lundin Committee recommending a low-altitude earth orbit rendezvous mode using the Saturn C-3 to accomplish the manned lunar landing mission.

June 16: Report of the Fleming Committee identifying the chief pacing items of a manned lunar landing mission within the decade as the development of and facilities for the launch vehicle.

July 28: NASA invitation to 12 companies to submit bids on the prime Apollo spacecraft contract.

August 9: Selection of the MIT Instrumentation Laboratory to develop under STG direction the Apollo navigation and guidance system - first major Apollo contract.

August: Report of the Heaton Committee recommending the earth orbit rendezvous technique and use of the Saturn C-4 for the manned lunar landing mission.

October 11: Presentations to NASA representatives by five industrial teams bidding on the Apollo spacecraft contract.

October 27: Successful flight of the first Saturn C-1 (SA-1) booster.

November. 1: Formal redesignation of the Space Task Group as the Manned Spacecraft Center (MSC).

November 8: First meeting of the MSC-MSFC Coordination Panels, formed to find solutions to the interrelated problems of the Apollo launch vehicle and spacecraft.

November 20: Report of the Rosen working group to the NASA Office of Manned Space Flight, recommending direct ascent as the primary lunar landing mission mode with a backup rendezvous capability development.

November 28: Selection of North American Aviation, Inc., as principal contractor for the Apollo spacecraft under MSC direction.

1961

December 15: Selection of The Boeing Company for negotiations as the prime contractor for the first stage (S-IC) of the Saturn C-5, under the direction of Marshall Space Flight Center (MSFC).

December 20: Selection of the Douglas Aircraft Company to develop the S-IVB stage of the Saturn C-

5, under the direction of MSFC.

December 21: Letter contract No. NAS 9-150 signed by NASA and North American Aviation, Inc. (NAA), authorizing work to begin on the Apollo spacecraft development program.

December 21: Decision by the Manned Space flight Management Council on the Saturn C-5 configuration.

December 21: Four major subcontractors on the Apollo spacecraft systems chosen by NAA.

1962

January 15: Apollo Spacecraft Project Office established at the Manned Spacecraft Center (MSC).

February 20: First successful American orbital flight, by Astronaut John H. Glenn, Jr.

March 12: Primary activities for the Apollo program relocated at MSC, Houston, Tex.

April 11: Assignment by the President of DX (highest) priority to the Apollo program.

May 8: Three major associate contractors on the Apollo spacecraft guidance and navigation system selected by the Massachusetts Institute of Technology Instrumentation Laboratory.

May 11: General Dynamics/Convair awarded contract by NASA to design and manufacture the Little Joe II test launch vehicle.

July 11: Announcement by NASA that the Saturn C-IB launch vehicle would be developed to test the Apollo spacecraft in earth orbit missions.

July 11: Selection by NASA of the lunar orbit rendezvous mode for the manned lunar landing mission.

July 20: Announcement by NASA that the Mission Control Center would be located at MSC.

July 25: Invitations by NASA to 11 companies to bid on the lunar excursion module contract.

July: Hamilton Standard Division of United Aircraft Corporation selected by NASA to develop the Apollo space suit.

September 5: Nine industry proposals for the lunar excursion module contract received by NASA.

October 30: Contract signed by NASA with NAA for the development and production of the S-II

(second) stage of the Saturn C-5, directed by MSFC.

November 7: Selection of the Grumman Aircraft Engineering Corporation by NASA to design and develop the lunar excursion module under MSC direction.

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PREFACE

Project Apollo, conceived as a successor to the Mercury program in this nation's manned exploration of space and originally planned as a circumlunar flight, now has as its primary objective a manned lunar landing and return within the decade. As a bridge between Mercury and Apollo, the Gemini program has provided essential experience in space rendezvous and demonstrated the feasibility of long-duration space flight. Like Mercury and Gemini, Apollo is a program of complex and interrelated elements: launch vehicles; spacecraft; and launch, tracking, and recovery facilities. This is the first volume of a chronology dealing with the spacecraft.

It is planned to publish *The Apollo Spacecraft: A Chronology* in several volumes. The intent of the authors is to concentrate on the important events that have affected the concept, design, and development of the Apollo spacecraft rather than to cover in detail the entire Apollo program. In keeping with this intent, the authors have tried to give a balanced overview of the Apollo spacecraft program, not limiting the chronology to the activities of a single NASA Center.

Part I, "Concept to Apollo," reviews the earliest years up to the official announcement of the Apollo program. Part II, "Design-Decision-Contract," continues through the selection of the principal contractor for the command and service modules. Part III, "Lunar Orbit Rendezvous: Mode and Module," completes Volume I, ending with the naming of the contractor for the lunar module.

As far as possible, primary sources were consulted. These included congressional documents, Apollo program status reports, Manned Spacecraft Center and Apollo Spacecraft Project Office weekly activity reports, contractors' progress reports, Apollo working papers, letters, memoranda, NASA and industry staff reports, minutes of meetings, and interviews with persons directly involved in the early years of the Apollo program. In addition, books, newspaper accounts, press releases, chronologies, and magazine articles were researched for material. The present volume was extensively revised several times as new sources of information came to light.

This and succeeding volumes are meant not only to provide a useful and accurate reference work for the scientist, historian, and general reader, but also to serve as a foundation for a narrative history of the Apollo program as part of the NASA Historical Series.

The materials used in this chronology were accumulated from a wide variety of sources and so the authors are indebted to a number of individuals and organizations for outstanding cooperation and assistance. Some have assisted to such a degree that special recognition seems warranted. This group includes: Rose Sidick, Redstone Scientific Information Center, and Lois Robertson, Marshall Space Flight Center, for their invaluable assistance in research and documentation retrieval;

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I.D.E.

M.L.M.

August 1968

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1923

During the Year

In a discussion of the uses of an interplanetary rocket, Hermann Oberth proposed circumlunar flight to explore the hidden face of the moon and discussed the possibility of storing cryogenic fuels in space. A spacecraft could rendezvous and dock in earth orbit with a fuel capsule. When the spacecraft reached the vicinity of a planet, it would detach itself from the capsule and descend to the surface. On departure, the spacecraft would ascend and reconnect to its fuel supply for the return trip.

Hermann Oberth, *Die Rakete zu den Planetenraeumen (The Rocket in Interplanetary Space)* (1923), pp. 94, 96-97.

1929

July - September

Hermann Noordung (pseudonym for Capt. Potocnik of the Austrian Imperial Army) expanded the ideas of Hermann Oberth on space flight in a detailed description of an orbiting space observatory. The problems of weightlessness, space communications, maintaining a livable environment for the crew, and extravehicular activity were considered. Among the uses of such an observatory were chemical and physical experiments in a vacuum, telescopes of great size and efficiency, detailed mapping of the earth's surface, weather observation, surveillance of shipping routes, and military reconnaissance.

Hermann Noordung, "The Problems of Space Flying," translated from the German, *Science Wonder Stories*, July-September, 1929; Wernher von Braun and Frederick I. Ordway III, *History of Rocketry and Space Travel* (1966), p. 202.

1945

During the Year

As part of a summary of his work on rockets during World War II, Wernher von Braun speculated on

future uses of rocket power. These included an observatory in space, the construction of space stations in earth orbit, a space mirror, and interplanetary travel, beginning with trips to the moon.

Wernher von Braun, "Survey of the Development of Liquid Rockets in Germany and Their Future Prospects," in F. Zwicky, *Report on Certain Phases of War Research in Germany*, Summary Report No. F-SU-3-RE (Headquarters Air Material Command, January 1947), pp. 38-42.

1948

November 13

A paper read to the British Interplanetary Society by H. E. Ross described a manned lunar landing mission which would require a combination of the earth orbit and lunar orbit rendezvous techniques. Three spacecraft would be launched simultaneously into earth orbit, each carrying a pilot. After rendezvous, the crew would transfer to ship A, which would refuel from ships B and C. Ship C would be discarded completely, but ship B would be fueled with the surplus not needed by A. The spacecraft would then be fired into a translunar trajectory. Upon reaching the vicinity of the moon, the spacecraft would go into lunar orbit, detach fuel tanks, and descend to the lunar surface. To return to earth, the spacecraft would rendezvous with the fuel tanks, refuel, and fire into a transearth trajectory. On approaching the earth, the spacecraft would rendezvous with ship B, the crew would transfer to ship B, and descend to earth. The ability to rendezvous in space was seen to be the essential element of such a project. The total payload weight at launch would be 1,326 tons equally divided among the three ships as compared to 2.6 times this weight required for a direct ascent and return from the moon.

H. E. Ross, "Orbital Bases," *Journal of the British Interplanetary Society*, 8 (1949), pp. 1-7.

1949-1952

The awakening public interest in the scientific exploration of space was shown by the publication in September 1949 of *The Conquest of Space* by Willy Ley, illustrations by Chesley Bonestell. Featured in this book was a detailed description of a manned lunar landing and return, using the direct ascent technique. In the same year the Technicolor film "Destination Moon" went into production. Again the direct ascent mode was used in a four-man lunar landing mission. The movie premiered in New York City in 1950. On October 12, 1951, the First Symposium on Space Flight was held at the Hayden Planetarium in New York City, *Collier's* published papers from this Symposium on March 22, 1952, under the title "Man Will Conquer Space Soon." Contributors were Wernher von Braun, Joseph Kaplan, Heinz Haber, Willy Ley, Oscar Schachter, and Fred L. Whipple. Among the topics discussed were an orbiting astronomical observatory, problems of survival in space, circumlunar flight, a manned orbiting space station, and the question of sovereignty in outer space. In 1952, Arthur C. Clarke's *The Exploration of Space* became a Book of the Month Club selection. First published in England in 1951, the book included an alternative to the direct ascent technique: assembling or refueling the space vehicle in earth orbit before injection into translunar trajectory, to be followed, possibly, by rendezvous in lunar

orbit with fuel tanker rockets launched from the earth.

Willy Ley, "Target for Tonight: Luna!," *The Conquest of Space* (1949), pp. 41-88;

"Destination Moon" (1950), produced by George Pal;

Collier's (March 22, 1952), pp. 22-36, 65-67, 70-72, 74;

Arthur C. Clarke, *The Exploration of Space* (1952), pp. 62-82.

1951

September

The uses of rendezvous techniques in space were discussed in a paper read to the Second International Congress on Astronautics in London, England. The problems involved in refueling in space might be simplified considerably if astronauts could maneuver freely, perhaps using a gas-jet pistol and a lifeline. The construction of a space station might then be possible. Mechanical linkage of objects in space was described as the most difficult task of all. While computing the position of an object in orbit might be comparatively easy, linking up with the object without damage by impact would require human intelligence to anticipate error in the attitude of approach.

R. A. Smith, "Establishing Contact Between Orbiting Vehicles," *Journal of the British Interplanetary Society*, 10 (1951), pp. 295-297.

November

During the Month

The first symposium on space medicine was held under U.S. Air Force and Lovelace Foundation sponsorship at Randolph Air Force Base, San Antonio, Tex.

Lloyd S. Swenson, Jr., James M. Grimwood, and Charles C. Alexander, *This New Ocean: A History of Project Mercury* (NASA SP-4201, 1966), p. 34.

1952

January 30

Robert J. Woods of the Bell Aircraft Company recommended to the Committee on Aerodynamics of the National Advisory Committee for Aeronautics (NACA) that a small study group be formed to

investigate the problems of space flight. On June 24, the NACA Committee adopted a resolution (1) that NACA research effort on problems of manned and unmanned flight in the upper stratosphere at altitudes between 12 and 50 miles and at Mach numbers between 4 and 10 be increased, and (2) that NACA devote a modest effort to problems associated with manned and unmanned flight at altitudes from 50 miles to infinity and at speeds from Mach 10 to the velocity of escape from earth's gravity. On July 14, the NACA Executive Committee approved an almost identical resolution and a month later authorized Langley Aeronautical Laboratory to set up a preliminary study group. Other NACA laboratories were requested to submit comments and recommendations. Formal authorization for the research study was forwarded to Langley on September 8.

Minutes of meeting, NACA Committee on Aerodynamics, June 24, 1952, pp. 19, 21 ; letters, Milton B. Ames, Jr., Acting Assistant Director for Research, to Langley Aeronautical Laboratory, July 10, 1952; John W. Crowley, Associate Director for Research, to Langley Aeronautical Laboratory, August 14, 1952; Research Authorization A73L95, NACA, September 8, 1952.

1955

March

During the Month

Rocketdyne Division of North American Aviation, Inc. (NAA), established the feasibility of a million-pound-thrust liquid-fueled rocket engine for the U.S. Air Force.

Rocketdyne *Skywriter*, May 20, 1960, p. 1.

1956

May 28

The RAND Corporation issued the first of a series of reports on the feasibility of a lunar instrument carrier, based on the use of an Atlas booster. A braking rocket would decelerate the vehicle before lunar landing, and a penetration spike on the forward point of the instrument package would help to absorb the 500 feet per second impact velocity. Instruments would then transmit information on the lunar surface to earth.

Historical Division, Office of Information, Space Systems Division, Air Force Systems Command, U.S. Air Force, "Chronology of Early Air Force Man-in-Space Activity, 1955-1960" (1964), unpublished, p. 5; H. A. Lang, *Lunar Instrument Carrier: Landing Factors*, RM-1725 (The RAND Corporation, June 4, 1956), pp. 1-3, 29, 31, 33-34.

1957

April

During the Month

The U.S. Army Ballistic Missile Agency, Redstone Arsenal, Ala., began studies of a large clustered-engine booster to generate 1.5 million pounds of thrust, as one of a related group of space vehicles. During 1957-1958, approximately 50,000 man-hours were expended in this effort.

H. H. Koelle, F. L. Williams, W. G. Huber, and R. C. Callaway, Jr., *Juno Space Vehicle Development Program; (Phase I): Booster Feasibility Demonstration* (Army Ballistic Missile Agency, October 13, 1958), p. 1.

October 4

Sputnik I, the first man-made earth satellite, was launched by the Soviet Union and remained in orbit until January 4, 1958.

Henry L. Richter, Jr., Editor, *Instruments and Spacecraft: Space Measurements Survey, October 1957-March 1965* (NASA SP-3028, 1966), p. 2.

October 14

The Rocket and Satellite Research Panel, established in 1946 as the V-2 Upper Atmosphere Research Panel and renamed the Upper Atmosphere Rocket Research Panel in 1948, together with the American Rocket Society proposed a national space flight program and a unified National Space Establishment. The mission of such an Establishment would be nonmilitary in nature, specifically excluding space weapons development and military operations in space. By 1959, this Establishment should have achieved an unmanned instrumented hard lunar landing and, by 1960, an unmanned instrumented lunar satellite and soft lunar landing. Manned circumnavigation of the moon with return to earth should have been accomplished by 1965 with a manned lunar landing mission taking place by 1968. Beginning in 1970, a permanent lunar base should be possible.

U.S. Congress, Senate, Special Committee on Space and Astronautics, *Compilation of Materials on Space and Astronautics No. 1*, 85th Congress, 2nd Session (1958), pp.17-19.

November 14

The General Assembly of the United Nations adopted Resolution 1148 (XII), calling, in part, for "the joint study of an inspection system designed to ensure that the sending of objects through outer space

shall be exclusively for peaceful and scientific purposes."

John Michael Kemp, *Evolution Toward a Space Treaty: An Historical Analysis* (NASA HHN-64, 1967), pp. 8-9.

December 9

The Air Force Scientific Advisory Board Ad Hoc Committee on Space Technology recommended acceleration of specific military projects and a vigorous space program with the immediate goal of landings on the moon because "Sputnik and the Russian ICBM (intercontinental ballistic missile) capability have created a national emergency."

Thomas A. Sturm, *The USAF Scientific Advisory Board: Its First Twenty Years, 1944-1964* (1967), pp. 82-83.

December 10

The Army Ballistic Missile Agency completed and forwarded to higher authority the first edition of *A National Integrated Missile and Space Vehicle Development Program*, which had been in preparation since April 1957. Included was a "short-cut development program" for large payload capabilities, covering the clustered-engine booster of 1.5 million pounds of thrust to be operational in 1963. The total development cost of \$850 million during the years 1958-1963 covered 30 research and development flights, some carrying manned and unmanned space payloads. One of six conclusions given in the document was that "Development of the large (1520 K-pounds thrust) booster is considered the key to space exploration and warfare." Later vehicles with greater thrust were also described.

A National Integrated Missile and Space Vehicle Development Program (Army Ballistic Missile Agency, 1957), pp. 3, 6, Table XV.

During the Month

The Martin Company proposed to the Department of Defense (DOD) that a stage of the Titan intercontinental ballistic missile be combined with the Vanguard rocket to provide a launch vehicle capable of placing an instrument package into lunar orbit and, ultimately, on the lunar surface.

The Martin Company, *Lunar Vehicle* (1957), p. 2.

1958

January 12

NACA established a Special Committee on Space Technology to study the problems of space flight. H. Guyford Stever of the Massachusetts Institute of Technology (MIT) was named Chairman. On November 21, 1957, NACA had authorized formation of the Committee.

NACA News Release, "Space Technology Committee Established by NACA," January 13, 1958.

January 16

NACA adopted a resolution recommending that the national space program be a cooperative effort by DOD, NACA, the National Academy of Sciences, and the National Science Foundation, together with the universities, research institutions, and industrial companies. NACA viewed the development and operation of military space vehicles as the responsibility of DOD, while NACA's primary interest lay in the scientific exploration of space.

"National Advisory Committee for Aeronautics, Resolution on the Subject of Space Flight, Adopted January 16, 1958."

January 31

Explorer I, the first U.S. earth satellite, was launched by a modified Army Ballistic Missile Agency Jupiter-C. Explorer I, developed by the Jet Propulsion Laboratory, carried the U.S.-IGY (International Geophysical Year) experiment of James A. Van Allen and resulted in the discovery of the radiation belt around the earth.

U.S. Congress, Senate, Special Committee on Space and Astronautics, *Compilation of Materials on Space and Astronautics No. 2*, 85th Congress, 2nd Session (1958), p. 365; Fletcher G. Watson, *Between the Planets* (1962), pp. 210-211.

February 7

To further the national space effort pending a decision as to permanent organization, the Secretary of Defense created the Advanced Research Projects Agency (ARPA). ARPA was authorized to direct or perform advanced projects in the field of research and development. It was also empowered to deal directly with operational elements on all aspects of ARPA projects; for example, to bypass the Army Staff and the Chief of Ordnance in dealing with the Army Ballistic Missile Agency on what was to be the Saturn project. Roy W. Johnson was named ARPA Director.

U.S. Congress, Senate, Committee on Aeronautical and Space Sciences, *Manned Space Flight Program of the National Aeronautics and Space Administration: Projects Mercury, Gemini, and Apollo*, Staff Report, 87th Congress, 2nd Session (1962), p. 156.

February 10

A greatly expanded NACA program of space flight research was proposed in a paper, "A Program for Expansion of NACA Research in Space Flight Technology," written principally by senior engineers of the Lewis Aeronautical Laboratory under the leadership of Abe Silverstein. The goal of the program would be "to provide basic research in support of the development of manned satellites and the travel of man to the moon and nearby planets." The cost of the program was estimated at \$241 million per year above the current NACA budget.

NACA Staff, "A Program for Expansion of NACA Research in Space Flight Technology," February 10, 1958, pp. 1-2, 29 ; Swenson *et al.*, *This New Ocean*, pp. 76-77.

March 5

President Dwight D. Eisenhower approved the recommendations of his Advisory Committee on Government Organization that the "leadership of the civil space effort be lodged in a strengthened and redesignated National Advisory Committee for Aeronautics," and that legislation be enacted to "give NACA the authority and flexibility" to carry out its expanded responsibilities.

Robert L. Rosholt, *An Administrative History of NASA, 1958-1963* (NASA SP-4101, 1966), p. 8.

April 1

A \$61,000 contract was signed by the Yerkes Observatory, University of Chicago, and the Air Force. Gerard P. Kuiper, principal investigator, was to produce a new lunar photographic atlas. The moon's visible surface would be divided into 44 areas, and each would be represented by at least four photographs taken under varying lighting conditions. The photographs would be assembled from the following observatories: Yerkes, Williams Bay, Wisc.; Lick, Mount Hamilton, Calif.; Mount Wilson-Palomar, Mount Wilson, Calif.; Pic-du-Midi, France; and McDonald, Fort Davis, Tex. The contract was to run from April 1, 1958, to March 31, 1959. It was extended on February 25, 1959, to September 3, 1959, with increase in funds of \$52,500, and again on November 18, 1959, to April 30, 1960, with no increase in funds.

U.S. Congress, House, Committee on Science and Astronautics, *Army Lunar Construction and Mapping Program*, Committee Report, 86th Congress, 2nd Session (1960), Appendix.

April 2

President Dwight D. Eisenhower, in a message to Congress, proposed the establishment of a National Aeronautics and Space Agency into which the National Advisory Committee for Aeronautics would be absorbed. The new agency would conduct the civilian space program through research in its own facilities or by contract and would also perform military research required by DOD. Projects primarily military in character would remain the responsibility of DOD. A National Aeronautics and Space Board,

appointed by the President and composed of eminent persons outside the government and representatives of interested government agencies (with at least one member from DOD), was to assist the President and the Director of the National Aeronautics and Space Agency.

Senate Committee Print, *Compilation of Materials on Space and Astronautics No. 2*, pp. 79-83.

April 25

The Air Force Ballistic Missile Division published the first development plan for an Air Force manned military space systems program. The objective was to "achieve an early capability to land a man on the moon and return him safely to earth." The program called for the start of a high priority effort (similar to that enjoyed by ballistic missiles), characterized by "concurrency" and single Air Force agency management. The complete program would be carried out in four phases: first, "Man-in-Space Soonest"; second, "Man-in-Space Sophisticated"; third, "Lunar Reconnaissance," exploring the moon by television camera and by a soft landing of an instrumented package on the moon's surface; and finally, "Manned Lunar Landing and Return," which would first test equipment by circumlunar flights returning to earth with instrumented capsules containing animals. At this stage of project development, the payload capacity would be increased to 9,000 pounds. The spacecraft would then undertake a full-scale flight to the moon and safe return with an animal passenger. The climax would be a manned lunar landing, brief surface exploration, and return. This would be followed by other flights to explore the lunar surface thoroughly and gather additional data. The program was scheduled for completion in December 1965 at a cost of \$1.5 billion.

Space Systems Division, Air Force Systems Command, and the USAF Historical Division Liaison Office, "Chronology of Early USAF Man-in-Space Activity, 1945-1958" (U.S. Air Force, 1965). unpublished, pp. 21-22.

June 23

The U.S. Air Force contracted with NAA, Rocketdyne Division, for preliminary design of a single-chamber, kerosene and liquid-oxygen rocket engine capable of 1 to 1.5 million pounds of thrust. During the last week in July, Rocketdyne was awarded the contract to develop this engine, designated the F-1.

Senate Staff Report, *Manned Space Flight Program*, p. 158; Rocketdyne Valley Skywriter, August 1, 1958, p. 1.

July 29

President Dwight D. Eisenhower signed the National Aeronautics and Space Act of 1958, Public Law 85-568, which established the National Aeronautics and Space Administration (NASA).

Senate Staff Report, *Manned Space Flight Program*, p. 159; Eugene M. Emme, *Aeronautics and*

Astronautics: An American Chronology of Science and Technology in the Exploration of Space, 1915-1960 (NASA, 1961), p. 100.

August 8

T. Keith Glennan, President of Case Institute of Technology, and Hugh L. Dryden, Director of the National Advisory Committee for Aeronautics, were nominated by President Dwight D. Eisenhower to be Administrator and Deputy Administrator of NASA. The Senate confirmed their nominations one week later.

Rosholt, *An Administrative History of NASA, 1958-1963*, pp. 40-42.

August 15

The Advanced Research Projects Agency ARPA provided the Army Ordnance Missile Command (AOMC) with authority and initial funding to develop the Juno V (later named Saturn launch vehicle. ARPA Order 14 described the project: "Initiate a development program to provide a large space vehicle booster of approximately 1.5 million pounds of thrust based on a cluster of available rocket engines. The immediate goal of this program is to demonstrate a full-scale captive dynamic firing by the end of calendar year 1959." Within AOMC, the Juno V project was assigned to the Army Ballistic Missile Agency at Redstone Arsenal Huntsville, Ala.

Koelle *et al.*, *Juno Space Vehicle Demonstration; (Phase I)*, p. 2.

August 17

The first Air Force lunar probe was launched, using a Thor-Able booster. An explosion ripped it apart 77 seconds after launch.

Instruments and Spacecraft, p. 27.

September 11

A letter contract was signed by NASA with NAA's Rocketdyne Division for the development of the H-1 rocket engine, designed for use in a clustered-engine booster.

MSFC Saturn Systems Office and MSFC Historical Office, *Saturn Illustrated Chronology* (George C. Marshall Space Flight Center, MHR-3, 1964), pp. 2-3.

September 23

Following a Memorandum of Agreement between Maj. Gen. John B. Medaris of Army Ordnance Missile Command (AOMC) and Advanced Research Projects Agency (ARPA) Director Roy W. Johnson on this date and a meeting on November 4, ARPA and AOMC representatives agreed to extend the Juno V project. The objective of ARPA Order 14 was changed from booster feasibility demonstration to "the development of a reliable high performance booster to serve as the first stage of a multistage carrier vehicle capable of performing advanced missions."

H. H. Koelle, F. L. Williams, W. G. Huber, and R. C. Callaway, Jr., *Juno V Space Vehicle Development Program (Status Report-15 November 1958)* (Army Ballistic Missile Agency, November 15, 1958), p. 2.

October 1

NASA was organized and NACA was abolished, at the close of business on September 30, with all personnel and facilities transferred to the new agency. At the same time, several space projects were transferred to NASA from DOD. Among these were two Air Force and two Army lunar probes; the services kept the actual work of construction and launching.

Rosholt, *An Administrative History of NASA, 1958-1963*, pp. 44-48; Swenson *et al.*, *This New Ocean*, p. 538.

October 11

Pioneer I, intended as a lunar probe, was launched by a Thor-Able rocket from the Atlantic Missile Range, with the Air Force acting as executive agent to NASA. The 39-pound instrumented payload did not reach escape velocity.

Instruments and Spacecraft, pp. 30-32.

October 25

The Stever Committee, which had been set up on January 12, submitted its report on the civilian space program to NASA. Among the recommendations:

- A vigorous, coordinated attack should be made upon the problems of maintaining the performance capabilities of man in the space environment as a prerequisite to sophisticated space exploration.
- Sustained support should be given to a comprehensive instrumentation development program, establishment of versatile dynamic flight simulators, and provision of a coordinated series of vehicles for testing components and subsystems.
- Serious study should be made of an equatorial launch capability.
- Lifting reentry vehicles should be developed.
- Both the clustered- and single-engine boosters of million-pound thrust should be developed.

- Research on high-energy propellant systems for launch vehicle upper stages should receive full support.
- The performance capabilities of various combinations of existing boosters and upper stages should be evaluated, and intensive development concentrated on those promising greatest usefulness in different categories of payload.

NASA Special Committee on Space Technology, "Recommendations Regarding a National Civil Space Program," October 28, 1958, pp. 1-2.

November 1

A contract was signed by the University of Manchester, Manchester, England, and the Air Force [AF 61 (052)-168] for \$21,509. Z. Kopal, principal investigator, was to provide topographical information on the lunar surface for production of accurate lunar maps. Kopal would work at the Pic-du-Midi Observatory in France, and the data would be transmitted to the Air Force Aeronautical Chart and Information Center for reduction. The lunar charts produced would be used for intelligence purposes and for the national space effort led by NASA. The contract was extended on August 4, 1959, to April 30, 1960, and was to include exploratory spectroscopic observations of the moon.

House Committee Report, *Army Lunar Construction and Mapping Program*, Appendix.

November 5

The Space Task Group (STG) was officially organized at Langley Field, Va., to implement the manned satellite project (later Project Mercury), NASA Administrator T. Keith Glennan had approved the formation of the Group, which had been working together for some months, on October 7. Its members were designated on November 3 by Robert R. Gilruth, Project Manager, and authorization was given by Floyd L. Thompson, Acting Director of Langley Research Center. STG would report directly to NASA Headquarters.

Memorandum, Gilruth, Project Manager, to Associate Director, "Space Task Group," November 3, 1958; Swenson et al., *This New Ocean*, p. 114.

November 8

Pioneer II was launched from the Atlantic Missile Range, using a Thor-Able booster, the Air Force acting as executive agent to NASA. The 86.3-pound instrumented payload, intended as a lunar probe, failed to reach escape velocity.

Instruments and Spacecraft, p. 34.

December 3

By Executive Order, President Dwight D. Eisenhower transferred the Jet Propulsion Laboratory JPL, a government-owned facility staffed and operated by the California Institute of Technology, from Army to NASA jurisdiction. The new JPL radio telescope at Camp Irwin, Calif., called the Goldstone Tracking Facility, was capable of maintaining radio contact at distances of up to 400,000 miles and was the first of NASA's deep-space tracking stations.

First Semiannual Report to Congress of the National Aeronautics and Space Administration, October 1, 1958-March 31, 1959 (1959), pp. 24, 36, 42-43; U.S. Congress, House, Committee on Science and Astronautics, *A Chronology of Missile and Astronautic Events*, 87th Congress, 1st Session (1961), p. 61.

December 3

Secretary of the Army Wilber M. Brucker and NASA Administrator T. Keith Glennan signed cooperative agreements concerning NASA, Jet Propulsion Laboratory, Army Ordnance Missile Command AOMC, and Department of the Army relationships. The agreement covering NASA utilization of the von Braun team made "the AOMC and its subordinate organizations immediately, directly, and continuously responsive to NASA requirements."

First NASA Semiannual Report, pp. 81-87.

December 6

Pioneer III, the third U.S.-IGY intended lunar probe under the direction of NASA with the Army acting as executive agent, was hunched from the Atlantic Missile Range by a Juno II rocket. The primary objective, to place the 12.95pound scientific payload in the vicinity of the moon, failed. *Pioneer III* reached an altitude of approximately 70,000 miles and revealed that the earth's radiation belt comprised at least two distinct bands.

Instruments and Spacecraft, p. 35. *New York Times*, December 7, 1958

December 17

NASA Administrator T. Keith Glennan announced that the manned satellite program would be called "Project Mercury."

Swenson *et al.*, *This New Ocean*, p. 132

December 17

Representatives of Advanced Research Projects Agency, the military services, and NASA met to

consider the development of future launch vehicle systems. Agreement was reached on the principle of developing a small number of versatile launch vehicle systems of different thrust capabilities, the reliability of which could be expected to be improved through use by both the military services and NASA.

NASA-Industry Program Plans Conference, July 28-29, 1960 (1960), p. 2.

December 17

The H-1 engine successfully completed its first full-power firing at NAA's Rocketdyne facility in Canoga Park, Calif.

Saturn Illustrated Chronology, p. 4.

During the Year

The U.S. Army Map Service studied methods of mapping the moon. This effort evolved into Project LAMP (Lunar Analysis and Mapping Program) in cooperation with the U.S. Geological Survey. By spring 1960, the first maps were in preparation. Four stages were incorporated in the project:

Stage I:

Moon map on scale of 1:500,000 and feasibility studies, through 1960 (\$200,000)

Stage II:

Expansion and acceleration of Stage I, including balloon photographic reconnaissance and radar investigation, through 1961 (\$800,000)

Stage III:

System design per requirements of the lunar mission, through 1962 (\$2 million)

Stage IV:

Operational program assembling all system components for lunar mission, through 1963 (\$5 million)

U.S. Congress, House, Committee on Science and Astronautics, *Lunar Mapping and Construction in Support of Space Programs*, Hearings, 86th Congress, 2nd Session (1960), p. 4.

1959

January 2

The Soviet Union announced the successful launching of *Mechta* ("Dream"), popularly called *Lunik I*, toward the moon. Carrying nearly 800 pounds of instruments, *Lunik I* missed the moon and became the first man-made solar satellite.

Instruments and Spacecraft, p. 38.

January 2

In a staff report of the House Select Committee on Astronautics and Space Exploration, Wernher von Braun of the Army Ballistic Missile Agency predicted manned circumlunar flight within the next eight to ten years and a manned lunar landing and return mission a few years thereafter. Administrator T. Keith Glennan, Deputy Administrator Hugh L. Dryden, Abe Silverstein, John P. Hagen, and Homer E. Newell, all of NASA, also foresaw manned circumlunar flight within the decade as well as instrumented probes soft-landed on the moon. Roy K. Knutson, Chairman of the Corporate Space Committee, NAA, projected a manned lunar landing expedition for the early 1970's with extensive unmanned instrumented soft lunar landings during the last half of the 1960's.

U.S. Congress, House, Select Committee on Astronautics and Space Exploration, *The Next Ten Years in Space, 1959-1969*, Staff Report, 86th Congress, 1st Session (1959), pp. 96, 122, 211.

January 6

The Army Ordnance Missile Command (AOMC), the Air Force, and missile contractors presented to the ARPA-NASA Large Booster Review Committee their views on the quickest and surest way for the United States to attain large booster capability. The Committee decided that the Juno V approach advocated by AOMC was best and NASA started plans to utilize the Juno V booster.

Senate Staff Report, *Manned Space Flight Program*, p. 165.

January 19

NASA signed a definitive contract with Rocketdyne Division, NAA, for \$102 million covering the design and development of a single-chamber, liquid-propellant rocket engine in the 1- to 1.5-million-pound-thrust class (the F-1, to be used in the Nova superbooster concept). NASA had announced the selection of Rocketdyne on December 12.

First NASA Semiannual Report, p. 27.

January 27

After consultation and discussion with DOD, NASA formulated a national space vehicle program. The central idea of the program was that a single launch vehicle should be developed for use in each series of future space missions. The launch vehicle would thus achieve a high degree of reliability, while the guidance and payload could be varied according to purpose of the mission. Four general-purpose launch vehicles were described: Vega, Centaur, Saturn, and Nova. The Nova booster stage would be powered

by a cluster of four F-1 engines, the second stage by a single F-1, and the third stage would be the size of an intercontinental ballistic missile but would use liquid hydrogen as a fuel. This launch vehicle would be the first in a series that could transport a man to the lunar surface and return him safely to earth in a direct ascent mission. Four additional stages would be required in such a mission.

"A National Space Vehicle Program," NASA report to the President, January 27, 1959.

February 2

The Army proposed that the name of the large clustered-engine booster be changed from Juno V to Saturn, since Saturn was the next planet after Jupiter. Roy W. Johnson, Director of the Advanced Research Projects Agency, approved the name on February 3.

Senate Staff Report, *Manned Space Flight Program*, p. 165; *Saturn Illustrated Chronology*, p. 5.

February 4

Maj. Gen. John B. Medaris of the Army Ordnance Missile Command (AOMC) and Roy W. Johnson of the Advanced Research Projects Agency (ARPA) discussed the urgency of early agreement between ARPA and NASA on the configuration of the Saturn upper stages. Several discussions between ARPA and NASA had been held on this subject. Johnson expected to reach agreement with NASA the following week. He agreed that AOMC would participate in the overall upper stage planning to ensure compatibility of the booster and upper stages.

Senate Staff Report, *Manned Space Flight Program*, p. 166.

February 5

A Working Group on Lunar Exploration was established by NASA at a meeting at Jet Propulsion Laboratory (JPL). Members of NASA, JPL, Army Ballistic Missile Agency, California Institute of Technology, and the University of California participated in the meeting. The Working Group was assigned the responsibility of preparing a lunar exploration program, which was outlined: circumlunar vehicles, unmanned and manned; hard lunar impact; close lunar satellites; soft lunar landings (instrumented). Preliminary studies showed that the Saturn booster with an intercontinental ballistic missile as a second stage and a Centaur as a third stage, would be capable of launching manned lunar circumnavigation spacecraft and instrumented packages of about one ton to a soft landing on the moon.

U.S. Army Ordnance Missile Command, *A Lunar Exploration Program Based Upon Saturn-Boosted Systems*, DV-TR-2-60 (February 1, 1960), p. i.

February 17

Roy W. Johnson, Director of the Advanced Research Projects Agency (ARPA), testified before the House Committee on Science and Astronautics that DOD and ARPA had no lunar landing program. Herbert F. York, DOD Director of Defense Research and Engineering, testified that exploration of the moon was a NASA responsibility.

U.S. Congress, House, Committee on Science and Astronautics, *Missile Development and Space Sciences*, Hearings, 86th Congress, 1st Session (1959), pp. 346, 359.

February 20

In testimony before the Senate Committee on Aeronautical and Space Sciences, Deputy Administrator Hugh L. Dryden and DeMarquis D. Wyatt described the long-range objectives of the NASA space program: an orbiting space station with several men, operating for several days; a permanent manned orbiting laboratory; unmanned hard-landing and soft-landing lunar probes; manned circumlunar flight; manned lunar landing and return; and, ultimately, interplanetary flight.

U.S. Congress, Senate, Committee on Aeronautical and Space Sciences, *NASA Supplemental Authorization for Fiscal Year 1959*, Hearings, 86th Congress, 1st Session (1959), pp. 46, 81.

March 3

The fourth U.S.-IGY lunar probe effort, *Pioneer IV*, a joint project of the Army Ballistic Missile Agency and Jet Propulsion Laboratory under the direction of NASA, was launched by a Juno II rocket from the Atlantic Missile Range. Intended to impact on the lunar surface, *Pioneer IV* achieved earth-moon trajectory, passing within 37,300 miles of the moon before going into permanent orbit around the sun.

Instruments and Spacecraft, pp. 45-46.

March 6

The thrust chamber of the F-1 engine was successfully static-fired at the Santa Susana Air Force-Rocketdyne Propulsion Laboratory in California. More than one million pounds of thrust were produced, the greatest amount attained to that time in the United States.

Washington *Evening Star*, April 1, 1959.

March 13

The Army Ordnance Missile Command (AOMC) submitted the "Saturn System Study" which had been requested by the Advanced Research Projects Agency ARPA on December 18, 1958. From the 1375 possible configurations screened, and the 14 most promising given detailed study, the Atlas and Titan

families were selected as the most attractive for upper staging. Either the 120-inch or the 160inch diameter was acceptable. The study included the statement: "An immediate decision by ARPA as to choice of upper stages on the first generation vehicle is mandatory if flight hardware is to be available to meet the proposed Saturn schedule." On March 17, AOMC presented the study to NASA, DOD, and ARPA reiterating the urgent need for an early decision on upper staging. Roy W. Johnson, ARPA Director, formed a Saturn ad hoc committee of NASA and DOD personnel to recommend upper stages and payload missions.

Senate Staff Report, *Manned Space Flight Program*, p. 167; *Saturn Illustrated Chronology*, p. 5.

March 20

An Army task force was formed to develop a plan for establishing a manned lunar outpost by the quickest practical means. The effort was called Project Horizon. The first phase of the project was to make a limited feasibility study, with estimated time and costs. The task force worked under the direction of Maj. Gen. John B. Medaris of the Army Ordnance Missile Command and in full collaboration with the von Braun team. The report was completed on June 8.

Senate Staff Report, *Manned Space Flight Program*, p. 167.

During the Month

H. Kurt Strass and Leo T. Chauvin of STG proposed a heatshield test of a fullscale Mercury spacecraft at lunar reentry speeds. This test, in which the capsule would penetrate the earth's radiation belt, was called Project Boomerang. An advanced version of the Titan missile was to be the launch vehicle. The project was postponed and ultimately dropped because of cost.

Interview with Strass, Manned Spacecraft Center, November 30, 1966; Memorandum, Strass to Chief, Flight Systems Division, "Second Meeting of the New Projects Panel," August 26, 1959.

April 1-8

John W. Crowley, Jr., NASA Director of Aeronautical and Space Research, notified the Ames, Lewis, and Langley Research Centers, the High Speed Flight Station (later Flight Research Center), the Jet Propulsion Laboratory, and the Office of Space Flight Development that a Research Steering Committee on Manned Space Flight would be formed. Harry J. Goett of Ames was to be Chairman of the Committee, which would assist NASA Headquarters in carrying out its responsibilities in long-range planning and basic research on manned space flight.

Memoranda, NASA Headquarters to Ames, Lewis, and Langley Research Centers and High Speed Flight Station, "Steering Committee on Manned Space Flight," April 1, 1959; Director of Aeronautical and Space Research to Director of Space Flight Development, "Research Steering Committee on

Manned Space Flight," April 2, 1959; NASA Headquarters to Jet Propulsion Laboratory, "Research Steering Committee on Manned Space Flight," April 8, 1959.

April 2-5

The advanced manned space program to follow Project Mercury was discussed at a NASA Staff Conference held in Williamsburg, Va. Three reasons for such a program were suggested:

1. Preliminary step to development of spacecraft for manned interplanetary exploration.
2. Extended duration work in the space environment.
3. Support of the military space mission.

Among areas requiring study were the cost of an equatorial launch site, adequacy of tracking stations and DOD-NASA coordination of tracking systems, and the need for NASA's own propulsion test stands and facilities.

"NASA Staff Conference, Williamsburg, Va., April 2-5, 1959," pp. 2-3.

April 7

NASA Administrator T. Keith Glennan requested \$3 million for research into rendezvous techniques as part of the NASA budget for Fiscal Year 1960. In subsequent hearings, DeMarquis D. Wyatt, Assistant to the NASA Director of Space Flight Development, explained that these funds would be used to resolve certain key problems in making space rendezvous practical. Among these were the establishment of referencing methods for fixing the relative positions of two vehicles in space; the development of accurate, lightweight target-acquisition equipment to enable the supply craft to locate the space station; the development of very accurate guidance and control systems to permit precisely determined flight paths; and the development of sources of controlled power.

U.S. Congress, Senate, NASA Authorization Subcommittee of the Committee on Aeronautical and Space Sciences, *NASA Authorization for Fiscal Year 1960*, Hearings on S. 1582, 86th Congress, 1st Session (1959), p. 7; U.S. Congress, House, Committee on Science and Astronautics, *1960 NASA Authorization*, Hearings on H.R. 6512, 86th Congress, 1st Session (1959), pp. 97, 170, 267-268.

April 8

Testifying before the House Committee on Science and Astronautics, Francis B. Smith, Chief of Tracking Programs for NASA, described the network of stations necessary for tracking a deep-space probe on a 24-hour basis. The stations should be located about 120 degrees apart in longitude. In addition to the Goldstone, Calif., site, two other locations had been selected: South Africa and Woomera, Australia.

1960 NASA Authorization, Hearings on H.R. 6512, p. 295.

April 9

At a press conference in Washington, D.C., NASA Administrator T. Keith Glennan announced that seven pilots had been selected for the Mercury program. They were Lt. Cdr. Alan B. Shepard, Jr., Navy; Capt. Virgil I. Grissom, Air Force; Lt. Col. John H. Glenn, Jr., Marines; Lt. Malcolm Scott Carpenter, Navy; Lt. Cdr. Walter M. Schirra, Jr., Navy; Capt. Donald K. Slayton, Air Force; and Capt. Leroy Gordon Cooper, Jr., Air Force.

U.S. Congress, House, Committee on Science and Astronautics, *Meeting with the Astronauts, Project Mercury, Man-in-Space Program*, Hearings, 86th Congress, 1st Session (1959).

April 9-28

Members of the new Research Steering Committee on Manned Space Flight were nominated by the Ames, Lewis, and Langley Research Centers, the High Speed Flight Station (HSFS) (later Flight Research Center), the Jet Propulsion Laboratory (JPL), the Office of Space Flight Development (OSFD), and the Office of Aeronautical and Space Research (OASR). They were: Alfred J. Eggers, Jr. (Ames); Bruce T. Lundin (Lewis); Laurence K. Loftin, Jr. (Langley); De E. Beeler (HSFS); Harris M. Schurmeier (JPL); Maxime A. Faget (STG); George M. Low of NASA Headquarters OSFD); and Milton B. Ames, Jr. (part-time) (OASR).

Memoranda, Ames, Lewis, and Langley Research Centers to NASA Headquarters, "Research Steering Committee on Manned Space Flight," April 9 and 17, 1959; High Speed Flight Station to NASA Headquarters, "Research Steering Committee on Manned Space Flight," April 28, 1959; letter, W. H. Pickering, Director of the Jet Propulsion Laboratory, to Dr. J. W. Crowley, Director of Aeronautical and Space Research, NASA, April 13, 1959; memorandum, Abe Silverstein, Director of Space Flight Development, to Director of Aeronautical and Space Research, "Research Steering Committee on Manned Space Flight," April 13, 1959.

April 15

In response to a request by the DOD-NASA Saturn Ad Hoc Committee, the Army Ordnance Missile Command (AOMC) sent a supplement to the "Saturn System Study" to the Advanced Research Projects Agency ARPA describing the use of Titan for Saturn upper stages. On May 19, Roy W. Johnson, ARPA Director, notified AOMC that the Saturn second stage would be the first stage of the Titan. After discussions by ARPA, AOMC, Air Force, and Martin Company personnel, ARPA authorized AOMC to enter into direct contracts for modification and procurement of Titan hardware, and on July 24 the appropriate government offices were told by Army Ballistic Missile Agency (ABMA) to conclude letter contracts with Aerojet-General Corporation and The Martin Company. Five days later, ARPA ordered all AOMC Saturn second-stage effort suspended. Johnson later testified that Herbert F. York, DOD

Director of Defense Research and Engineering, had informed him: "I have decided to cancel the Saturn program on the grounds that there is no military justification therefore, on the grounds that any military requirement can be accommodated by Titan-C as proposed by the Air Force [Titan-C was a booster, not yet developed, of lower thrust than the Saturn and intended for use in the Dyna-Soar program], and on the ground that by the cancellation the Defense Department will be in a position to terminate the costly operation being conducted at ABMA." Johnson testified that he had been ready to concur in the cancellation of the Saturn program if it were established that the Titan G could be developed for about 75 percent of the cost of Saturn and if the Titan C could accomplish the military missions projected for the next ten years. York then appointed a Booster Evaluation Committee which convened on September 16.

U.S. Congress, House, Committee on Science and Astronautics, *To Amend the National Aeronautics and Space Act of 1958*, Hearings, 86th Congress, 2nd Session (1960), pp. 408, 412, 413; Senate Staff Report, *Manned Space Flight Program*, pp. 171, 172, 173.

April 24

Testifying before the Senate Committee on Aeronautical and Space Sciences, Maj. Gen. Bernard A. Schriever, Commander of the Air Force Ballistic Missile Division, stated that all three military services should be studying the possibility of a base on the moon. Up to that point, he felt, all such studies had been "in the blue thinking."

U.S. Congress, Senate, Committee on Aeronautical and Space Sciences, *Investigation of Governmental Organization for Space Activities*, Hearings, 86th Congress, 1st Session (1959), p. 483.

May 1

The Army Ordnance Missile Command submitted to NASA a report entitled "Preliminary Study of an Unmanned Lunar Soft Landing Vehicle," recommending the use of the Saturn booster.

Senate Staff Report, *Manned Space Flight Program*, p. 168.

May 1

STG was transferred to the authority of the newly formed Goddard Space Flight Center but remained based at Langley Field, Va.

Memorandum, T. E. Jenkins to Assistant Directors and Division Chiefs, Goddard Space Flight Center, "Organization and Functions of the Goddard Space Flight Center," May 1, 1959, with attachment: Abe Silverstein, Director of Space Flight Development, "Organization of Activities of Goddard Space Flight Center," May 1, 1959.

May 3

The first Rocketdyne H-1 engine for the Saturn arrived at the Army Ballistic Missile Agency (ABMA). The H-1 engine was installed in the ABMA test stand on May 7, first test-fired on May 21, and fired for 80 seconds on May 29. The first long-duration firing - 151.03 seconds - was on June 2.

Senate Staff Report, *Manned Space Flight Program*, p. 168.

May 9

Milton W. Rosen of NASA Headquarters proposed a plan for obtaining high-resolution photographs of the moon. A three-stage Vega would place the payload within a 500-mile diameter circle on the lunar surface. A stabilized retrorocket fired at 500 miles above the moon would slow the instrument package sufficiently to permit 20 photographs to be transmitted at a rate of one picture per minute. A radio altimeter could be used to index the height at which each picture was taken. The camera system, developed by the Eastman Kodak Company for the Air Force, would be available within the year. The alternative approach of using direct television appeared less attractive because the resolution of the television system was at least an order of magnitude lower than the comparable photographic system. Because of the difficulty in placing an instrument package in a close lunar orbit, photographs taken by a vehicle orbiting the moon, including those taken of the far side and recorded on magnetic tape for later transmission, would probably have low resolution owing to the distance from the lunar surface. On June 12, Rosen described a new television system which could be used for early attempts at lunar photography. The system, which would be available within a year, would relay pictures comparable to that of the Eastman Kodak camera system.

Memoranda, Rosen to A. Silverstein, "Lunar Photography," May 9, 1959; Rosen to Silverstein, "Lunar Photography, Revisions to Memorandum of May 9, 1959," June 12, 1959.

May 25-26

The first meeting of the Research Steering Committee on Manned Space Flight was held at NASA Headquarters. Members of the Committee attending were: Harry J. Goett, Chairman; Milton B. Ames, Jr. (part-time); De E. Beeler; Alfred J. Eggers, Jr.; Maxime A. Faget; Laurence K. Loftin, Jr.; George M. Low; Bruce T. Lundin; and Harris M. Schurmeier. Observers were John H. Disher, Robert M. Crane, Warren J. North, Milton W. Rosen (part-time), and H. Kurt Strass.

The purpose of the Committee was to take a long-term look at man-in-space problems, leading eventually to recommendations on future missions and on broad aspects of Center research programs to ensure that the Centers were providing proper information. Committee investigations would range beyond Mercury and Dyna-Soar but would not be overly concerned with specific vehicular configurations. The Committee would report directly to the Office of Aeronautical and Space Research.

Minutes, Research Steering Committee on Manned Space Flight, May 25-26, 1959, pp. 1-2.

May 25-26

The national booster program, Dyna-Soar, and Project Mercury were discussed by the Research Steering Committee. Members also presented reviews of Center programs related to manned space flight. Maxime A. Faget of STG endorsed lunar exploration as the present goal of the Committee although recognizing the end objective as manned interplanetary travel. George M. Low of NASA Headquarters recommended that the Committee:

- Adopt the lunar landing mission as its long-range objective.
- Investigate vehicle staging so that Saturn could be used for manned lunar landings without complete reliance on Nova.
- Make a study of whether parachute or airport landing techniques should be emphasized.
- Consider nuclear rocket propulsion possibilities for space flight.
- Attach importance to research on auxiliary power plants such as hydrogen-oxygen systems.

Minutes, Research Steering Committee on Manned Space Flight, May 25-26, 1959, pp. 3-10.

May 25-26

Tentative manned space flight priorities were established by the Research Steering Committee: Project Mercury, ballistic probes, environmental satellite, maneuverable manned satellite, manned space flight laboratory, lunar reconnaissance satellite, lunar landing, Mars Venus reconnaissance, and Mars-Venus landing. The Committee agreed that each NASA Center should study a manned lunar landing and return mission, the study to include the type of propulsion, vehicle configuration, structure, anti guidance requirements. Such a mission was an end objective; it did not have to be supported on the basis that it would lead to a more useful end. It would also focus attention at the Centers on the problems of true space flight.

Minutes, Research Steering Committee on Manned Space Flight, May 25-26, 1959, pp. 10, 11; memorandum, Harry J. Goett to Ira H. Abbott, Director of Aeronautical and Space Research, "Interim Report on Operations of 'Research Steering Committee on Manned Space Flight' " July 17. 1959.

May 27

Director Robert R. Gilruth met with members of his STG staff (Paul E. Purser, Charles J. Donlan, James A. Chamberlin, Raymond L. Zavasky, W. Kemble Johnson, Charles W. Mathews, Maxime A. Faget, and Charles H. Zimmeman) and George M. Low from NASA Headquarters to discuss the possibility of an advanced manned spacecraft.

Memorandum, Purser to Gilruth, "Log for the Week of May 25, 1959," p. 2.

June 3

Construction of the first Saturn launch area, Complex 34, began at Cape Canaveral, Fla.

Senate Staff Report, *Manned Space Flight Program*, p. 169.

June 4

At an STG staff meeting, Director Robert R. Gilruth suggested that study should be made of a post-Mercury program in which maneuverable Mercury spacecraft would make land landings in limited areas.

Memorandum, Paul E. Purser to Gilruth, "Log for the Week of June 1, 1959," p. 4.

June 8

The Project Horizon Phase I report was completed. In it, a U.S. manned landing on the moon in 1965 was proposed, to be followed in 1966 by an operational lunar outpost. Expenditures would average \$667 million a year from Fiscal Year 1960 through Fiscal Year 1968. The guiding philosophy of the report was one of "enlightened conservatism of technical approach." On July 28 the report was presented to the Secretary of the Army and the Chief of Staff. In discussion following the presentations, several conclusions emerged:

- The earliest possible U.S. manned lunar outpost was vital to American interests.
- Project Horizon was the earliest feasible means by which the United States could achieve that objective.
- The extensive and in many cases exclusive Army capabilities in this field should be used in the nation's service, regardless of who would have the responsibility for the lunar outpost.
- The general reception accorded U.S. Army proposals of space operations had not been uniformly enthusiastic.
- The source of the proposal should not be allowed to prejudice the reception of the proposal.

For these reasons, it was decided that the report should be recast to eliminate any U.S. Army organization to manage the lunar operation, at the same time deleting all possible military implications and inferences and emphasizing the scientific and inherently peaceful intent of the United States in its space operations. The report was accordingly revised, leaving the time frame intact, and on September 4 was submitted to the Secretary of the Army. It was later forwarded to the Secretary of Defense and (after the transfer of the von Braun team to NASA) to the NASA Administrator.

Senate Staff Report, *Manned Space Flight Program*, pp. 169, 172.

June 18

NASA authorized \$150,000 for Army Ordnance Missile Command studies of a lunar exploration program based on Saturn-boosted systems. To be included were circumlunar vehicles, unmanned and manned; close lunar orbiters; hard lunar impacts; and soft lunar landings with stationary or roving payloads.

Senate Staff Report, *Manned Space Flight Program*, p. 170.

June 25-26

At the second meeting of the Research Steering Committee on Manned Space Flight, held at the Ames Research Center, members presented reports on intermediate steps toward a manned lunar landing and return.

Bruce T. Lundin of the Lewis Research Center reported to members on propulsion requirements for various modes of manned lunar landing missions, assuming a 10,000-pound spacecraft to be returned to earth. Lewis mission studies had shown that a launch into lunar orbit would require less energy than a direct approach and would be more desirable for guidance, landing reliability, etc. From a 500,000-foot orbit around the moon, the spacecraft would descend in free fall, applying a constant-thrust decelerating impulse at the last moment before landing. Research would be needed to develop the variable-thrust rocket engine to be used in the descent. With the use of liquid hydrogen, the launch weight of the lunar rocket and spacecraft would be 10 to 11 million pounds.

If the earth orbit rendezvous concept were adopted, using Saturns to launch Centaurs for the lunar landing mission, nine Saturns would be needed to boost nine Centaurs into earth orbit for assembly to attain escape from earth orbit; three more Centaurs would have to be launched into earth orbit for assembly to accomplish the lunar orbit and landing; two additional Centaurs would be needed to provide for return and for the payload. The total of 14 Saturn/Centaur launches would be a formidable problem, not even considering the numerous complex rendezvous and assembly operations in space. The entire operation would have to be accomplished within two to three weeks because of the limitations on storing cryogenics in space.

Research would be needed on propulsion problems; on reliable, precisely controlled, variable-thrust engines for lunar landing; on a high-performance, storable-propellant, moon-takeoff engine; on auxiliary power systems; and on ground operations. Reduction of the ultimate payload weight was extremely vital, and more accurate information was needed on power and weight requirements for life support, capsule weight and size, and the exact scientific payload.

Lundin felt that a decision on whether to use the Saturn or Nova approach should be made as soon as possible since it would affect research and intermediate steps to be taken.

Minutes, Research Steering Committee on Manned Space Flight, June 25-26, 1959, pp. 2-5.

June 25-26

During the Research Steering Committee meeting, John H. Disher of NASA Headquarters discussed the lunar mission studies under way at the Army Ballistic Missile Agency (ABMA):

- ABMA had a large and competent group concentrating primarily on the lunar mission.
- Velocity and thrust requirements agreed well with those determined by the Lewis Research Center.
- ABMA was recommending a Saturn C-2 launch vehicle having a 2million-pound-thrust first stage, a 1-million-pound-thrust second stage, and a 200,000-pound-thrust third stage. Another launch vehicle six times larger than the Saturn C-2 was also being studied for direct ascent.
- ABMA was interested in obtaining a NASA contract to study the Saturn C-2 vehicle.
- Two approaches were being studied for the manned lunar landing, one refueling in earth orbit and the other assembling separately landed parcels on the moon for the return flight (lunar surface rendezvous).
- The ABMA schedule dates were unrealistic considering present funding and problem complexities.
- Orbit control and landing point control experiments were urgently needed, possibly with Mercury-type capsules.
- Large-scale controlled reentry experiments at lunar reentry velocity should begin as soon as possible.

The Committee agreed that studies should continue on the direct ascent versus earth orbital assembly and that Lewis should become more familiar with ABMA studies, while concentrating on the Nova approach. It was also suggested that the High Speed Flight Station look into the operational problems of assembly in orbit.

Minutes, Research Steering Committee on Manned Space Flight, June 25-26, 1959, pp. 5-6.

June 25-26

A report on a projected manned space station was made to the Research Steering Committee by Laurence K. Loftin, Jr., of the Langley Research Center. In discussion, Chairman Harry J. Goett expressed his opinion that consideration of a space laboratory ought to be an integral and coordinated part of the planning for the lunar landing mission. George M. Low of NASA Headquarters warned that care should be exercised to assure that each step taken toward the goal of a lunar landing was significant, since the number of steps that could be funded was extremely limited.

Minutes, Research Steering Committee on Manned Space Flight, June 25 26, 1959,

June 25-26

Alfred J. Eggers, Jr., of the Ames Research Center told the members of the Research Steering Committee of studies on radiation belts, graze and orbit maneuvers on reentry, heat transfer, structural concepts and requirements, lift over drag considerations, and guidance systems which affected various aspects of the manned lunar mission. Eggers said that Ames had concentrated on a landing maneuver involving a reentry approach over one of the poles to lessen radiation exposure, a graze through the outer edge of the atmosphere to begin an earth orbit, and finally reentry and landing.

Manned steps beyond Mercury, he said, should be:

- The use of the Vega or Centaur boosters to put a manned satellite into an orbit with a 50,000-mile apogee, carrying two men for two weeks to gain experience beyond Mercury with reentry techniques and extended manned space flight applicable to the lunar mission.
- The use of the Saturn booster in manned flight to the vicinity of the moon and return, putting two men in a highly elliptical orbit, with an apogee of up to 250,000 miles or even one pass around the moon before heading back to earth. The flight time would be about one week, providing experience similar to that of the manned lunar mission, including hyperbolic reentry to earth. A close, direct view of the lunar surface by man would support lunar landing.
- The use of the Nova or clustered-engine Saturn booster for a lunar landing and return. Two men would carry out this one-week to one-month expedition.

Eggers recommended that the same type of return capsule be used in all these missions to build up reliability and experience with the spacecraft before the lunar landing mission. Unmanned space probes should also be used to investigate certain factors related to the success of the lunar mission: polar radiation, lunar radiation, grazing reentry, lunar surface characteristics, and micrometeoroids.

The Committee unanimously agreed that investigation of a grazing reentry was necessary and would require an unmanned space probe. NASA Centers would look into experiments that might be launched by a Scout or Thor-Delta booster. Committee members would check to be sure that the basic programs in the Office of Space Flight Development space sciences programs covered the requirements for investigation of the other factors of special interest to the manned lunar mission.

Minutes, Research Steering Committee on Manned Space Flight, June 25-26, 1959, pp. 6-7.

June 25-26

Members of the Research Steering Committee determined the study and research areas which would require emphasis for manned flight to and from the moon and for intermediate flight steps:

Lunar mission studies:

More work would be required on determining "end" vehicle weight, life-support requirements, scientific payload requirements and objectives, exploring the possibility of using the "end" vehicle configuration in intermediate flight steps, booster requirement analysis, and Mercury

stretch-out capabilities.

Direct ascent versus assembly in earth orbit:

Lewis to continue Nova studies and become familiar with Army ballistic Missile Agency (ABMA) work on the rendezvous approach, High Speed Flight Station (HSFS) to study operational requirements for assembly in earth orbit, and recommended for ABMA study of assembly in earth orbit.

A reliable, precisely controlled, variable-thrust engine for lunar landing. A storable propellant lunar takeoff rocket. Storage of cryogenics in space (emissivity, absorptivity, etc.).

Structural work:

A study of molybdenum coating life at higher temperatures, a contract for test specimens to expedite NASA research, emphasis on research on ablating materials suitable for low heating rates, and study of combination radiation and ablation techniques. Life support (short term up to one month : contract study proposed.

Space suit development:

HSFS to study desired specifications.

Guidance system studies focused on the lunar mission:

Development of light but sophisticated onboard computers, data-smoothing techniques and effects on midcourse guidance accuracies, effects of gravity anomalies on initial instrumentation, terminal guidance system including retrothrust programming, and error analysis and energy requirements for the entry corridor on return to earth.

Minutes, Research Steering Committee on Manned Space Flight, June 25-26, 1959, attached summary pages 1-2.

During the Month

A report entitled "Recoverable Interplanetary Space Probe" was issued at the direction of C. Stark Draper, Director of the Instrumentation Laboratory, MIT. Several organizations had participated in this study, which began in 1957.

Interview with Milton B. Trageser, Instrumentation Laboratory, MIT, April 27, 1966.

Summer

Members of STG - including H. Kurt Strass, Robert L. O'Neal, Lawrence W. Enderson, Jr., and David C. Grana - and Thomas E. Dolan of Chance Vought Corporation worked on advanced design concepts of earth orbital and lunar missions. The goal was a manned lunar landing within ten years, rather than an advanced Mercury program.

Interview with H. Kurt Strass, November 30, 1966.

July 23

Advanced Research Projects Agency representatives visited Army Ordnance Missile Command to discuss studies of a Maneuverable Recoverable Space Vehicle (MRS. V). The general purpose was to identify U.S. space needs before 1970 which might require vehicles of this type.

Senate Staff Report, *Manned Space Flight Program*, p. 171.

August 1

The Advanced Research Projects Agency (ARPA) directed the Army Ordnance Missile Command to proceed with the static firing of the first Saturn vehicle, the test booster SA-T, in early calendar year 1960 in accordance with the \$70 million program and not to accelerate for a January 1960 firing. ARPA asked to be informed of the scheduled firing date.

David S. Akens, Paul K. Freiwirth, and Helen T. Wells, *History of the George C. Marshall Space Flight Center from July 1 to December 31, 1960* (MHM-2, 1961), Vol. 1, Appendix D, p. 23.

August 12

The STG New Projects Panel (proposed by H. Kurt Strass in June) held its first meeting to discuss NASA's future manned space program. Present were Strass, Chairman, Alan B. Kehlet, William S. Augerson, Jack Funk, and other STG members. Strass summarized the philosophy behind NASA's proposed objective of a manned lunar landing : maximum utilization of existing technology in a series of carefully chosen projects, each of which would provide a firm basis for the next step and be a significant advance in its own right. Each project would be an intermediate practical goal to focus attention on the problems and guide new technological developments. The Panel considered the following projects essential to the goal of lunar landing and return : a detailed investigation of the earth's radiation belts, recovery of radiation belt probes carrying biological specimens, an environmental satellite three men for two weeks, lunar probes, lunar reconnaissance (both manned and automatic), and lunar landing beacons and stores. The Panel recommended that work start immediately on an advanced recovery capsule that would incorporate the following features: reentry at near lunar return velocity, maneuverability both in space and in the atmosphere, and a parachute recovery for an earth landing. Kehlet was assigned to begin a program leading to a "second-generation" space capsule with a three-man capacity, space and atmospheric maneuverability, advanced abort devices, potential for near lunar return velocity, and advanced recovery techniques.

Memorandum, Strass to Chief, Flight Systems Division, "First Meeting of New Projects Panel," August 17, 1959.

August 18

At its second meeting, STG's New Projects Panel decided that the first major project to be investigated would be the second-generation reentry capsule. The Panel was presented a chart outlining the proposed sequence of events for manned lunar mission system analysis. The target date for a manned lunar landing was 1970.

Memorandum, H. Kurt Strass to Chief, Flight Systems Division, "Second Meeting of the New Projects Panel," August 26, 1959.

August 31

A House Committee Staff Report stated that lunar flights would originate from space platforms in earth orbit according to current planning. The final decision on the method to be used, "which must be made soon," would take into consideration the difficulty of space rendezvous between a space platform and space vehicles as compared with the difficulty of developing single vehicles large enough to proceed directly from the earth to the moon.

U.S. Congress, House, Committee on Science and Astronautics, *Space Propulsion*, Staff Report, 86th Congress, 1st Session (1959), p. 2.

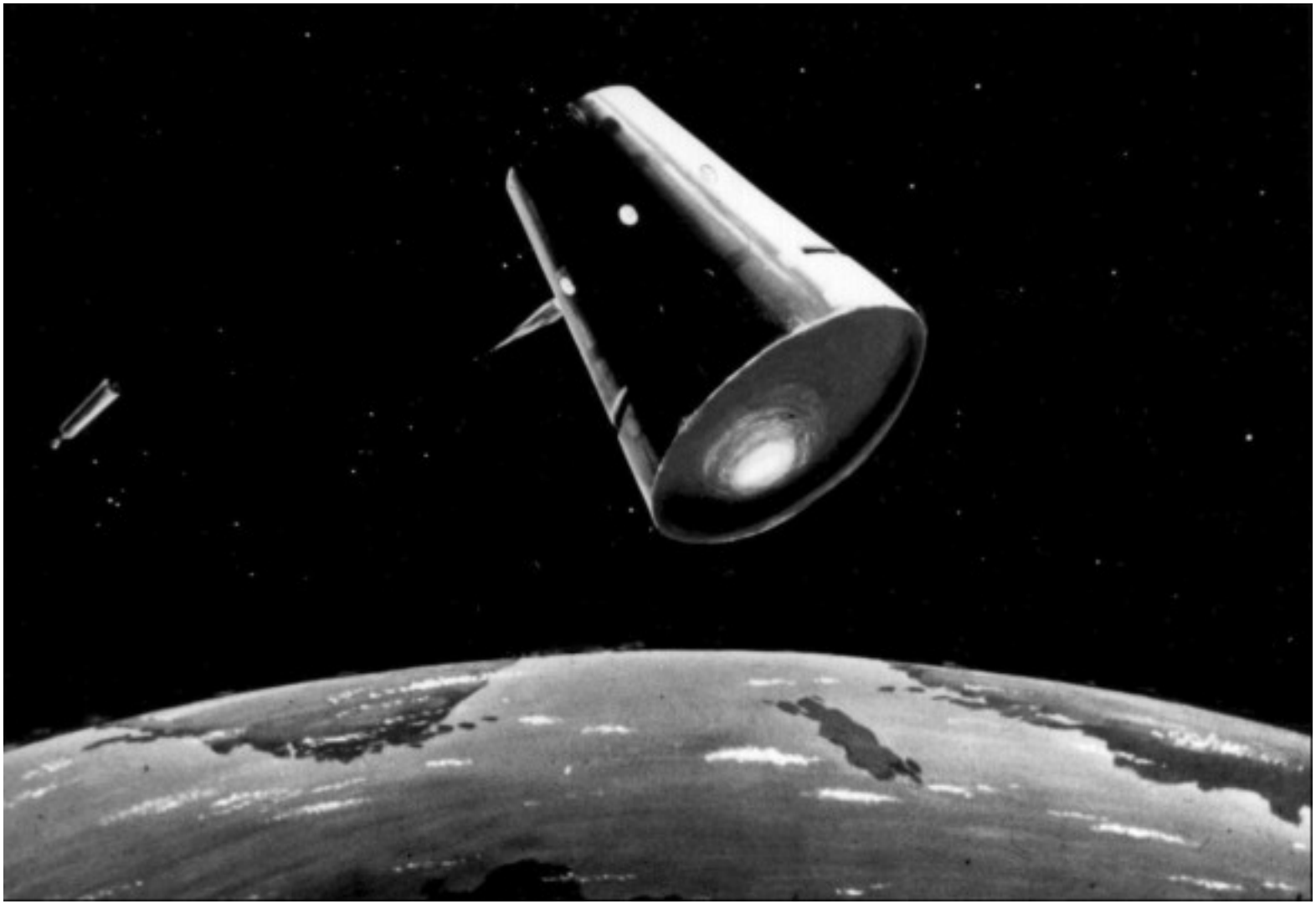
August 31



The artist's concepts on this page were used in a presentation by M. W. Rosen and F. C. Schwenk at the Tenth International Astronautical Congress in London, England, August 31, 1959. (1) Astronauts egress from the spacecraft and prepare to investigate the lunar surface.



(2) The takeoff from the moon.



(3) The reentry vehicle starts to enter the atmosphere while the jettisoned propulsion unit, shown more clearly in the lunar takeoff concept, is at left.

In a paper presented to the Tenth International Astronautical Congress in London, England, Milton W. Rosen and F. Carl Schwenk described a five-stage launch vehicle for manned lunar exploration. The direct ascent technique would be used in landing an 8000-pound spacecraft on the moon and returning it to earth. The F-1 engine would power both the booster and second stage of the launch vehicle. The concepts presented in the paper had been developed between February and April.

Milton W. Rosen and F. Carl Schwenk, "A Rocket for Manned Lunar Exploration," *Proceedings of the Tenth International Astronautical Congress, London, 1959* (1960).

September 1

McDonnell Aircraft Corporation reported to NASA the results of several company-funded studies of

follow-on experiments using Mercury spacecraft with heatshields modified to withstand lunar reentry conditions. In one experiment, a Centaur booster would accelerate a Mercury spacecraft plus a third stage into an eccentric earth orbit with an apogee of about 1,200 miles, so that the capsule would reenter at an angle similar to that required for reentry from lunar orbit. The third stage would then fire, boosting the spacecraft to a speed of 36,000 feet per second as it reentered the atmosphere.

McDonnell Aircraft Corporation, *Project Mercury Capsules, Follow On Experiments*, Engineering Report 6919 (September 1, 1959), p. 6.0-1.

September 12

The Soviet Union launched *Lunik II*, total payload weight 858.4 pounds. After a flight of about 35 hours, covering a distance of 236,875 miles, *Lunik II* became the first man-made object to impact on the moon. Three radio transmitters sent back signals until the crash landing.

Instruments and Spacecraft, p. 63.

September 16-18

The ARPA-NASA Booster Evaluation Committee appointed by Herbert F. York, DOD Director of Defense Research and Engineering, April 15, 1959, convened to review plans for advanced launch vehicles. A comparison of the Saturn (C-1) and the Titan-C boosters showed that the Saturn, with its substantially greater payload capacity, would be ready at least one year sooner than the Titan-C. In addition, the cost estimates on the Titan-C proved to be unrealistic. On the basis of the Advanced Research Projects Agency presentation, York agreed to continue the Saturn program but, following the meeting, began negotiations with NASA Administrator T. Keith Glennan to transfer the Army Ballistic Missile Agency (and, therefore, Saturn) to NASA.

To Amend the National Aeronautics and Space Act of 1958, Hearings, p. 410; Senate Staff Report, *Manned Space Flight Program*, p. 175.

September 28

At the third meeting of STG's New Projects Panel, Alan B. Kehlet presented suggestions for the multimanned reentry capsule. A lenticular-shaped vehicle was proposed, to ferry three occupants safely to earth from a lunar mission at a velocity of about 36,000 feet per second.

Memorandum, H. Kurt Strass to Chief, Flight Systems Division, "Third Meeting of New Projects Panel," October 1, 1959.

During the month

A study of the guidance and control design for a variety of space missions began at the MIT Instrumentation Laboratory under a NASA contract.

Interview with Milton B. Trageser, Instrumentation Laboratory, MIT, April 27, 1966.

October 4

The Soviet Union launched *Lunik III* toward the moon on the second anniversary of Sputnik I. The spacecraft, called an "Automatic Interplanetary Station," carried 345 pounds of instruments including cameras. On October 7, a signal from earth activated the cameras, which photographed about 70 percent of the hidden side of the moon in 40 minutes. The photographs were transmitted to Soviet stations on October 18 and released to the world press on October 27. First analyses of the photographs by Soviet astronomers seemed to indicate that the hidden side of the lunar surface had fewer craters than its visible face.

New York Times, October 27, 1959; *Instruments and Spacecraft*, pp. 69-71.

October 21

After a meeting with officials concerned with the missile and space program, President Dwight D. Eisenhower announced that he intended to transfer to NASA control the Army Ballistic Missile Agency's Development Operations Division personnel and facilities. The transfer, subject to congressional approval, would include the Saturn development program.

New York Times, October 22, 1959; Emme, *Aeronautics and Astronautics*, p. 114.

November 2

At an STG meeting, it was decided to begin planning of advanced spacecraft systems. Participants in the meeting were Director Robert R. Gilruth, Paul E. Purser, Charles J. Donlan, Maxime A. Faget, Robert O. Piland, H. Kurt Strass, Charles W. Mathews, John D. Hodge, James A. Chamberlin, and Caldwell C. Johnson. Three primary assignments were made:

1. The preliminary design of a multi-man (probably three-man) capsule for a circumlunar mission, with particular attention to the use of the capsule as a temporary space laboratory, lunar landing cabin, and deep-space probe;
2. Mission analysis studies to establish exit and reentry corridors, weights, and propulsion requirements;
3. Test program planning to decide on the number and purpose of launches.

A panel composed of Piland, Strass, Hodge, and Johnson was appointed to carry out these assignments. The ground rules given to the panel, which was responsible to the Director's office, were:

1. Use personnel necessary to accomplish the work, but do not slow down Mercury;
2. As many as 30 persons (10 percent of the STG staff) might possibly be used in the future.

Memorandum, Purser to Gilruth, "Log for the Week of November 2, 1959."

November 19

In a memorandum to the members of the Research Steering Committee on Manned Space Flight, Chairman Harry J. Goett discussed the increased importance of the weight of the "end vehicle" in the lunar landing mission. This was to be an item on the agenda of the third meeting of the Committee, to be held in early December. Abe Silverstein, Director of the NASA Office of Space Flight Development, had recently mentioned to Goett that a decision would be made within the next few weeks on the configuration of successive generations of Saturn, primarily the upper stages, Silverstein and Goett had discussed the Committee's views on a lunar spacecraft. Goett expressed the hope in the memorandum that members of the Committee would have some specific ideas at their forthcoming meeting about the probable weight of the spacecraft.

In addition, Goett informed the Committee that the Vega had been eliminated as a possible booster for use in one of the intermediate steps leading to the lunar mission. The primary possibility for the earth satellite mission was now the first-generation Saturn and for the lunar flight the second-generation Saturn.

Memorandum, Goett, Chairman, to the Research Steering Committee on Manned Space Flight, "Estimate of Weight of 'End Vehicle' for Lunar Soft Landing and Return Mission To Aid in Choice of Booster Configuration," November 19, 1959.

November 26

An intended lunar probe launched from the Atlantic Missile Range by an Atlas-Able booster disintegrated about 45 seconds later when the protective sheath covering the payload detached prematurely. The probe was sponsored by NASA, developed by the Jet Propulsion Laboratory, and launched by the Air Force Ballistic Missile Division.

Instruments and Spacecraft, p. 81; *New York Times*, November 28, 1959.

November 27

While awaiting the formal transfer of the Saturn program, NASA formed a study group to recommend upper-stage configurations. Membership was to include the DOD Director of Defense Research and Engineering and personnel from NASA, Advanced Research Projects Agency, Army Ballistic Missile Agency, and the Air Force. This group was later known both as the Saturn Vehicle Team and the

Silverstein Committee (for Abe Silverstein, Chairman).

Senate Staff Report, *Manned Space Flight Program*, p. 179.

December 1

Twelve nations signed a treaty making the Antarctic continent a preserve for scientific research, immune from political and military strife. Signatories were Argentina, Australia, Great Britain, Chile, France, New Zealand, Norway, Belgium, Japan, South Africa, the Soviet Union, and the United States. Legal experts have suggested that the Antarctic Treaty provided a precedent for similar agreements demilitarizing the moon and other bodies in space.

U.S. Congress, Senate, Committee on Aeronautical and Space Sciences, *Legal Problems of Space Exploration: A Symposium*, 87th Congress, 1st Session (1961), pp. 1297-1303.

December 6

The initial plan for transferring the Army Ballistic Missile Agency and Saturn to NASA was drafted. It was submitted to President Dwight D. Eisenhower on December 11 and was signed by Secretary of the Army Wilber M. Brucker and Secretary of the Air Force James H. Douglas on December 16 and by NASA Administrator T. Keith Glennan on December 17.

David S. Akens, *Historical Origins of the George C. Marshall Space Flight Center* (MSFC Historical Monograph No. 1, 1960), p. 73, Appendix C, approval page.

December 7

The Advanced Research Projects Agency ARPA and NASA requested the Army Ordnance Missile Command AOMC to prepare an engineering and cost study for a new Saturn configuration with a second stage of four 20,000-pound-thrust liquid-hydrogen and liquid-oxygen engines (later called the S-IV stage) and a modified Centaur third stage using two of these engines later designated the S-V stage). AOMC was also asked to indicate what significant program improvements or acceleration could be achieved with an increase in Fiscal Year 1960 funding if provided late in the fiscal year. The study was sent to ARPA and NASA by AOMC on December 10 and formally submitted on December 28.

Senate Staff Report, *Manned Space Flight Program*, p. 180.

December 8-9

At the third meeting of the Research Steering Committee on Manned Space Flight held at Langley Research Center, H. Kurt Strass reported on STG's thinking on steps leading to manned lunar flight and

on a particular capsule-laboratory spacecraft. The project steps beyond Mercury were: radiation experiments, minimum space and reentry vehicle (manned), temporary space laboratory (manned), lunar data acquisition (unmanned), lunar circumnavigation or lunar orbiter (unmanned), lunar base supply (unmanned), and manned lunar landing. STG felt that the lunar mission should have a three-man crew. A configuration was described in which a cylindrical laboratory was attached to the reentry capsule. This laboratory would provide working space for the astronauts until it was jettisoned before reentry. Preliminary estimates put the capsule weight at about 6,600 pounds and the capsule plus laboratory at about 10,000 pounds.

Minutes, Research Steering Committee on Manned Space Flight, December 8-9, 1959, p. 3.

December 8-9

H. H. Koelle told members of the Research Steering Committee of mission possibilities being considered at the Army Ballistic Missile Agency. These included an engineering satellite, an orbital return capsule, a space crew training vehicle, a manned orbital laboratory, a manned circumlunar vehicle, and a manned lunar landing and return vehicle. He described the current Saturn configurations, including the "C" launch vehicle to be operational in 1967. The Saturn C (larger than the C-1) would be able to boost 85,000 pounds into earth orbit and 25,000 pounds into an escape trajectory.

Minutes, Research Steering Committee on Manned Space Flight, December 8-9, 1959, p. 4.

December 8-9

Several possible configurations for a manned lunar landing by direct ascent being studied at the Lewis Research Center were described to the Research Steering Committee by Seymour C. Himmel. A six-stage launch vehicle would be required, the first three stages to boost the spacecraft to orbital speed, the fourth to attain escape speed, the fifth for lunar landing, and the sixth for lunar escape with a 10,000-pound return vehicle. One representative configuration had an overall height of 320 feet. H. H. Koelle of the Army Ballistic Missile Agency argued that orbital assembly or refueling in orbit [earth orbit rendezvous] was more flexible, more straightforward, and easier than the direct ascent approach. Bruce T. Lundin of the Lewis Research Center felt that refueling in orbit presented formidable problems since handling liquid hydrogen on the ground was still not satisfactory. Lewis was working on handling cryogenic fuels in space.

Minutes, Research Steering Committee on Manned Space Flight, December 8-9, 1959, pp. 4-5.

December 12

The General Assembly of the United Nations unanimously approved Resolution 1472 (XIV), establishing the Committee on the Peaceful Uses of Outer Space to replace the Ad Hoc Committee. There were no meetings of the Committee until November 27, 1961, because of failure to agree on the

composition of the Committee.

Legal Problems of Space Exploration, pp. 1274-1275.

December 21

A guideline letter was sent to William H. Pickering, Director of the Jet Propulsion Laboratory (JPL), from Abe Silverstein, Director of NASA's Office of Space Flight Development, outlining a program of five lunar spacecraft flights, intended primarily to obtain information on the lunar surface. JPL was requested to conduct tradeoff studies on spacecraft design and mission. The scientific objective would be to "acquire and transmit a number of images of the lunar surface." In addition, JPL was asked to "evaluate the probability of useful data return from a survivable package incorporating . . . a lunar seismometer of the type . . . being developed for NASA." This letter provided the formal basis for what was subsequently the Ranger program.

U.S. Congress, House, Subcommittee on NASA Oversight of the Committee on Science and Astronautics, *Investigation of Project Ranger*, Hearings, 88th Congress, 2nd Session (1964), p. 56.

December 29

In a memorandum to Don R. Ostrander, Director of Office of Launch Vehicle Programs, and Abe Silverstein, Director of Office of Space Flight Programs, NASA Associate Administrator Richard E. Horner described the proposed Space Exploration Program Council, which would be concerned primarily with program development and implementation. The Council would be made up of the Directors of the Jet Propulsion Laboratory, the Goddard Space Flight Center, the Army Ballistic Missile Agency, the Office of Space Flight Programs, and the Office of Launch Vehicle Programs. Horner would be Chairman of the Council which would have its first meeting on January 28-29, 1960 [later changed to February 10-11, 1960].

Memorandum, Horner to Ostrander and Silverstein, December 29, 1959.

December 31

NASA accepted the recommendations of the Saturn Vehicle Evaluation Committee Silverstein Committee on the Saturn C-1 configuration and on a long-range Saturn program. A research and development plan of ten vehicles was approved. The C-1 configuration would include the S-1 stage (eight H-1 engines clustered, producing 1.5 million pounds of thrust), the S-IV stage (four engines producing 80,000 pounds of thrust), and the S-V stage two engines producing 40,000 pounds of thrust .

Akens *et al.*, *History of the George C. Marshall Space Flight Center from July 1 to December 31, 1960*, Vol. 1, Appendix D, p. 33; *Saturn Illustrated Chronology*, pp. 8-10.

1959-1960

For the first time, attention was focused on the lunar orbit rendezvous scheme at Langley Research Center during studies in support of the Langley Research Center Lunar Mission Steering Group. This committee was active in 1959 and 1960. In 1960, the lunar trajectory group of the Theoretical Mechanics Division prepared information for presentation to the Lunar Mission Steering Group and for circulation throughout the laboratory to stimulate interest in problems related to the lunar mission.

John D. Bird, "Short History of the Development of the Lunar Orbit Rendezvous Plan at the Langley Research Center," September 6, 1963, unpublished, pp. 1-2.

1960

January 14

President Dwight D. Eisenhower directed NASA Administrator T. Keith Glennan "to make a study, to be completed at the earliest date practicable, of the possible need for additional funds for the balance of FY 1960 and for FY 1961 to accelerate the super booster program for which your agency recently was given technical and management responsibility."

Letter, President Dwight D. Eisenhower to Dr. T. Keith Glennan, January 14, 1960.

January 28

In testimony before the House Committee on Science and Astronautics, Richard E. Horner, Associate Administrator of NASA, presented NASA's ten-year plan for 1960-1970. The essential elements had been recommended by the Research Steering Committee on Manned Space Flight. NASA's Office of Program Planning and Evaluation, headed by Homer J. Stewart, formalized the ten-year plan.

1960:

- First launching of a meteorological satellite

- First launching of a passive reflector communications satellite

- First launching of the Scout vehicle

- First launching of the Thor-Delta vehicle

- First launching of the Atlas-Agena B (DOD)

- First suborbital flight by an astronaut

1961:

First launching of a lunar impact vehicle

First launching of an Atlas-Centaur vehicle

Attainment of orbital manned space flight, Project Mercury

1962:

First launching of a probe to the vicinity of Venus or Mars

1963:

First launching of a two-stage Saturn

1963-1964:

First launching of an unmanned vehicle for controlled landing on the moon

First launching of an orbiting astronomical and radio astronomical laboratory

1964:

First launching of an unmanned circumlunar vehicle and return to earth

First reconnaissance of Mars or Venus, or both, by an unmanned vehicle

1965-1967:

First launching in a program leading to manned circumlunar flight and to a permanent near-earth space station

Beyond 1970:

Manned lunar landing and return

On February 19, NASA officials again presented the ten-year timetable to the House Committee. A lunar soft landing with a mobile vehicle had been added for 1965. On March 28, NASA Administrator T. Keith Glennan described the plan to the Senate Committee on Aeronautical and Space Sciences. He estimated the cost of the program to be more than \$1 billion in Fiscal Year 1962 and at least \$1.5 billion annually over the next five years, for a total cost of \$12 to \$15 billion.

U.S. Congress, House, Committee on Science and Astronautics, *Review of the Space Program*, Part I, Hearings, 86th Congress, 2nd Session (1960), p. 189; U.S. Congress, House, Committee on Science and Astronautics, *1961 NASA Authorization*, Hearings on H.R. 10246, 86th Congress, 2nd Session (1960), p. 176; U.S. Congress, Senate, NASA Authorization Subcommittee of the Committee on Aeronautical and Space Sciences, *Hearings on H.R. 10809*, 86th Congress, 2nd Session (1960), pp. 21-22; "Highlights of GSFC Program - Mr. Goett," NASA Staff Conference, Monterey, Calif., March 3-5, 1960; Rosholt, *An Administrative History of NASA, 1958-1963*, pp. 130-131.

During the Month

The Chance Vought Corporation completed a company-funded, independent, classified study on manned lunar landing and return (MALLAR), under the supervision of Thomas E. Dolan. Booster limitations

indicated that earth orbit rendezvous would be necessary. A variety of lunar missions were described, including a two-man, 14-day lunar landing and return. This mission called for an entry vehicle of 6,600 pounds, a mission module of 9,000 pounds, and a lunar landing module of 27,000 pounds. It incorporated the idea of lunar orbit rendezvous though not specifically by name.

Interview with John D. Bird, Langley Research Center, June 20, 1966.

During the Month

At a luncheon in Washington, Abe Silverstein, Director of the Office of Space Flight Programs, suggested the name "Apollo" for the manned space flight program that was to follow Mercury. Others at the luncheon were Don R. Ostrander from NASA Headquarters and Robert R. Gilruth, Maxime A. Faget, and Charles J. Donlan from STG.

Interview with Charles J. Donlan, Langley Research Center, June 20, 1966.

February 1

The Army Ballistic Missile Agency submitted to NASA the study entitled "A Lunar Exploration Program Based Upon Saturn-Boosted Systems." In addition to the subjects specified in the preliminary report of October 1, 1959, it included manned lunar landings.

U.S. Army Ordnance Missile Command, *A Lunar Exploration Program Based Upon Saturn-Boosted Systems*, DV-TR-2-60 (February 1, 1960).

February 10-11

The first meeting of the NASA Space Exploration Council was held at NASA Headquarters. The objective of the Council was "to provide a mechanism for the timely and direct resolution of technical and managerial problems . . . common to all NASA Centers engaged in the space flight program." Present at the meeting were Richard E. Horner, Chairman, Don R. Ostrander, Abe Silverstein, Nicholas E. Golovin, Abraham Hyatt, and Robert L. King Executive Secretary of NASA Headquarters; Wernher von Braun of the Army Ballistic Missile Agency; Harry J. Goett of Goddard Space Flight Center; and William H. Pickering of the Jet Propulsion Laboratory. Among the agreements were:

- Membership of the Council would be expanded to include the Director of Advanced Research Programs.
- Meetings would be quarterly.
- A Senior Steering Group would be appointed by Homer to resolve policy issues concerning the proposed NASA Headquarters reliability staff. This staff was to develop policies and methods for ensuring the functional reliability of space systems from initial design stage through final launch.
- The Council would decide whether to move up the firing date of the first Atlas-Agena B lunar

mission from May to February 1961.

Minutes, Space Exploration Program Council Meeting, February 10-11, 1960, pp. 1, 3-5.

February 29

Eleven companies submitted contract proposals for the Saturn second stage (S-IV): Bell Aircraft Corporation; The Boeing Airplane Company; Chrysler Corporation; General Dynamics Corporation, Convair Astronautics Division; Douglas Aircraft Company, Inc.; Grumman Aircraft Engineering Corporation; Lockheed Aircraft Corporation; The Martin Company; McDonnell Aircraft Corporation; North American Aviation, Inc.; and United Aircraft Corporation.

Akens *et al.*, *History of the George C. Marshall Space Flight Center from July 1 to December 31, 1960*, Vol. 1, Appendix D, p. 41.

March 1

NASA established the Office of Life Sciences Programs with Clark T. Randt as Director. The Office would assist in the fields of biotechnology and basic medical and behavioral sciences. Proposed biological investigations would include work on the effects of space and planetary environments on living organisms, on evidence of extraterrestrial life forms, and on contamination problems. In addition, the Office would arrange grants and contracts and plan a life sciences research center.

U.S. Congress, House, Committee on Science and Astronautics, *Space Medicine Research*, Hearings before the Special Investigating Subcommittee, 86th Congress, 2nd Session (1960), p. 3; U.S. Congress, House, Committee on Science and Astronautics, *Life Sciences and Space*, Hearings, 86th Congress, 2nd Session (1960), p. 13 ; Mae Mills Link, *Space Medicine in Project Mercury* (NASA SP-4003, 1965), p. 38.

March 3-5

At a NASA staff conference at Monterey, Calif., officials discussed the advanced manned space flight program, the elements of which had been presented to Congress in January. The Goddard Space Flight Center was asked to define the basic assumptions to be used by all groups in the continuing study of the lunar mission. Some problems already raised were: the type of heatshield needed for reentry and tests required to qualify it, the kind of research and development firings, and conditions that would be encountered in cislunar flight. Members of STG would visit NASA Centers during April to define the tasks and request assistance. STG representatives were directed to maintain contact with the Centers and try to identify gaps in the technology. STG was also assigned the responsibility for preparing a first draft of specifications for a lunar spacecraft.

"Highlights of GSFC Program - Mr. Goett," NASA Staff Conference, Monterey, Calif., March 3-5, 1960.

March 8

STG formulated preliminary guidelines by which an "advanced manned spacecraft and system" would be developed. These guidelines were further refined and elaborated; they were formally presented to NASA Centers during April and May.

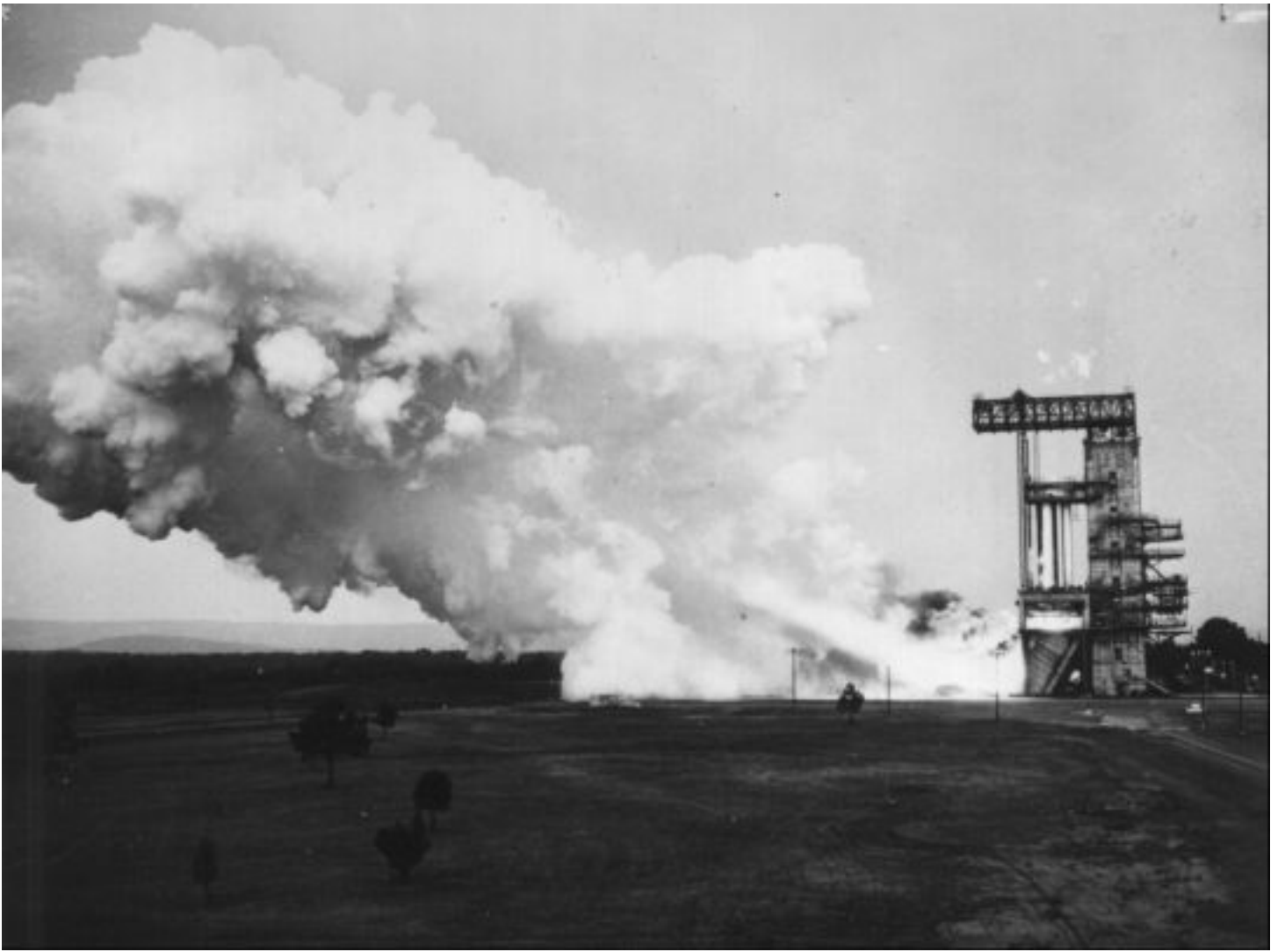
STG, "Ground Rules for Manned Lunar Reconnaissance," March 8, 1960.

March 15

The Army Ballistic Missile Agency's Development Operations Division and the Saturn program were transferred to NASA after the expiration of the 60-day limit for congressional action on the President's proposal of January 14. [The President's decision had been made on October 21, 1959.] By Executive Order, the President named the facilities the "George C. Marshall Space Flight Center." Formal transfer took place on July 1.

Akens, *Historical Origins of the George C. Marshall Space Flight Center*, pp. 76-7.

March 28



A cloud of smoke mushroomed from the base of the static firing facility at Redstone Arsenal, Ala., when two of the eight H-1 engines of the Saturn C-1 launch vehicle's first stage were tested for the first time.

Two of the eight H-1 engines of the Saturn C-1 first stage were successfully static-fired for approximately eight seconds. The test, conducted at Redstone Arsenal, was designated SAT-01 - the first live firing of the Saturn test booster SA-T).

Saturn Illustrated Chronology, p. 11.

April 1-May 3

Members of STG presented guidelines for an advanced manned spacecraft program to NASA Centers to enlist research assistance in formulating spacecraft and mission design.

To open these discussions, Director Robert R. Gilruth summarized the guidelines: manned lunar

reconnaissance with a lunar mission module, corollary earth orbital missions with a lunar mission module and with a space laboratory, compatibility with the Saturn C-1 or C-2 boosters (weight not to exceed 15,000 pounds for a complete lunar spacecraft and 25,000 pounds for an earth orbiting spacecraft), 14-day flight time, safe recovery from aborts, ground and water landing and avoidance of local hazards, point (ten square-mile) landing, 72-hour postlanding survival period, auxiliary propulsion for maneuvering in space, a "shirtsleeve" environment, a three-man crew, radiation protection, primary command of mission on board, and expanded communications and tracking facilities. In addition, a tentative time schedule was included, projecting multiman earth orbit qualification flights beginning near the end of the first quarter of calendar year 1966.

STG, "Guidelines for Advanced Manned Space Vehicle Program," June 1960, pp. ii, 1-5.

April 1-May 3

STG's Robert O. Piland, during briefings at NASA Centers, presented a detailed description of the guidelines for missions, propulsion, and flight time in the advanced manned spacecraft program:

1. The spacecraft should be capable ultimately of manned circumlunar reconnaissance. As a logical intermediate step toward future goals of lunar and planetary landing many of the problems associated with manned circumlunar flight would need to be solved.
2. The lunar spacecraft should be capable of earth orbit missions for initial evaluation and training. The reentry component of this spacecraft should be capable of missions in conjunction with space laboratories or space stations. To accomplish lunar reconnaissance before a manned landing, it would be desirable to approach the moon closer than several thousand miles. Fifty miles appeared to be a reasonable first target for study purposes.
3. The spacecraft should be designed to be compatible with the Saturn C-1 or C-2 boosters for the lunar mission. The multiman advanced spacecraft should not weigh more than 15,000 pounds including auxiliary propulsion and attaching structure.
4. A flight-time capability of the spacecraft for 14 days without resupply should be possible. Considerable study of storage batteries, fuel cells, auxiliary power units, and solar batteries would be necessary. Items considered included the percentage of the power units to be placed in the "caboose" (space laboratory), preference for the use of storage batteries for both power and radiation shielding, and redundancy for reliability by using two different types of systems versus two of the same system.

STG, "Guidelines for Advanced Manned Space Vehicle Program," June 1960, pp. 6-14.

April 1-May 3

In discussing the advanced manned spacecraft program at NASA Centers, Maxime A. Faget of STG detailed the guidelines for aborted missions and landing:

1. The spacecraft must have a capability of safe crew recovery from aborted missions at any speed up to the maximum velocity, this capability to be independent of the launch propulsion system.
2. A satisfactory landing by the spacecraft on both water and land, avoiding local hazards in the recovery area, was necessary. This requirement was predicated on two considerations: emergency conditions or navigation errors could force a landing on either water or land; and accessibility for recovery and the relative superiority of land versus water landing would depend on local conditions and other factors. The spacecraft should be able to land in a 30-knot wind, be watertight, and be seaworthy under conditions of 10- to 12-foot waves.
3. Planned landing capability by the spacecraft at one of several previously designated ground surface locations, each approximately 10 square miles in area, would be necessary. Studies were needed to assess the value of impulse maneuvers, guidance quality, and aerodynamic lift over drag during the return from the lunar mission. Faget pointed out that this requirement was far less severe for the earth orbit mission than for the lunar return.
4. The spacecraft design should provide for crew survival for at least 72 hours after landing. Because of the unpredictability of possible emergency maneuvers, it would be impossible to provide sufficient recovery forces to cover all possible landing locations. The 72-hour requirement would permit mobilization of normally existing facilities and enough time for safe recovery. Locating devices on the spacecraft should perform adequately anywhere in the world.
5. Auxiliary propulsion should be provided for guidance maneuvers needed to effect a safe return in a launch emergency. Accuracy and capability of the guidance system should be studied to determine auxiliary propulsion requirements. Sufficient reserve propulsion should be included to accommodate corrections for maximum guidance errors. The single system could serve for either guidance maneuvers or escape propulsion requirements.

STG, "Guidelines for Advanced Manned Space Vehicle Program," June 1960, pp. 15-23.

April 1-May 3

Stanley C. White of STG outlined at NASA Centers the guidelines for human factors in the advanced manned spacecraft program:

1. A "shirtsleeve" spacecraft environment would be necessary because of the long duration of the lunar flight. This would call for a highly reliable pressurized cabin and some means of protection against rapid decompression. Such protection might be provided by a quick-donning pressure suit. Problems of supplying oxygen to the spacecraft; removing carbon dioxide, water vapor, toxic gases, and microorganisms from the capsule atmosphere; basic monitoring instrumentation; and restraint and couch design were all under study. In addition, research would be required on noise and vibration in the spacecraft, nutrition, waste disposal, interior arrangement and displays, and bioinstrumentation.
2. A minimum crew of three men was specified. Studies had indicated that, for a long-duration mission, multiman crews were necessary and that three was the minimum number required.
3. The crew should not be subjected to more than a safe radiation dose. Studies had shown that it was not yet possible to shield the crew against a solar flare. Research was indicated on structural

materials and equipment for radiation protection, solar-flare prediction, minimum radiation trajectories, and the radiation environment in cislunar space.

STG, "Guidelines for Advanced Manned Space Vehicle Program," June 1960, pp. 24-38.

April 1-May 3

Command and communications guidelines for the advanced manned spacecraft program were listed by STG's Robert G. Chilton at NASA Centers:

1. Primary command of the mission should be on board. Since a manned spacecraft would necessarily be much more complex and its cost much greater than an unmanned spacecraft, maximum use should be made of the command decision and operational capabilities of the crew. Studies would be needed to determine the extent of these capabilities under routine, urgent, and extreme emergency conditions. Onboard guidance and navigation hardware would include inertial platforms for monitoring insertion guidance, for abort command, and for abort-reentry navigation; optical devices; computers; and displays. Attitude control would require a multimode system.
2. Communications and ground tracking should be provided throughout the mission except when the spacecraft was behind the moon. Voice contact once per orbit was considered sufficient for orbital missions. For the lunar mission, telemetry would be required only for backup data since the crew would relay periodic voice reports. Television might be desirable for the lunar mission. For ground tracking, a study of the Mercury system would determine whether the network could be modified and relocated to satisfy the close-in requirements of a lunar mission. The midcourse and circumlunar tracking requirements might be met by the deep-space network facilities at Goldstone, Calif., Australia, and South Africa. Both existing and proposed facilities should be studied to ensure that frequencies for all systems could be made compatible to permit use of a single beacon for midcourse and reentry tracking.

STG, "Guidelines for Advanced Manned Space Vehicle Program," June 1960, pp. 39-46.

April 5

John C. Houbolt of the Langley Research Center presented a paper at the National Aeronautical Meeting of the Society of Automotive Engineers in New York City in which the problems of rendezvous in space with the minimum expenditure of fuel were considered. To resupply a space station, for example, the best solution appeared to be to launch the ferry rocket into an adjacent orbit. A minimum amount of fuel would then be needed to inject the ferry rocket into the same orbital plane as the space station. Attention was also focused on the wait time before a rendezvous launch.

If launch were made into the correct orbital plane, with subsequent lead or lag correction, wait periods of many days would be necessary, but if launch were made into an incorrect orbital plane with a later plane

correction, wait periods of only a day or two would be feasible.

John C. Houbolt, "Considerations of the Rendezvous Problems for Space Vehicles," paper presented at the Society of Automotive Engineers, National Aeronautical Meeting, April 5-8, 1960.

April 6

Four of the eight H-1 engines of the Saturn C-1 first-stage booster were successfully static-fired at Redstone Arsenal for seven seconds.

Saturn Illustrated Chronology, p. 11.

April 9-16

Detailed lunar charts, consisting of 230 photographic sheets, were published by the Air Force and the University of Chicago Press. The atlas, in preparation under Air Force contract since April 1958, was assembled by Gerard P. Kuiper of the Yerkes Observatory.

New York Herald Tribune, April 10, 1960.

April 15

Briefings on the guidelines for the advanced manned spacecraft program were presented by STG representatives at NASA Headquarters.

Memorandum, John H. Disher to Abe Silverstein, May 10, 1960.

April 18

In a memorandum to NASA Administrator T. Keith Glennan, Robert L. King, Executive Secretary of the Space Exploration Program Council (SEPC), reported on the status of certain actions taken up at the first meeting of the Council:

- Rather than appoint a separate Senior Steering Group to resolve policy problems connected with the reliability program, SEPC itself tentatively would be used. A working committee would be appointed for each major system and would and rely on the SEPC for broad policy guidance,
- Proposed rescheduling of the first Atlas-Agena 13 lunar mission for an earlier flight date was abandoned as impractical.

Memorandum, King to Glennan via Richard E. Horner, "SEPC Meeting of February 10-11, 1960 - Status of Actions," April 18, 1960.

April 15

STG members, visiting Moffett Field, Calif., briefed representatives of the Jet Propulsion Laboratory, Flight Research Center, and Ames Research Center on the advanced manned spacecraft program. Ames representatives then described work at their Center which would be applicable to the program: preliminary design studies of several aerodynamic configurations for reentry from a lunar trajectory, guidance and control requirements studies, potential reentry heating experiments at near-escape velocity, flight simulation, and pilot display and navigation studies. STG asked Ames to investigate heating and aerodynamics on possible lifting capsule configurations. In addition, Ames offered to tailor a payload applicable to the advanced program for a forthcoming Wallops Station launch.

Memoranda, John H. Disher to Abe Silverstein, May 10, 1960; Paul E. Purser to Robert R. Gilruth, "Log for the Week of April 18, 1960."

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Memoranda, John H. Disher to Abe Silverstein, May 10, 1960; Paul E. Purser to Robert R. Gilruth, "Log for the Week of April 18, 1960."

April 21

Members of STG visited the Flight Research Center to be briefed on current effort and planned activities there. Of special interest were possibilities of the Flight Research Center's conducting research on large parachutes in cooperation with Ames Research Center, analytical and simulator studies of pilot control of launch vehicles, and full-scale tests of landing capabilities of low lift over drag configurations.

Memoranda, John H. Disher to Abe Silverstein, May 10, 1960; Paul E. Purser to Robert R. Gilruth, "Log for the Week of April 18, 1960."

April 26

NASA announced the selection of the Douglas Aircraft Company to build the second stage (S-IV) of the

Saturn C-1 launch vehicle.

Wall Street Journal, April 27, 1960; Emme, *Aeronautics and Astronautics*, p. 122.

April 26

NASA announced that Aeronutronic Division of the Ford Motor Company had been selected from 13 bidders for a \$3.5 million contract to design and build a 300pound instrumented capsule which would be crash-landed on the surface of the moon. The capsule would be launched by an Atlas-Agena B and would be attached to a larger payload currently under development at the Jet Propulsion Laboratory. The larger payload was intended to carry television cameras. When the spacecraft (later named "Ranger") had reached a point 25 miles above the lunar surface, the smaller capsule would detach itself and crash-land. The instruments, including a seismometer and a temperature recorder, would then transmit data back to earth.

New York Times, April 27, 1960.

April 29

At Redstone Arsenal, all eight H-1 engines of the first stage of the Saturn C-1 launch vehicle were static-fired simultaneously for the first time and achieved 1.3 million pounds of thrust.

New York Times, April 30, 1960.

During the Month

A study report was issued by the MIT Instrumentation Laboratory on guidance and control design for a variety of space missions. This report, approved by C. Stark Draper, Director of the Laboratory, showed that a vehicle, manned or unmanned, could have significant onboard navigation and guidance capability.

Interview with Milton B. Trageser, Instrumentation Laboratory, MIT, April 27, 1966.

Spring

Thomas E. Dolan of the Chance Vought Corporation prepared a company-funded design study of the lunar orbit rendezvous method for accomplishing the lunar landing mission.

Interview with H. Kurt Strass, MSC, November 30, 1966.

May 1

An additional contract for \$10,000 was signed by the University of Manchester, Manchester, England, and the Air Force. Z. Kopal, principal investigator, would continue to work at the Pic-du-Midi Observatory in France, providing topographical information on the lunar surface for the production of accurate lunar maps. The contract [AF 61(052)380] was a continuation of one signed on November 1, 1958, and was to run from May 1, 1960, to October 31, 1960. In addition, the Air Force provided \$40,000 for a 40-inch reflector telescope at the Observatory, tremendously increasing its capability for lunar topographical research. By June 1960, information on one-fourth of the visible area of the moon had been produced.

House Committee Report, *Army Lunar Construction and Mapping Program*, Appendix.

May 2

Members of STG presented the proposed advanced manned spacecraft program to Wernher von Braun and 25 of his staff at Marshall Space Flight Center. During the ensuing discussion, the merits of a completely automatic circumlunar mission were compared with those of a manually operated mission. Further discussions were scheduled.

Memoranda, John H. Disher to Abe Silverstein, May 10, 1960; Paul E. Purser to Robert R. Gilruth, "Log for the Week of May 2, 1960."

May 3

STG members presented the proposed advanced manned spacecraft program to the Lewis Research Center staff. Work at the Center applicable to the program included: analysis and preliminary development of the onboard propulsion system, trajectory analysis, and development of small rockets for midcourse and attitude control propulsion.

Memorandum, John H. Disher to Abe Silverstein, May 10, 1960.

May 4

Clifford I. Cummings, Jet Propulsion Laboratory spacecraft program director, announced at a meeting of the Aviation Writers Association in Los Angeles, Calif., that the spacecraft which would carry television and a detachable instrumented capsule to be crash-landed on the moon would be called "Ranger."

Baltimore *Sun*, May 5, 1960.

May 5

Robert R. Gilruth, Paul E. Purser, James A. Chamberlin, Maxime A. Faget, and H. Kurt Strass of STG met with a group from the Grumman Aircraft Engineering Corporation to discuss advanced spacecraft

programs. Grumman had been working on guidance requirements for circumlunar flights under the sponsorship of the Navy and presented Strass with a report of this work.

Memorandum, Purser to Gilruth, "Log for the Week of May 2, 1960."

May 9

The first production Mercury spacecraft, using its launch escape rocket as propulsion, was launched from Wallops Island in a successful "beach abort" test.

Swenson *et al.*, *This New Ocean*, p. 262.

May 12

A discussion on the advanced manned spacecraft program was held at the Langley Research Center with members of STG and Langley Research Center, together with George M. Low and Ernest O. Pearson, Jr., of NASA Headquarters and Harry J. Goett of Goddard Space Flight Center. Floyd L. Thompson, Langley Director, said that Langley would be studying the radiation problem, making configuration tests (including a lifting Mercury) , and studying aerodynamics, heating, materials, and structures.

Memorandum, Paul E. Purser to Robert R. Gilruth, "Log for the Week of May 9, 1960."

May 15

The Soviet Union launched an unmanned spacecraft into near-earth orbit. Designated *Korabl Sputnik I* by the Russians and called *Sputnik IV* by the Western press, the spacecraft weighed approximately 10,000 pounds and contained a pressurized space cabin with a dummy astronaut. On May 19, the attempt to bring the spacecraft back to earth failed when a flaw in the guidance system deflected the ship into a higher orbit. Soviet scientists said that conditions in the cabin, which had separated from the remainder of the spacecraft, were normal.

Wall Street Journal, May 16, 1960; *Baltimore Sun*, May 21, 1960; *Instruments and Spacecraft*, p. 105.

May 16-17

A meeting on space rendezvous was held at the Langley Research Center and attended by representatives from NASA Headquarters, Flight Research Center, Goddard Space Flight Center, Space Task Group, Langley Research Center, Jet Propulsion Laboratory, Lewis Research Center, and Marshall Space Flight Center. Bernard Maggin of NASA Headquarters was chairman. Current NASA Center programs on rendezvous were reviewed and ideas were exchanged on future projects. Many of the studies in progress involved the concept of a space ferry rendezvousing with a station in cislunar space.

The consensus of the meeting was that the rendezvous technique would be essential in the foreseeable future and that experiments should be made to establish feasibility and develop the technique. There was as yet no funding for my rendezvous flight test program.

Inter-NASA Research and Development Centers Discussion on Space Rendezvous, Langley Research Center, May 16-17, 1960.

May 25

STG formed the Advanced Vehicle Team, reporting directly to Robert R. Gilruth, Director of the Mercury program. The Team would conduct research and make preliminary design studies for an advanced multiman spacecraft. In addition, the Team would maintain contacts and information flow between STG and the Langley, Lewis, Ames, and Flight Research Centers and the Jet Propulsion Laboratory and would effect necessary liaison with the Marshall Space Flight Center on the development and planned use of boosters. Contacts with industrial groups and government agencies on advanced systems studies would be focused in this group. Robert O. Piland was appointed Head of the Advanced Vehicle Team ; other members assigned full-time were H. Kurt Strass, Robert G. Chilton, Jack Funk, Alan B. Kehlet, Jr., R. Bryan Erb, Owen E. Maynard, Richard B. Ferguson, and Alfred B. Eickmeier. Team members would retain their current permanent organizational status and receive technical direction and guidance in their particular areas from their supervisors, as well as support from other specialists.

Memorandum, Gilruth to Staff, STG, "Advanced Vehicle Team," May 25, 1960.

May 26

Assembly of the first Saturn flight booster, SA-1, began at Marshall Space Flight Center.

Senate Staff Report, *Manned Space Flight Program*, p. 187.

May 26

Eight H-1 engines of the first stage of the Saturn C-1 launch vehicle were static-fired for 35.16 seconds, producing 1.3 million pounds of thrust. This first public demonstration of the H-1 took place at Marshall Space Flight Center.

Rocketdyne *Skywriter*, June 3, 1960, p. 1.

May 31

NASA selected Rocketdyne Division of NAA to develop the J-2, a 200,000-pound-thrust rocket engine, burning liquid hydrogen and liquid oxygen. [A decision was later made to use the J-2 in the upper stages

of the Saturn C-5.]

Saturn Illustrated Chronology, pp. 13-14; *Rocketdyne Skywriter*, June 3, 1960.

June 15

The Saturn C-1 first stage successfully completed its first series of static tests at the Marshall Space Flight Center with a 122-second firing of all eight H-1 engines.

Rocketdyne Skywriter, June 24, 1960, p. 4.

June 21

Robert O. Piland, Head of the STG Advanced Vehicle Team, and Stanley C. White of STG attended a meeting in Washington, D. C., sponsored by the NASA Office of Life Sciences Programs, to discuss radiation and its effect on manned space flight. Three consultants presented their views: John R. Winckler of the University of Minnesota, a cosmic-ray physicist; Cornelius A. Tobias of the University of California, a radiologist specializing in radiation effects on cells and other human subsystems; and Col. John E. Pickering, Director of Research at the Air Force School of Aviation Medicine. Their research showed that it would be impracticable to shield against the inner Van Allen belt radiation but possible to shield against the outer belt with a moderate amount of protection.

Memorandum, Piland, Head, Advanced Vehicle Team, to Project Director, "Radiation and Its Effects on Manned Space Vehicles - June 21 Meeting, Washington, D.C.," June 24, 1960.

Summer

H. Kurt Strass of STG and John H. Disher of NASA Headquarters proposed that boilerplate Apollo spacecraft be used in some of the forthcoming Saturn C-1 hunches. [Boilerplates are research and development vehicles which simulate production spacecraft in size, shape, structure, mass, and center of gravity.] These flight tests would provide needed experience with Apollo systems and utilize the Saturn boosters effectively. Four or five such tests were projected. On October 5, agreement was reached between members of Marshall Space Flight Center and STG on tentative Saturn vehicle assignments and flight plans.

Interview with Strass, MSC, November 30, 1966.

July 5

The House Committee on Science and Astronautics declared: "A high priority program should be undertaken to place a manned expedition on the moon in this decade. A firm plan with this goal in view

should be drawn up and submitted to the Congress by NASA. Such a plan, however, should be completely integrated with other goals, to minimize total costs. The modular concept deserves close study. Particular attention should be paid immediately to long lead-time phases of such a program." The Committee also recommended that development of the F-1 engine be expedited in expectation of the Nova launch vehicle, that there be more research on nuclear engines and less conventional engines before freezing the Nova concept, and that the Orion project be turned over to NASA. It was the view of the Committee that "NASA's 10-year program is a good program, as far as it goes, but it does not go far enough. Furthermore the space program is not being pushed with sufficient energy."

U.S. Congress, House, Committee on Science and Astronautics, *Space, Missiles, and the Nation*, 86th Congress, 2nd Session (1960), pp. 55-56.

July 9

After reviewing proposals by 37 companies, NASA awarded contracts to the Hughes Aircraft Company, McDonnell Aircraft Corporation, North American Aviation, Inc., and Space Technology Laboratories, Inc., for preliminary competitive design studies of an instrumented soft-landing lunar spacecraft, the Surveyor. The companies were scheduled to submit their reports in December.

Fourth Semiannual Report of the National Aeronautics and Space Administration, April 1, 1960, through September 30, 1960 (1961), pp. 60-61; *Fifth Semiannual Report to Congress of the National Aeronautics and Space Administration*, October 1, 1960, through June 30, 1961 (1961), p. 49; Los Angeles Times, July 10, 1960.

July 14-15

The third meeting of the Space Exploration Program Council was held at NASA Headquarters. The question of a speedup of Saturn C-2 production and the possibility of using nuclear upper stages with the Saturn booster were discussed. The Office of Launch Vehicle Programs would plan a study on the merits of using nuclear propulsion for some of NASA's more sophisticated missions. If the study substantiated such a need, the amount of in-house basic research could then be determined.

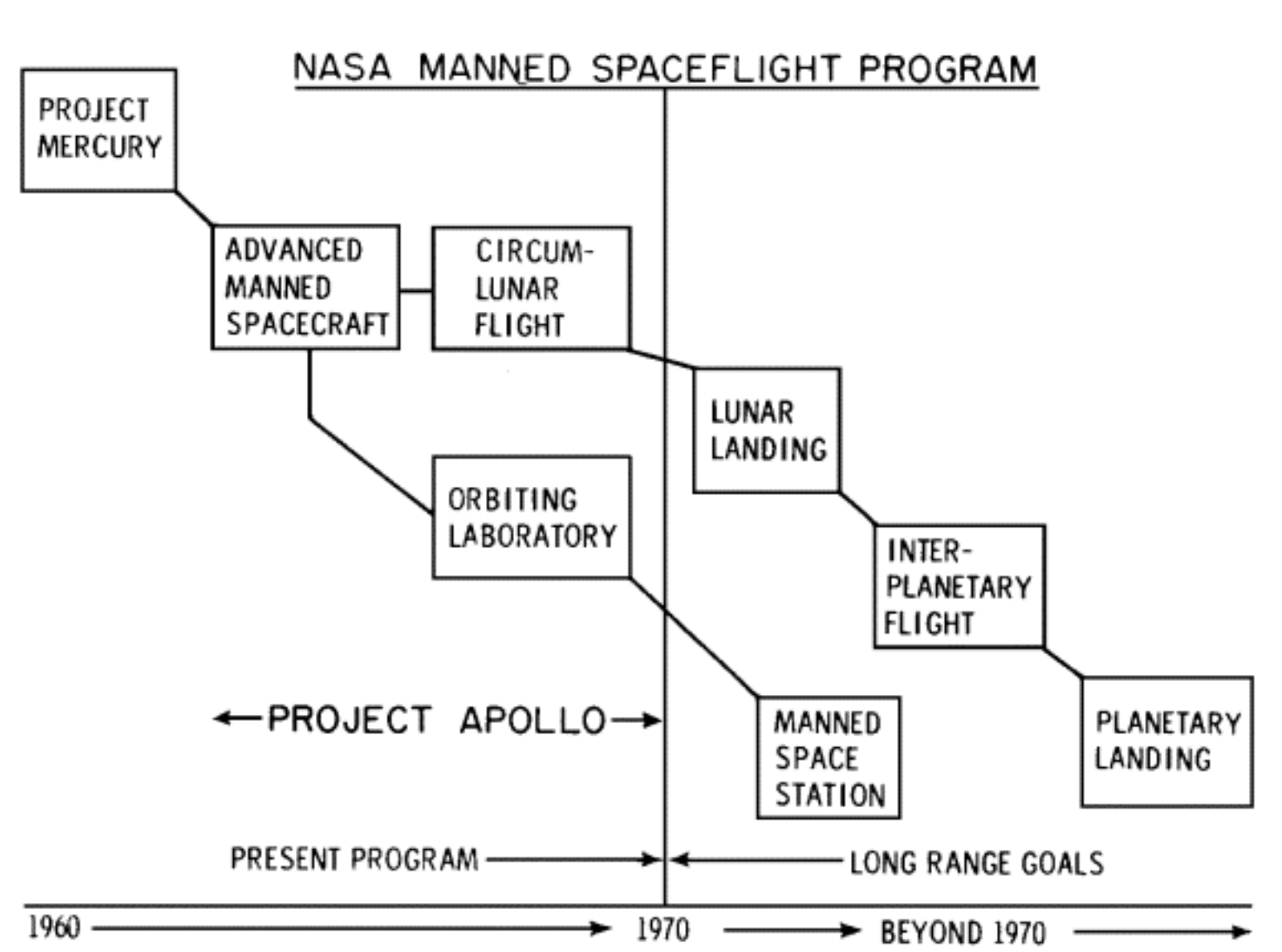
Minutes, Space Exploration Program Council Meeting, July 14-15, 1960, pp. 1, 4-5.

July 25

NASA Director of Space Flight Programs Abe Silverstein notified Harry J. Goett, Director of the Goddard Space Flight Center, that NASA Administrator T. Keith Glennan had approved the name "Apollo" for the advanced manned space flight program. The program would be so designated at the forthcoming NASA-Industry Program Plans Conference.

Memorandum, NASA Headquarters to Goddard Space Flight Center, Attn: Dr. H. J. Goett, "Official

Name for the Advanced Manned Space Flight Program," July 25, 1960.



This chart was used by George M. Low July 29, 1960, as he described the plans for Project Apollo during the NASA-Industry Program Plans Conference.

July 28-29

The first NASA-Industry Program Plans Conference was held in Washington, D.C. The purpose was to give industrial management an overall picture of the NASA program and to establish a basis for subsequent conferences to be held at various NASA Centers. The current status of NASA programs was outlined, including long-range planning, launch vehicles, structures and materials research, manned space flight, and life sciences.

NASA Deputy Administrator Hugh L. Dryden announced that the advanced manned space flight

program had been named "Apollo." George M. Low, NASA Chief of Manned Space Flight, stated that circumlunar flight and earth orbit missions would be carried out before 1970. This program would lead eventually to a manned lunar landing and a permanent manned space station.

Three follow-up conferences were planned: Goddard Space Flight Center in August (held in Washington, D.C.), the Marshall Space Flight Center in September, and Jet Propulsion Laboratory in October. Industry representatives would receive more detailed briefings on specific phases of the NASA program.

NASA-Industry Program Plans Conference, July 28-29, 1960 (1960).

July 29

Mercury-Atlas 1 (MA-1) was launched from the Atlantic Missile Range in a test of spacecraft structural integrity under maximum heating conditions. After 58.5 seconds of flight, MA-1 exploded and the spacecraft was destroyed upon impact off-shore. None of the primary capsule test objectives were met.

Swenson *et al.*, *This New Ocean*, pp. 275-278.

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PART 2 (A)

Design - Decision - Contract

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1960

August 8

In a memorandum to Abe Silverstein, Director of NASA's Office of Space Flight Programs, Harry J. Goett, Director of Goddard Space Flight Center, outlined the tentative program of the Goddard industry conference to be held on August 30. At this conference, more details of proposed study contracts for an advanced manned spacecraft would be presented. The requirements would follow the guidelines set down by STG and presented to NASA Headquarters during April and May. Three six-month study contracts at \$250,000 each would be awarded.

Draft Memorandum, Goett to Director, Office of Space Flight Programs, August 8, 1960.

August 13

Secretary of the Interior Fred A. Seaton and Secretary of the Army Wilber M. Brucker announced that the U.S. Geological Survey had completed the first known photogeological survey of the surface of the moon. The study, part of a program to select lunar landing sites for manned and unmanned spacecraft, consisted of three diagrams, all showing the visible face of the moon at 36 inches diameter. These

diagrams depicted, respectively, the physiographic lunar regions, naming features on the moon's surface ; a generalized photogeologic map giving the age of craters and structural features; and the prominent lunar rays.

Palo Alto Times, August 18, 1960.

August 19

The Soviet Union launched its second spaceship satellite, the *Korabl Sputnik II*, or *Sputnik V*. The spacecraft was similar to the one launched on May 15 and carried two dogs, Strelka and Belka, in addition to a gray rabbit, rats, mice, flies, plants, fungi, microscopic water plants, and seeds. Electrodes attached to the dogs and linked with the spacecraft communications system, which included a television camera, enabled Soviet scientists to check the animals' hearts, blood pressure, breathing, and actions during the trip. After the spacecraft reentered and landed safely the next day, the animals and biological specimens were reported to be in good condition.

Baltimore Sun, August 20, 1960; *New York Herald Tribune*, August 22, 1960; *Instruments and Spacecraft*, pp. 120-121.

August 30

The Goddard Space Flight Center GSFC conducted its industry conference in Washington, D.C., presenting details of GSFC projects, current and future. The objectives of the proposed six-month feasibility contracts for an advanced manned spacecraft were announced:

- To define a manned spacecraft system fulfilling STG guidelines
- To formulate a program plan for implementation
- To identify areas requiring long lead-time research and development effort
- To analyze the cost of providing the system.

Fixed-fee contracts were to be let to prime contractors only; several contracts would be let concurrently. The timetable was announced:

1. August 30, 1960, industry familiarization;
2. August 31-September 6, expression of interest to NASA;
3. September 7, invitation to bidders' conference;
4. September 12, bidders' conference at STG;
5. October 10, proposals received;
6. November 14, contracts awarded;
7. May 15, 1961, contracts completed.

Presentations for the Industry Conference to be conducted by the Goddard Space Flight Center,

Greenbelt, Md., August 30, 1960.

September 1

In an organizational change within STG, Maxime A. Faget was appointed Chief of the Flight Systems Division and Robert O. Piland was named Assistant Chief for Advanced Projects. The Apollo Project Office was formed with Piland as Head of the Office; members included John B. Lee, J. Thomas Markley, William W. Petynia, and H. Kurt Strass.

Memorandum, Robert R. Gilruth to Staff, STG, "Change in Organization of the Space Task Group," September 1, 1960.

September 2

NASA Administrator T. Keith Glennan directed that an accelerated joint planning effort be made by persons at NASA Headquarters who were most familiar with the Saturn, Apollo, manned orbital laboratory, and unmanned lunar and planetary programs. They were to determine whether the Saturn and Saturn-use programs were effectively integrated and whether sufficient design study and program development work had been done to support decisions on projected Saturn configurations. The group responsible for the study consisted of Lloyd Wood, Richard B. Canright, Alfred M. Nelson, John L. Sloop, Oran W. Nicks, Fred D. Kochendorfer, and George M. Low.

Memorandum, Donald H. Heaton to Director, Launch Vehicle Programs, and Director, Space Flight Programs, "Integration of the Saturn and Saturn Applications Programs," September 2, 1960.

September 10

A NASA contract for approximately \$44 million was signed by Rocketdyne Division of NAA for the development of the J-2 engine.

Rocketdyne *Skywriter*, September 16, 1960, p. 1.

September 13

An STG briefing was held at Langley Field, Va., for prospective bidders on three six-month feasibility studies of an advanced manned spacecraft as part of the Apollo program. A formal Request for Proposal was issued at the conference.

Ralph B. Oakley, *Historical Summary, S&ID Apollo Program* (NAA, Space and Information Systems Division, January 20, 1966), p. 3; "Agenda for Bidders' Briefing for a Feasibility Study. Project Apollo" September 13, 1960.

September 13

A formal agreement was signed by the United States and South Africa providing for the construction of a new deep-space tracking facility at Krugersdorp, near Johannesburg. It would be one of three stations equipped to maintain constant contact with lunar and planetary spacecraft.

Fourth NASA Semiannual Report, p. 111.

September 20

A staff meeting of the Flight Systems Division of STG was held to discuss design constraints for an in-house design study of the Apollo spacecraft. [\[See October 21, 1960.\]](#)

Memorandum, H. Kurt Strass to Apollo Design Team, "Design Restraints for FSD Apollo Design Study (Information and Action)," October 25, 1960.

September 25

An attempt to launch a Pioneer satellite into lunar orbit failed when one of the upper stages of the Atlas-Able rocket malfunctioned.

Washington Post, September 26, 1960.

September 29

In a memorandum to NASA Associate Administrator Robert C. Seamans, Jr., Robert L. King, Executive Secretary, described the action taken on certain items discussed at the July 14-15 meeting of the Space Exploration Program Council. Among these actions was the awarding of a contract to The RAND Corporation to evaluate missions for which nuclear propulsion would be desirable. Included in the study would be the determination of availability dates, cost of development, operational costs, the safety aspects of the missions, and an evaluation of research requirements.

Memorandum, King to Seamans, "Actions Since SEPC Meeting of 14-15 July 1960," September 29, 1960.

September 30

The fourth meeting of the Space Exploration Program Council was held at NASA Headquarters. The results of a study on Saturn development and utilization was presented by the Ad Hoc Saturn Study Committee. Objectives of the study were to determine (1) if and when the Saturn C-2 launch vehicle should be developed and (2) if mission and spacecraft planning was consistent with the Saturn vehicle

development schedule. No change in the NASA Fiscal Year 1962 budget was contemplated. The Committee recommended that the Saturn C-2 development should proceed on schedule (S-II stage contract in Fiscal Year 1962, first flight in 1965). The C-2 would be essential, the study reported, for Apollo manned circumlunar missions, lunar unmanned exploration, Mars and Venus orbiters and capsule landers, probes to other planets and out-of- ecliptic, and for orbital starting of nuclear upper stages.

During a discussion on the Saturn program, several major problems were brought up:

- The adequacy of the Saturn C-1 launch vehicle for orbital qualification of the complete Apollo spacecraft was in question. Although the C-1 could be used to launch a command module of 5,100 pounds, it was probable that the command module weight would increase to as much as 8,000 pounds, George M. Low of NASA Headquarters, in a critical review of the Apollo program, pointed out that a spacecraft for a circumlunar mission could be constructed within the payload limitation of the C-2 launch vehicle. Both the developmental and production spacecraft could be available to meet the Saturn schedules.
- Much basic research would be needed before the first Apollo flight, In particular, the problem of reentry heating was of great concern. Low noted that a prediction criterion for proton beam events had been developed, making possible safe manned circumlunar flights insofar as the radiation problem was concerned.
- Concern was also expressed as to the possible need and availability of additional personnel to support the Apollo program.

Minutes, Space Exploration Program Council Meeting, September 30, 1960, pp. 1, 4-5; Low, "Saturn Requirements for Project Apollo," presentation to Space Exploration Program Council, September 30, 1960; "Presentation of Results of Saturn Study by Ad Hoc Study Committee to Space Exploration Program Council," September 30, 1960.

September 30 - October 3

Charles J. Donlan of STG, Chairman of the Evaluation Board which would consider contractors' proposals on feasibility studies for an advanced manned spacecraft, invited the Directors of Ames Research Center, Jet Propulsion Laboratory, Flight Research Center, Lewis Research Center, Langley Research Center, and Marshall Space Flight Center to name representatives to the Evaluation Board. The first meeting was to be held on October 10 at Langley Field, Va.

Letters, Donlan to Smith J. DeFrance, Brian O. Sparks, Paul F. Bikle, Eugene J. Manganiello, Floyd L. Thompson, Wernher von Braun, September 30-October 3, 1960.

October 4

Members were appointed to the Technical Assessment Panels and the Evaluation Board to consider

industry proposals for Apollo spacecraft feasibility studies. Members of the Evaluation Board were: Charles J. Donlan (STG), Chairman; Maxime A. Faget (STG) ; Robert O. Piland (STG), Secretary; John H. Disher (NASA Headquarters Office of Space Flight Programs); Alvin Seiff (Ames); John V. Becker (Langley); H. H. Koelle (Marshall); Harry J. Goett (Goddard), ex officio; and Robert R. Gilruth (STG), ex officio.

Memorandum, Donlan to Members, Technical Assessment Panels, "Instruction for Members of Technical Assessment Panels for Evaluation of Contractors' Proposals for a Feasibility Study of an Advanced Manned Spacecraft, RFP-302 (Project Apollo)," October 4, 1960; NASA, Goddard Space Flight Center, and STG, "Project Apollo: Plan for the Evaluation of Contractors' Proposals for a Feasibility Study of an Advanced Manned Spacecraft and System," October 6, 1960.

October 5

Members of STG visited the Marshall Space Flight Center to discuss possible Saturn and Apollo guidance integration and potential utilization of Apollo onboard propulsion to provide a reserve capability. Agreement was reached on tentative Saturn vehicle assignments on abort study and lunar entry simulation; on the use of the Saturn guidance system; and on future preparations of tentative flight plans for Saturns SA-6, 8, 9, and 10.

Memorandum, H. Kurt Strass to Chief, Flight Systems Division, "Report on Visit to MSFC October 5 1960 by STG personnel" October 5 1960.

October 9

Contractors' proposals on feasibility studies for an advanced manned spacecraft were received by STG. Sixty-four companies expressed interest in the Apollo program, and of these 14 actually submitted proposals: The Boeing Airplane Company; Chance Vought Corporation; Convair/Astronautics Division of General Dynamics Corporation; Cornell Aeronautical Laboratory, Inc.; Douglas Aircraft Company; General Electric Company; Goodyear Aircraft Corporation; Grumman Aircraft Engineering Corporation; Guardite Division of American Marietta Company; Lockheed Aircraft Corporation; The Martin Company; North American Aviation, Inc.; and Republic Aviation Corporation. These 14 companies, later reduced to 12 when Cornell and Guardite withdrew, were subsequently invited to submit prime contractor proposals for the Apollo spacecraft development in 1961. The Technical Assessment Panels began evaluation of contractors' proposals on October 10.

"Participating Companies or Company Teams," partial set of material for Evaluation Board use; "Apollo Spacecraft Chronology," unpublished, annotated by Robert O. Piland, p. 4.

October 17

In a memorandum to Abe Silverstein, Director of NASA's Office of Space Flight Programs, George M.

Low, Chief of Manned Space Flight, described the formation of a working group on the manned lunar landing program: "It has become increasingly apparent that a preliminary program for manned lunar landings should be formulated. This is necessary in order to provide a proper justification for Apollo, and to place Apollo schedules and technical plans on a firmer foundation.

"In order to prepare such a program, I have formed a small working group, consisting of Eldon Hall, Oran Nicks, John Disher, and myself. This group will endeavor to establish ground rules for manned lunar landing missions; to determine reasonable spacecraft weights; to specify launch vehicle requirements; and to prepare an integrated development plan, including the spacecraft, lunar landing and takeoff system, and launch vehicles. This plan should include a time-phasing and funding picture, and should identify areas requiring early studies by field organizations."

Memorandum, Low to Director of Space Flight Programs, "Manned Lunar Landing Programs," October 17, 1960.

October 21

A staff meeting of STG's Flight Systems Division was held to fix additional design constraints for the in-house design study of the Apollo spacecraft.

Fundamental decisions were made as a result of this and a previous meeting on September 20:

- The entry vehicle should have a Mercury-type configuration, a lift over drag ratio of 0.35, and an overall heatshield and should follow the modular concept, in which a module containing redundant equipment could be jettisoned before reentry.
- Solid propellant systems should be used throughout for onboard propulsion.
- The nominal design load should be 8 g, with an emergency ultimate of 20 g.
- For flight path control in atmospheric flight, with lift over drag ratio of 0.35 constant, roll control only would be used; for space flight, midcourse corrections should be made by fixed-impulse solid-propellant units.
- Attitude control should be maintained during powered flight by thrust vector, during space flight by control jets, and during atmospheric flight by control jets for damping.
- The onboard guidance system should utilize special purpose computers and inertial reference based on the use of fundamentally manual star-sight systems with provision for automatic use.
- Both parachutes and rotors should be studied for the touchdown mode.
- Further research on the spacecraft atmosphere would be necessary.

Memorandum, H. Kurt Strass to Apollo Design Team, "Design Restraints for FSD Apollo Design Study (Information and Action)," October 25, 1960.

October 21

The Technical Assessment Panels presented to the Evaluation Board their findings on the contractors' proposals for feasibility studies of an advanced manned spacecraft. On October 24, the Evaluation Board findings and recommendations were presented to the STG Director.

"Apollo Spacecraft Chronology," pp. 4, 5.

October 25

Included in the current Saturn flight schedule were: mid-1961, begin first-stage flights with dummy upper stages; early 1963, begin two-stage flights; late 1963, begin three-stage flights; early 1964, conclude ten-vehicle research and development flight test program.

Senate Staff Report, *Manned Space Flight Program*, p. 193.

October 25

NASA selected three contractors to prepare individual feasibility studies of an advanced manned spacecraft as part of Project Apollo. The contractors were Convair/Astronautics Division of General Dynamics Corporation, General Electric Company, and The Martin Company.

TWXs, Goddard Space Flight Center to John A. Powers; NASA Headquarters to STG, Langley; STG Public Affairs Office, Langley Field, Va., Powers to Convair/Astronautics of General Dynamics Corporation, General Electric Company, and The Martin Company, October 25, 1960; Oakley, *Historical Summary, S&ID Apollo Program*, p. 3.

October 27 - November 2

Representatives of the General Electric Company, The Martin Company, and Convair/Astronautics Division of General Dynamics Corporation visited STG to conduct negotiations on the Apollo systems study contracts announced on October 25. The discussions clarified or identified areas not completely covered in company proposals. Contracts were awarded on November 15.

Minutes of Technical Negotiation Meetings with the General Electric Company, The Martin Company, and Convair/Astronautics Division of General Dynamics Corporation for Apollo Systems Study (RFP-302), October 27, November 1, and November 2, 1960; "Apollo Spacecraft Chronology," p. 5.

October 28

Key staff members of NASA Headquarters and the Commander, U.S. Air Force Research and Development Command, met at the Air Force Ballistic Missile Division, Los Angeles, Calif., to attend briefings and discuss matters of mutual concern.

At an executive session, Air Force and NASA programs of orbital rendezvous, refueling, and descent from orbit were discussed. Long-range Air Force studies on a lunar base were in progress as well as research on more immediate missions, such as rendezvous by an unmanned satellite interceptor for inspection purposes, manned maintenance satellites, and reentry methods. NASA plans for the manned lunar landing mission included the possible use of the Saturn booster in an orbital staging operation employing orbital refueling. Reentry studies beyond Mercury were concentrated on reentry at escape speeds and on a spacecraft configuration capable of aerodynamic maneuvering during reentry.

Memorandum, Donald H. Heaton, Assistant Administrator for Resources, for the Record, "Minutes of the Executive Meeting at AFBMD on October 28, 1960," November 2, 1960.

November 3

The Department of the Interior announced that the U.S. Geological Survey would undertake detailed studies of lunar geology as part of a new \$205,000 program in astrogeology financed by NASA. The program would include geological analysis of photographs of selected areas on the moon, terrestrial crater studies, and investigations into the origin of tektites, meteorites, and related material of possible extraterrestrial origin. Certain lunar features would be studied more closely and larger scale diagrams would be made of specific areas in the vicinity of sites selected by NASA for unmanned spacecraft landings.

New York Times, November 9, 1960.

November 4

At a meeting, Charles J. Donlan of STG and George M. Low, John H. Disher, Milton W. Rosen, and Elliott Mitchell, all of NASA Headquarters, discussed a plan to set up informal technical liaison groups to broaden the base for inter-Center information exchange on the Apollo program with particular reference to onboard propulsion.

Memorandum, Abe Silverstein to Director, Launch Vehicle Programs, "Apollo Technical Liaison Groups," November 29, 1960.

November 8

Little Joe 5 with a Mercury production spacecraft was launched from Wallops Island to test the spacecraft in an abort simulating the most severe launch conditions. At 15.4 seconds after liftoff, the escape rocket motor and tower jettison motor ignited prematurely. Booster, capsule, and tower remained mated through ballistic trajectory until destroyed on impact.

James M. Grimwood, *Project Mercury: A Chronology* (NASA SP-4001, 1963), p. 117; Swenson *et al.*, *This New Ocean*, p. 291.

November 12

Discoverer XVII was launched into polar orbit from Vandenberg Air Force Base and the payload was recovered on November 14. On December 2, the Air Force revealed that exceedingly valuable information had been obtained from human tissues carried by *Discoverer XVII*. The tissues had been exposed to an unexpectedly heavy dose of radiation for more than 50 hours in flight.

Baltimore *Sun*, November 14, 1960; *Los Angeles Times*, December 3, 1960.

November 16

STG formulated a plan for the proposed Apollo Technical Liaison Groups. These Groups were to effect systematic liaison in technical areas related to the Apollo project. The objectives and scope of the plan were as follows:

- Provide an up-to-date summary of progress on the Apollo project in specific technical areas at the Centers.
- Give a regular summary of Apollo research and study investigations to ensure their use in the project.
- Report Apollo contractor activities to Group members.
- Bring expert consideration to the technical problems as they arose.
- Point out research activity needed in support of Apollo for its assignment to the centers.
- Assist in monitoring contractor studies through participation of individual panel members.
- Develop requirements for flight tests resulting from research and study activity.
- Provide assessments of progress in the technical areas.

To carry out these objectives, Technical Liaison Groups would be formed:

Trajectory Analysis;

Studies related to the manned circumlunar mission including atmospheric and non-atmospheric phases of normal and emergency maneuvers.

Configurations and Aerodynamics.

Theoretical and experimental studies of the aerodynamic characteristics and performance of vehicles proposed for the manned circumlunar mission.

Guidance and Control:

Studies and developments in the guidance, navigation, and control areas related to all phases of the manned circumlunar mission.

Heating:

Convective, conductive, and radiative heat-transfer studies during launch, abort, and reentry for various configurations; investigations of heat transfer through turbulent boundary layers; ablation rates for materials at different heating conditions; and pressure distribution for various

configurations.

Structures and Materials:

Studies of design concepts for proposed circumlunar vehicle structures including the optimum payload distribution, protection against radiation and meteoroids, and possible shapes and types of structures suitable for circumlunar missions.

Instrumentation and Communications:

Studies and developments of instruments required for the mission; studies on voice, telemetry, and tracking communications.

Human Factors:

Studies on human tolerance levels, life-support requirements, and the assessment of the biological effects of radiation.

Mechanical Systems:

Studies and developments of systems required for the manned circumlunar mission.

Onboard Propulsion:

Studies and developments in propulsion systems and components required to meet the abort and midcourse performance requirements.

Representatives in a given Group would be limited to a single member from each Center. STG would be responsible for meeting arrangements.

STG, "Apollo Technical Liaison Plan," November 16, 1960.

November 21

An attempt was made to launch Mercury-Redstone 1 (MR-1) from the Atlantic Missile Range. After a four- or five-inch liftoff, MR-1 launched its escape tower but not the capsule. The undamaged spacecraft was recovered for reuse.

Swenson *et al.*, *This New Ocean*, pp. 293-297.

November 22

STG held a meeting at Goddard Space Flight Center to discuss a proposed contract with MIT Instrumentation Laboratory for navigation and guidance support for Project Apollo. The proposed six-month contract for \$100,000 might fund studies through the preliminary design stage but not actual hardware. Milton B. Trageser of the Instrumentation Laboratory presented a draft work statement which divided the effort into three parts: midcourse guidance, reentry guidance, and a satellite experiment feasibility study using the Orbiting Geophysical Observatory. STG decided that the Instrumentation Laboratory should submit a more detailed draft of a work statement to form the basis of a contract. In a discussion the next day, Robert G. Chilton of STG and Trageser clarified three points:

1. The current philosophy was that an onboard computer program for a normal mission sequence

would be provided and would be periodically updated by the crew. If the crew were disabled, the spacecraft would continue on the programmed flight for a normal return. No capability would exist for emergency procedures.

2. Chilton emphasized that consideration of the reentry systems design should include all the guideline requirements for insertion monitoring by the crew, navigation for aborted missions, and, in brief, the whole design philosophy for manned flight.
3. The long-term objective of a lunar landing mission should be kept in mind although design simplicity was of great importance.

Chilton and Trageser agreed that the purpose of the Apollo program was the development of manned space flight system capability, not simply circumnavigation of the moon with an encapsulated man.

Memorandum, Chilton to Associate Director, "Meeting with MIT Instrumentation Laboratory to Discuss Navigation and Guidance Support for Project Apollo," November 28, 1960.

November 22

Charles J. Donlan, Associate Director of STG, invited Langley, Ames, Lewis, and Flight Research Centers, Marshall Space Flight Center, and Jet Propulsion Laboratory to participate in Technical Liaison Groups in accordance with the plan drawn up on November 16.

Letters, Donlan to Langley, Ames, Lewis, and Flight Research Centers, Marshall Space Flight Center, and Jet Propulsion Laboratory, November 22, 1960; memorandum, Abe Silverstein to Director, Launch Vehicle Programs, "Apollo Technical Liaison Groups," November 29, 1960.

November 29

A joint briefing on the Apollo and Saturn programs was held at Marshall Space Flight Center MSFC, attended by representatives of STG and MSFC. Maxime A. Faget of STG and MSFC Director Wernher von Braun agreed that a joint STG-MSFC program would be developed to accomplish a manned lunar landing. Areas of responsibility were: MSFC launch vehicle and landing on the moon; STG - lunar orbit, landing, and return to earth.

Memorandum, J. Thomas Markley, Apollo Project Office, to Associate: Director, STG, "Meeting between MSFC and STG on Mission for Saturn C-1 R and D Program and Summary of MSFC Trips by J. T. Markley," December 8, 1960.

November 30

Smith J. DeFrance, Director of the Ames Research Center, designated Ames working members on six of the nine Apollo Technical Liaison Groups. They were Stanley F. Schmidt (Trajectory Analysis), Clarence A. Syvertson (Configurations and Aerodynamics), G. Allen Smith (Guidance and Control),

Glen Goodwin (Heating), Charles A. Hermach (Structures and Materials), and Harald S. Smedal (Human Factors).

Letter, DeFrance to STG, Attn: Mr. C. J. Donlan, "Apollo Technical Liaison Groups," November 30, 1960.

December 1

The Soviet Union launched its third spaceship satellite, *Korabl Sputnik III*, or *Sputnik VI*. The spacecraft, similar to those launched on May 15 and August 19, carried two dogs in addition to other animals, insects, and plants. The next day, during reentry, the spacecraft disintegrated and burned.

Washington *Post*, December 2 and 3, 1960; *Instruments and Spacecraft*, p. 143.

December 1

Eugene J. Manganiello, Associate Director of the Lewis Research Center, appointed Lewis members to six of the Apollo Technical Liaison Groups. They were Seymour C. Himmel (Trajectory Analysis), Jack B. Esgar (Structures and Materials), Robert E. Tozier (Instrumentation and Communications), Robert F. Seldon (Human Factors), Robert R. Goodman (Mechanical Systems), and Edmund R. Jonash (Onboard Propulsion).

Letter, Manganiello to STG, Attn: Charles J. Donlan, "Apollo Technical Liaison Groups," December 1, 1960.

December 2

A meeting was held by representatives of STG and the MIT Lincoln Laboratory to discuss the scope of the studies to be performed by the Lincoln Laboratory on the ground instrumentation system for the Apollo program. The discussion centered about the draft work statement prepared by STG. In general, those at the meeting agreed that Lincoln Laboratory should conduct an overall analysis of the requirements for the ground system, leading to the formulation of a general systems concept. The study should be completed by the end of December 1961, with interim results available in the middle of 1961.

Memorandum, Jack Cohen, Operations Representative, Apollo Office, to Associate Director, "Meeting with Lincoln Laboratory Personnel to Discuss Apollo Study Contract," December 5, 1960.

December 2

Milton B. Trageser of MIT Instrumentation Laboratory transmitted to Charles J. Donlan of STG the outline of a study program on the guidance aspects of Project Apollo. He outlined what might be covered by a formal proposal on the Apollo spacecraft guidance and navigation contract discussed by

STG and Instrumentation Laboratory representatives on November 22.

Letter, Trageser, Assistant Director, MIT Instrumentation Laboratory, to Donlan, Associate Director of STG, December 2, 1960.

December 2

The Director of the Flight Research Center, Paul F. Bikle, nominated Flight Research Center members to eight of the nine Apollo Technical Liaison Groups. They were Donald R. Bellman (Trajectory Analysis), Hubert M. Drake (Configurations and Aerodynamics), Euclid C. Holleman (Guidance and Control), Thomas V. Cooney (Heating), Kenneth C. Sanderson (Instrumentation and Communications), Milton O. Thompson (Human Factors), Perry V. Row (Mechanical Systems), and Norman E. DeMar (Onboard Propulsion).

Letter, Bikle to STG, Attn: Mr. C. J. Donlan, "Apollo Technical Liaison Groups," December 2, 1960.

December 2

Representatives of Marshall Space Flight Center (MSFC) were assigned to eight of the nine Apollo Technical Liaison Groups by H. H. Koelle, Director, Future Projects Office, MSFC. They were Rudolph F. Hoelker (Trajectory Analysis), Edward L. Linsley (Configurations and Aerodynamics), Werner K. Dahm and Harvey A. Connell (Heating), Erich E. Goerner (Structures and Materials), David M. Hammock and Alexander A. McCool (Onboard Propulsion), Heinz Kampmeier (Instrumentation and Communications), Wilbur G. Thornton (Guidance and Control), and Herman F. Beduerftig (Mechanical Systems). Dual representation on two of the Groups would be necessary because of the division of technical responsibilities within MSFC.

Memorandum, Koelle to STG, Attn: Charles J. Donlan, Assistant Director, Project Mercury, "Apollo Technical Liaison Groups," December 2, 1960.

December 6-8

The first technical review of the General Electric Company Apollo feasibility study was held at the contractor's Missile and Space Vehicle Department. Company representatives presented reports on the study so that STG representatives might review progress, provide General Electric with pertinent information from NASA or other sources, and discuss and advise as to the course of the study.

Minutes of General Electric Missile and Space Vehicle Department Meeting No. 1, December 6-8, 1960.

December 7

Floyd L. Thompson, Director of the Langley Research Center, assigned Langley members to eight of the Apollo Technical Liaison Groups. They were William H. Michael, Jr. (Trajectory Analysis), Eugene S. Love (Configurations and Aerodynamics), John M. Eggleston (Guidance and Control), Robert L. Trimpi (Heating), Roger A. Anderson (Structures and Materials), Wilford E. Sivertson, Jr. (Instrumentation and Communications), David Adamson (Human Factors), and Joseph G. Thibodaux, Jr. (Onboard Propulsion).

Letter, Thompson to STG, "Langley Appointments to Apollo Technical Liaison Groups," December 7, 1960.

December 7-9

The Martin Company presented the first technical review of its Apollo feasibility study to STG officials in Baltimore, Md. At the suggestion of STG, Martin agreed to reorient the study in several areas: putting more emphasis on lunar orbits, putting man in the system, and considering landing and recovery in the initial design of the spacecraft.

Minutes of The Martin Company Apollo Technical Review No. 1, December 7-9, 1960.

December 9

Brian O. Sparks, Deputy Director of the Jet Propulsion Laboratory (JPL), designated JPL members to serve on six of the nine Apollo Technical Liaison Groups. They were Victor C. Clarke, Jr. (Trajectory Analysis), Edwin Pounder (Configurations and Aerodynamics), James D. Acord (Guidance and Control), John W. Lucas (Heating), William J. Carley (Structures and Materials), and Duane F. Dipprey (Onboard Propulsion),

Letter, Sparks to Charles J. Donlan, Associate Director of Project Mercury, December 9,

December 10

Representatives of the Langley Research Center briefed members of STG on the lunar orbit method of accomplishing the lunar landing mission.

Langley Research Center, *Manned Lunar-Landing through use of Lunar-Orbit Rendezvous* (Langley Research Center, 1961), p. 5.

December 14-15

Convair/Astronautics Division of the General Dynamics Corporation held its first technical review of the

Apollo feasibility study in San Diego, Calif. Brief presentations were made by contractor and subcontractor technical specialists to STG representatives. Convair/Astronautics' first approach was oriented toward the modular concept, but STG suggested that the integral spacecraft concept should be investigated.

Minutes of Meeting of Convair Astronautics Technical Review No. 1, December 14- 15, 1960.

December 14

Associate Administrator of NASA Robert C. Seamans, Jr., and his staff were briefed by Langley Research Center personnel on the rendezvous method as it related to the national space program. Clinton E. Brown presented an analysis made by himself and Ralph W. Stone, Jr., describing the general operational concept of lunar orbit rendezvous for the manned lunar landing. The advantages of this plan in contrast with the earth orbit rendezvous method, especially in reducing launch vehicle requirements, were illustrated. Others discussing the rendezvous were John C. Houbolt, John D. Bird, and Max C. Kurbjun.

Bird, "Short History of the Development of the Lunar Orbit Rendezvous Plan at the Langley Research Center," p. 2.

December 15

The final launch in the Pioneer lunar probe program was unsuccessful; the Atlas-Able booster rocket went out of control and exploded at an altitude of 40,000 feet off Cape Canaveral.

New York Times, December 16, 1960.

December 19

Mercury-Redstone 1A (unmanned) was launched successfully from the Atlantic Missile Range. The objective was to qualify the spacecraft for a primate flight scheduled shortly thereafter. Apart from the launch vehicle cutoff velocity being slightly higher than normal, all flight sequences were satisfactory.

Grimwood, *Project Mercury: A Chronology*, pp. 119-120.

December 22

The MIT Instrumentation Laboratory submitted a formal proposal to NASA for a study of a navigation and guidance system for the Apollo spacecraft.

Memorandum, Robert G. Chilton to Associate Director, "Massachusetts Institute of Technology

Guidance System Study for Apollo," January 16, 1961.

December 29

The Grumman Aircraft Engineering Corporation began work on a company- funded lunar orbit rendezvous feasibility study.

Interview with Saul Ferdman, Grumman Aircraft Engineering Corporation, Bethpage, N.Y., May 2, 1966.

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January 3

STG, which was responsible for Project Mercury and other NASA manned space flight programs, became a separate field element reporting to the Director of Space Flight Programs at NASA Headquarters.

Fifth NASA Semiannual Report, p. 2.

January 5-6

During a meeting of the Space Exploration Program Council at NASA Headquarters, the subject of a manned lunar landing was discussed. Following presentations on earth orbit rendezvous (Wernher von Braun, Director of Marshall Space Flight Center), lunar orbit rendezvous (John C. Houbolt of Langley Research Center), and direct ascent (Melvyn Savage of NASA Headquarters), the Council decided that NASA should not follow any one of these specific approaches, but should proceed on a broad base to afford flexibility. Another outcome of the discussion was an agreement that NASA should have an orbital rendezvous program which could stand alone as well as being a part of the manned lunar program. A task group was named to define the elements of the program insofar as possible. Members of the group were George M. Low, Chairman, Eldon W. Hall, A. M. Mayo, Ernest O. Pearson, Jr., and Oran W. Nicks, all of NASA Headquarters; Maxime A. Faget of STG; and H. H. Koelle of Marshall Space Flight Center. This group became known as the Low Committee.

Minutes, Space Exploration Program Council Meeting, January 5-6, 1961; Bird, "Short History of the Development of the Lunar Orbit Rendezvous Plan at the Langley Research Center," p. 2.

January 6

Three of the Apollo Technical Liaison Groups held their first meetings at STG (Instrumentation and Communications, Mechanical Systems, and Onboard Propulsion).

The Group for Instrumentation and Communications discussed a set of working guidelines on spacecraft instrumentation and communications, tracking considerations, and deep-space communication requirements. Progress of the three Apollo feasibility study contracts was reviewed and the proposed MIT Lincoln Laboratory study on a systems concept for the ground instrumentation and tracking required for the Apollo mission was discussed. Reports of studies were given by members from the NASA Centers. The Group recommendations were :

- All Group members should be supplied with copies of the Apollo contractors' proposals.
- Existing ground facilities should be used as much as possible.
- Jet Propulsion Laboratory JPL should be asked to participate in future panel activities.
- All Group members should be supplied with copies of the STG-Lincoln Laboratory Work Statement.

Members of the Group for Mechanical Systems considered studies being done at NASA Centers. Some specific points of interest in these studies were:

- Lewis and Langley work on reaction controls, Langley research on auxiliary power systems, Marshall Space Flight Center (MSFC) investigations on mechanical elements
- A call for more detailed definitions of the environmental control system requirements, further investigation of chemical auxiliary power systems, consideration of artificial gravity configuration effects on mechanical systems, and development of reliable materials for use in the space environment.

The Group for Onboard Propulsion reviewed the three contractors' work on the Apollo feasibility studies. Among studies being undertaken by the NASA Centers and reported on at this meeting were: an STG consideration of an all-solid fuel propulsion system for a circumlunar flight, determination of midcourse and abort propulsion system requirements based on Saturn trajectories (MSFC), experimental evaluation at zero gravity of expulsion bag techniques for cryogenic propellants (Lewis), analysis and experiments on solid propellant rocket motors of very high mass fraction (Langley), methods of achieving thrust vector control by secondary injection of gases and the design of a highly reliable and versatile bipropellant spacecraft propellant system using hydrogen tetroxide and hydrazine or hydrazine derivatives (JPL), and a contract to examine hardware requirements for space missions and lunar landings (NASA Headquarters).

Minutes of meetings of Technical Liaison Groups on Instrumentation and Communications, Mechanical Systems, and Onboard Propulsion, January 6, 1961.

January 6

The Manned Lunar Landing Task Group (Low Committee) set up by the Space Exploration Program Council was instructed to prepare a position paper for the NASA Fiscal Year 1962 budget presentation to Congress. The paper was to be a concise statement of NASA's lunar program for Fiscal Year 1962 and was to present the lunar mission in terms of both direct ascent and rendezvous. The rendezvous program would be designed to develop a manned spacecraft capability in near space, regardless of whether such a technique would be needed for manned lunar landing. In addition to answering such questions as the reason for not eliminating one of the two mission approaches, the Group was to estimate the cost of the lunar mission and the date of its accomplishment, though not in specific terms. Although the decision to land a man on the moon had not been approved, it was to be stressed that the development of the scientific and technical capability for a manned lunar landing was a prime NASA goal, though not the only one. The first meeting of the Group was to be held on January 9.

"Instructions to Manned Lunar Landing Task Group," January 6 and 9, 1961.

January 9

At the first meeting of the Manned Lunar Landing Task Group, Associate Administrator Robert C. Seamans, Jr., Director of the Office of Space Flight Programs Abe Silverstein, and Director of the Office of Advanced Research Programs Ira H. Abbott outlined the purpose of the Group to the members. After a discussion of the instructions, the Group considered first the objectives of the total NASA program:

1. the exploration of the solar system for knowledge to benefit mankind; and
2. the development of technology to permit exploitation of space flight for scientific, military, and commercial uses.

NASA's lunar program was a logical step toward these objectives. In current lunar program planning, three steps were projected:

1. a manned landing on the moon with return to earth,
2. limited manned lunar exploration, and
3. a scientific lunar base.

To accomplish the first step, a great increase in launch vehicle capability would be needed beyond that provided by current funding. A comparison of a three-million-pound-thrust and a six-million-pound-thrust Nova launch vehicle was made. It was estimated that a 60,000- to 80,000-pound payload to escape velocity would be needed for a manned lunar landing mission.

Manned Lunar Exploration Working Group [Manned Lunar Landing Task Group] Minutes, January 9, 1961.

January 10

Representatives of STG visited Convair Astronautics Division of the General Dynamics Corporation to monitor the Apollo feasibility study contract. The meeting consisted of several individual informal discussions between the STG and Convair specialists on configurations and aerodynamics, heating, structures and materials, human factors, trajectory analysis, guidance and control, and operation implementation.

Memorandum, William W. Petynia, Convair Liaison Engineer, to Associate Director, STG, "Visit to Convair Astronautics on January 10 Regarding Apollo Study," February 3, 1961.

January 10

A conference was held at the Langley Research Center between representatives of STG and Langley to discuss the feasibility of incorporating a lunar orbit rendezvous phase into the Apollo program. Attending the meeting for STG were Robert L. O'Neal, Owen E. Maynard, and H. Kurt Strass, and for the Langley Research Center, John C. Houbolt, Clinton E. Brown, Manuel J. Queijo, and Ralph W. Stone, Jr. The presentation by Houbolt centered on a performance analysis which showed the weight saving to be gained by the lunar rendezvous technique as opposed to the direct ascent mode. According to the analysis, a saving in weight of from 20 to 40 percent could be realized with the lunar orbit rendezvous technique.

Memorandum, O'Neal, Systems Integration Section, to Associate Director, STG, "Discussion with Dr. Houbolt, LRC, Concerning the Possible Incorporation of a Lunar Orbital Rendezvous Phase as a Prelude to Manned Lunar Landing," January 30, 1961.

January 11

Three of the Apollo Technical Liaison Groups (Trajectory Analysis, Heating, and Human Factors) held their first meetings at the Ames Research Center.

After reviewing the status of the contractors' Apollo feasibility studies, the Group on Trajectory Analysis discussed studies being made at NASA Centers. An urgent requirement was identified for a standard model of the Van Allen radiation belt which could be used in all trajectory analysis related to the Apollo program,

The Group on Heating, after consideration of NASA and contractor studies currently in progress, recommended experimental investigation of control surface heating and determination of the relative importance of the unknowns in the heating area by relating estimated "ignorance" factors to resulting

weight penalties in the spacecraft. The next day, three members of this Group met for further discussions and two areas were identified for more study: radiant heat inputs and their effect on the ablation heatshield, and methods of predicting heating on control surfaces, possibly by wind tunnel tests at high Mach numbers.

The Group on Human Factors considered contractors' studies and investigations being done at NASA Centers. In particular, the Group discussed the STG document, "Project Apollo Life Support Programs," which proposed 41 research projects. These projects were to be carried out by various organizations, including NASA, DOD, industry, and universities. Medical support experience which might be applicable to Apollo was also reviewed.

Minutes of meetings of Technical Liaison Groups on Trajectory Analysis, on Heating, and on Human Factors, January 11, 1961.

January 11

J. Thomas Markley of the Apollo Spacecraft Project Office reported to Associate Director of STG Charles J. Donlan that an informal briefing had been given to the Saturn Guidance Committee on the Apollo program. The Committee had been formed by Don R. Ostrander, NASA Director of the Office of Launch Vehicle Programs, to survey the broad guidance and control requirements for Saturn. The Committee was to review Marshall Space Flight Center guidance plans, review plans of mission groups who intended to use Saturn, recommend an adequate guidance system for Saturn, and prepare a report of the evaluation and results during January. Members of STG, including Robert O. Piland, Markley, and Robert G. Chilton, presented summaries of the overall Apollo program and guidance requirements for Apollo.

Memorandum, Markley to Associate Director, STG, "Briefing for Saturn Guidance Committee," January 11, 1961.

January 11

President-elect John F. Kennedy released a report made to him by his Ad Hoc Committee on Space named to review the U.S. space and missile programs and identify personnel, technical, or administrative problems which would require the prompt attention of the Kennedy Administration. The Committee, whose chairman was Jerome B. Wiesner of MIT, concluded that the national space program required a redefinition of objectives, that the National Aeronautics and Space Council should be made an effective agency for managing the space program, that there should be a single responsible agency within the military establishment to manage the military part of the space program, that NASA management should be reorganized with stronger emphasis on technical direction, and that organizational machinery should be set up within the government to administer an industry-government civilian space program.

Report to the President-Elect of the Ad Hoc Committee on Space, January 11, 1961, pp. 1, 4-5; *New York Times*, January 12, 1961.

January 11

John Blake of the Air Force Aeronautical Chart and Information Center (ACIC) described to STG representatives the progress made by ACIC in mapping the moon. Lunar maps to the scale of 1: 5,000,000 and 1: 10,000,000 were later requested and received by STG. In addition, the first two sheets of a projected 144 sheet map coverage of the lunar surface on a 1:1,000,000 scale were forwarded to STG by the Center.

Letter, Charles J. Donlan to Commander, ACIC, January 17, 1961; Lt. Col. Ross J. Foster, ACIC, to Donlan, STG, January 31, 1961.

January 12

Three of the Apollo Technical Liaison Groups Structures and Materials, Configurations and Aerodynamics, and Guidance and Control held their first meetings at the Ames Research Center.

The Group on Structures and Materials, after reviewing contractors' progress on the Apollo feasibility studies, considered reports on Apollo-related activities at NASA Centers. Among these activities were work on the radiative properties of material suitable for temperature control of spacecraft (Ames), investigation of low-level cooling systems in the reentry module (Langley), experiments on the landing impact of proposed reentry module shapes (Langley), meteoroid damage studies (Lewis), and the definition of suitable design criteria and safety factors to ensure the structural integrity of the spacecraft STG.

The Group on Configurations and Aerodynamics recommended :

- Investigations to determine the effects of aerodynamic heating on control surfaces.
- Studies of the roll control maneuvers with center of gravity offset for range control.
- Tests of packaging and deployment of paraglider and multiple parachute landing systems.
- Studies to determine the effects of jet impingement upon the static and dynamic stability of the spacecraft.

The various spacecraft configurations under consideration by the Apollo feasibility study contractors were reviewed:

1. The General Electric Company effort was being concentrated on the Mark-II, NERV, RVX (9 degree blunted cone), elliptical cone, half-cone, and Bell Aerospace Corporation Dyna-Soar types.
2. The Martin Company was studying the M-1 and M-2 lifting bodies, the Mercury with control

flap, the Hydrag (Avco Corporation), and a winged vehicle similar to Dyna-Soar. In addition, Martin was proposing to investigate the M-1-1, a lifting body halfway between the M-1 and the M-2; a flat-bottomed lifting vehicle similar to the M-1-1; a lenticular shape; and modified flapped Mercury (the Langley L-2C).

3. Convair/Astronautics Division of the General Dynamics Corporation had subcontracted the major effort on reentry to Avco, which was looking into five configurations: a Mercury-type capsule, the lenticular shape, the M-1, the flat-face cone, and half-cone.

The Group for Guidance and Control drew up a list of suggestions for research and development programs:

- An "absolute emergency" navigation system in which the crew would use only a Land camera and a slide rule.
- The possible applications of the equipment and test programs to be used on Surveyor.
- The question whether Apollo lunar landing trajectories should be based on minimum fuel expenditure - if so, doubts were raised that the current STG concept would accomplish this goal.
- The question whether radio ranging could be used to reduce the accuracy requirements for celestial observations and whether such a composite system would fall within the limits set by the Apollo guidelines.
- The effects of lunar impact on the return spacecraft navigation equipment.
- Studies of hardware drift-error in the guidance and navigation systems and components.
- A study of the effect of rotating machinery aboard the spacecraft on attitude alignment and control requirements.
- Problems of planet tracking when the planetary disk was only partially illuminated.
- A study of the transient effects of guidance updating by external information.
- One adequate guidance and control concept to be mechanized and errors analyzed and evaluated.
- The effects of artificial g configurations on observation and guidance.
- The development of a ground display mission progress evaluation for an entire mission
- An abort guidance sequence including an abort decision computer and pilot display
- An earth orbit evaluation of the position computer input in a highly eccentric orbit (500- to 1000-mile perigee, 60,000-mile apogee).

Minutes of meetings of Apollo Technical Liaison Groups on Structures and Materials, Configurations and Aerodynamics, and Guidance and Control, January 12, 1961.

January 12-13

Representatives of STG visited The Martin Company in Baltimore, Md., to review the progress of the Apollo feasibility study contract. Discussions on preliminary design of the spacecraft, human factors, propulsion, power supplies, guidance and control, structures, and landing and recovery were held with members of the Martin staff.

Memorandum, John B. Lee, Apollo Liaison Engineer, to Associate Director, STG, "Visit to The Martin Company, Baltimore, Md., on January 12-13, 1961, Regarding the Monitoring of the Apollo Study Contract," February 6, 1961.

January 16-17

At the second meeting of the Manned Lunar Landing Task Group (Low Committee), a draft position paper was presented by George M. Low, Chairman. A series of reports on launch vehicle capabilities, spacecraft, and lunar program support were presented and considered for possible inclusion in the position paper.

Minutes of Manned Lunar Landing Working Group [Manned Lunar Landing Task Group], January 16 and 17, 1961.

January 19

The Marshall Space Flight Center awarded contracts to the Douglas Aircraft Company and Chance Vought Corporation to study the launching of manned exploratory expeditions into lunar and interplanetary space from earth orbits.

U.S. Congress, House, Committee on Science and Astronautics, *Aeronautical and Astronautical Events of 1961*, Report of the National Aeronautics and Space Administration, 87th Congress, 2nd Session (1962), p. 3.

January 19

After evaluating preliminary design studies, NASA selected the Hughes Aircraft Company to build seven Surveyor spacecraft. This 750-pound, three-legged, unmanned spacecraft would carry 200 pounds of instruments, including zoom television cameras, a drill to sample the lunar soil, chemical analysis equipment, and a seismometer. The first Surveyor was scheduled to be launched in 1963.

Fifth NASA Semiannual Report, p. 49; *Los Angeles Examiner*, January 20, 1961.

January 24

The Manned Lunar Landing Task Group (Low Committee) submitted its first draft report to NASA Associate Administrator Robert C. Seamans, Jr. A section on detailed costs and schedules still was in preparation and a detailed itemized backup report was expected to be available in mid- February.

Memorandum, George M. Low, Program Chief, Manned Space Flight, to Associate Administrator, "A Plan for Manned Lunar Landing," January 24, 1961.

January 25

NASA announced that the Lockheed Aircraft Corporation had been awarded a contract by the Marshall Space Flight Center to study the feasibility of refueling a spacecraft in orbit.

Baltimore *Sun*, January 26, 1961.

January 26

Wernher von Braun, Director of Marshall Space Flight Center, proposed that the Saturn C-1 launch vehicle be changed from a three-stage to a two-stage configuration to meet Apollo program schedules. The planned third stage (S-V) would be dropped.

Saturn Illustrated Chronology, p. 17.

January 30

President John F. Kennedy announced that he was nominating James E. Webb as Administrator of the National Aeronautics and Space Administration and Hugh L. Dryden as Deputy Administrator, Senate confirmation followed on February 9 and they were sworn in on February 14.

Washington Post, January 31, 1961; *Fifth NASA Semiannual Report*, p. 2.

January 31

Mercury-Redstone 2 was launched successfully from the Atlantic Missile Range, with Ham, a chimpanzee, aboard. Despite the over-acceleration of the launch vehicle, which caused the spacecraft to reach a higher altitude than planned, the capsule was recovered safely with Ham in good condition.

Grimwood, *Project Mercury: A Chronology*, p. 121.

January 31-February 1

Members of STG met with representatives of the Convair Astronautics Division of the General Dynamics Corporation and Avco Corporation to monitor the progress of the Apollo feasibility study. Configurations and aerodynamics and Apollo heating studies were discussed. Current plans indicated that final selection of their proposed spacecraft configuration would be made by Convair Astronautics within a week. The status of the spacecraft reentry studies was described by Avco specialists.

Memorandum, William W. Petynia, Convair Liaison Engineer, to Associate Director, STG, "Visit to Avco, Wilmington, Mass., on January 31 and February 1, 1961, Regarding Monitoring of Apollo Study

Contract;" February 13, 1961.

During the Month

Marshall Space Flight Center awarded contracts to NAA and Ryan Aeronautical Corporation to investigate the feasibility of recovering the first stage (S-I) of the Saturn launch vehicle by using a Rogallo wing paraglider.

Saturn Illustrated Chronology, pp. 17-18.

February 7

The Manned Lunar Landing Task Group (Low Committee) transmitted its final report to NASA Associate Administrator Robert C. Seamans, Jr. The Group found that the manned lunar landing mission could be accomplished during the decade, using either the earth orbit rendezvous or direct ascent technique. Multiple launchings of Saturn C-2 launch vehicles would be necessary in the earth orbital mode, while the direct ascent technique would require the development of a Nova-class vehicle. Information to be obtained through supporting unmanned lunar exploration programs, such as Ranger and Surveyor, was felt to be essential in carrying out the manned lunar mission. Total funding for the program was estimated at just under \$7 billion through Fiscal Year 1968.

Memorandum, George M. Low, Program Chief, Manned Space Flight, to Associate Administrator, "Transmittal of Report Prepared by Manned Lunar Working Group [Manned Lunar Landing Task Group]," February 7, 1961.

February 7

NASA selected the Instrumentation Laboratory of MIT for a six-month study of a navigation and guidance system for the Apollo spacecraft.

Information from the Apollo Procurement Branch, Procurement and Contracts Division, Manned Spacecraft Center, Houston, Tex., October 2, 1967.

February 10

A voice message was sent from Washington, D.C., to Woomera, Australia, by way of the moon. NASA Deputy Administrator Hugh L. Dryden spoke by telephone to Goldstone, Calif., which "bounced" it to the deep-space instrumentation station at Woomera. The operation was conducted as part of the official opening ceremony of the Australian facility.

Aeronautical and Astronautical Events of 1961, p. 6.

February 10

Rocketdyne Division's first static test of a prototype thrust chamber for the F-1 engine achieved a thrust of 1.550 million pounds in a few seconds at Edwards Air Force Base, Calif.

Rocketdyne *Skywriter*, February 17, 1961; *Washington Post*, February 11, 1961.

February 10

At the first meeting of the House Committee on Science and Astronautics, during the first session of the 87th Congress, Charles F. Ducander, Executive Director and Chief Counsel of the Committee staff, outlined a number of proposed subjects for study. One subject was the Air Force's interest in a three-man spacecraft similar to the Apollo spacecraft planned by NASA. A Committee staff member had been assigned to investigate this duplication of effort. On February 22, testifying before the Committee, Air Force Undersecretary Joseph V. Charyk stated that the Dyna-Soar program was a direct approach to manned military space applications. The Air Force interest in an Apollo-type spacecraft was part of the post-Dyna- Soar program, Charyk said.

U.S. Congress, House, Committee on Science and Astronautics, *Miscellaneous Committee Business*, 87th Congress, 1st Session (1961), p. 6; U.S. Congress, House, Committee on Science and Astronautics, *Research and Development for Defense*, 87th Congress, 1st Session (1961), p. 161.

February 21

Mercury-Atlas 2 (unmanned) was launched successfully from the Atlantic Missile Range in a test of maximum heating and its effects during the worst reentry design conditions. All test objectives were met.

Grimwood, *Project Mercury: A Chronology*, p. 124.

February 27-25

A NASA inter-Center meeting on space rendezvous was held in Washington, D.C. Air Force and NASA programs were discussed and the status of current studies was presented by NASA Centers. Members of the Langley Research Center outlined the basic concepts of the lunar orbit rendezvous method of accomplishing the lunar landing mission.

"Apollo Spacecraft Chronology," p. 6; Bird, "Short History of the Development of the Lunar Orbit Rendezvous Plan at the Langley Research Center," p.3; *Manned Lunar Landing through use of Lunar-Orbit Rendezvous*, p. 5.

March 1

The current Saturn launch vehicle configurations were announced:

C-1:

S-I stage eight H-1 engines, 1.5 million pounds of thrust; S-IV stage four (LR-119 engines, 70,000 pounds of thrust); and S-V stage (two LR-119 engines, 35,000 pounds of thrust).

C-2 (four-stage version):

S-1 stage (same as first stage of the C-1); S-II (not determined); S-IV (same as second stage of the C-1); S-V (same as third Stage of C- 1).

C-2 (three-stage version):

S-I (same as first stage of C-1); S-II (not determined); and S-IV (same as third stage of C-1).

Senate Staff Report, *Manned Space Flight Program*, p. 196.

March 1-3

The midterm review of the Apollo feasibility studies was held at STG. Oral status reports were made by officials of Convair Astronautics Division of the General Dynamics Corporation on March 1, The Martin Company on March 2, and the General Electric Company on March 3. The reports described the work accomplished, problems unsolved, and future plans. Representatives of all NASA Centers attended the meetings, including a majority of the members of the Apollo Technical Liaison Groups. Members of these Groups formed the nucleus of the mid-term review groups which met during the three-day period and compiled lists of comments on the presentations for later discussions with the contractors.

Project Apollo, A Feasibility Study of an Advanced Manned Spacecraft and System, Comments on the Convair-Astronautics Company Midterm Presentation, March 1, 1961; Comments on The Martin Company Midterm Presentation, March 2, 1961; and Comments on the General Electric (Missile and Space Vehicle Division) Company Midterm Presentation, March 3, 1961.

March 7

The first flight model of the Saturn C-1 booster SA-1 was installed on the static test stand for preflight checkout at the Marshall Space Flight Center.

Saturn Illustrated Chronology, p. 21.

The Soviet Union launched and recovered on the same day Korabl Sputnik VI, or Sputnik IX, in a test of spacecraft construction and systems and the influence of cosmic rays on living beings. The spacecraft carried a dog, guinea pigs, mice, and insects.

New York Times, March 10 1961; *Baltimore Sun*, March 13, 1961; *Instruments and Spacecraft*, pp. 162-163.

March 20

Management personnel from NASA Headquarters and STG met to plan general requirements for a proposal for advanced manned spacecraft development.

"Apollo Spacecraft Chronology," p. 7.

March 23

Representatives of Marshall Space Flight Center recommended configuration changes for the Saturn C-1 launch vehicles to NASA Headquarters. These included:

- Elimination of third-stage development, since two stages could put more than ten tons into earth orbit.
- Use of six LR-115 (15,000-pound) Centaur engines (second-stage thrust thus increased from 70,000 to 90,000 pounds).
- Redesign of the first stage (S-1) to offer more safety for manned missions.

Plans were also presented to accelerate the development of the Saturn C- 2, and a recommendation was made that a prime contractor be selected to work on the second stage (S-II) of the C-2. NASA Headquarters approved the C-2 plans on March 31.

Saturn Illustrated Chronology, pp. 21-22; Senate Staff Report, *Manned Space Flight Program*, p. 196.

March 25

In an apparent duplication of the March 9 launch, the Soviet Union orbited and recovered *Korabl Sputnik VII*, or *Sputnik X*. The spacecraft, the third of its kind to be recovered safely by the Russians, carried a dog and other animals.

Baltimore *Sun*, March 26, 1961; *Instruments and Spacecraft*, p. 164.

March 28

President John F. Kennedy submitted to Congress an amended budget request for NASA which totaled \$1,235,300,000. This total was \$125,670,000 greater than the Eisenhower Administration's request. The increase included \$56 million for Saturn research and development and \$11 million for the extension of Cape Canaveral facilities.

Senate Staff Report, *Manned Space Flight Program*, p. 197.

March 29-30

William W. Petynia of STG visited the Convair Astronautics Division of General Dynamics Corporation to monitor the Apollo feasibility study contract. A selection of the M-1 in preference to the lenticular configuration had been made by Convair. May 17 was set as the date for the final Convair presentation to NASA.

Memorandum, Petynia, Convair Liaison Engineer, to Associate Director, STG, "Visit to Convair Astronautics on March 29-30, 1961, Regarding Monitoring of the Apollo Study Contract," April 5, 1961.

March 31

The Space Science Board of the National Academy of Sciences submitted to President John F. Kennedy its recommendation that "scientific exploration of the moon and planets should be clearly stated as the ultimate objective of the U.S. space program for the foreseeable future." While stressing the importance of the scientific goals of the program, the Board also emphasized other factors such as "the sense of national leadership emergent from bold and imaginative U.S. space activity." The recommendations of the Board had been adopted at a meeting on February 10-11 and were made public on August 7.

Space Science Board, "Man's Role in the National Space Program," August 7, 1961.

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PART 2 (C)

Design - Decision - Contract

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1961

April 6

The Marshall Space Flight Center announced that 1.640 million pounds of thrust was achieved in a static- firing of the F-1 engine thrust chamber at Edwards Air Force Base, Calif. This was a record thrust for a single chamber.

Baltimore *Sun*, April 12, 1961; Rocketdyne *Skywriter*, April 14, 1961.

April 10

A joint meeting of the Apollo Technical Liaison Groups was held at STG. NASA Headquarters and STG representatives briefed members of the Groups on the status of the Apollo program. The individual Liaison Groups were asked to reexamine the Apollo guidelines in the light of NASA and contractor studies conducted during the past year and to help gather detailed technical information for use as background material in the preparation of the Apollo spacecraft specification.

Minutes of meeting of Apollo Technical Liaison Group, Configurations and Aerodynamics, April 10 12, 1961.

April 10-12

At the second meeting of the Apollo Technical Liaison Group for Configurations and Aerodynamics at STG, presentations were made on Apollo-related activities at the NASA Centers: heatshield tests (Ames Research Center); reentry configurations (Marshall Space Flight Center); reentry configurations, especially lenticular (modified) and spherically blunted, paraglider soft-landing system, dynamic stability tests, and heat transfer tests (Langley Research Center); tumbling entries in planetary atmospheres (Mars and Venus) (Jet Propulsion Laboratory); air launch technique for Dyna-Soar (Flight Research Center); and steerable parachute system and reentry spacecraft configuration (STG). Work began on the background material for the Apollo spacecraft specification. Minutes of meeting of Apollo Technical Liaison Group, Configurations and Aerodynamics, April 10-12, 1961.

April 10-12

The Apollo Technical Liaison Group for Heating heard reports at STG by Group members on current studies at the NASA Centers. Recommendations concerning the spacecraft specification included:

- The contractor should present the design philosophy and criteria to be used for the heat protection system and discuss the interplay of thermal and structural design criteria.
- The details of the analysis should be presented: for example, the methods used in calculating the various modes of the heating load; the listing of the material properties and ablation effectiveness of heatshields; and the listing, in terms of temperature or extra heat protection weight, of the safety factors that had been used.

Minutes of meeting of Apollo Technical Liaison Group, Heating, April 10- 12, 1961.

April 10-12

At STG the Apollo Technical Liaison Group for Human Factors discussed the proposed outline for the spacecraft specification. Its recommendations included:

- NASA Headquarters Offices should contact appropriate committees and other representatives of the scientific community to elicit recommendations for scientific experiments aboard the orbiting laboratory to be designed as a mission module for use with the Apollo spacecraft.
- NASA should sponsor a conference of recognized scientists to suggest a realistic radiation dosage design limit for Apollo crews.

Minutes of meeting of Apollo Technical Liaison Group, Human Factors, April 10, 11, and 12, 1961.

April 10-12

The Apollo Technical Liaison Group for Instrumentation and Communications met at STG and drafted an informal set of guidelines and sent them to the other Technical Liaison Groups:

- Instrumentation requirements: all Groups should submit their requests for measurements to be made on the Apollo missions, including orbital, circumlunar, and lunar landing operations.
- Television: since full-rate, high-quality television for the missions would add a communications load that could swamp all others and add power and bandwidth requirements not otherwise needed, other Groups should restate their justification for television requirements.
- Temperature environment; heat normally pumped overboard might be made available for temperature control systems without excessive cost and complexity.
- Reentry communications; continuous reentry communications were not yet feasible and could not be guaranteed. It was suggested that all Groups plan their systems as though no communications would exist at altitudes between about 250,000 feet and 90,000 feet.
- Vehicle reentry and recovery: if tracking during reentry were desired, it would be far more economical to use a water landing site along the Atlantic Missile Range or another East Coast site.
- Digital computer : the onboard digital computer, if it were flexible enough, would permit the examination of telemetry data for bandwidth reduction before transmission.
- Antenna-pointing information: the spacecraft should have information relative to its orientation so that any high-gain directive antenna could be positioned toward the desired location on earth.

The Group then discussed the preparation of material for the Apollo spacecraft specification.

Minutes of meeting of Apollo Technical Liaison Group, Instrumentation and Communications, April 10, 11, and 12, 1961.

April 10-12

The Apollo Technical Liaison Group for Onboard Propulsion met at STG and considered preparation of background material for the Apollo spacecraft specification. It agreed that there were several problem areas for study before onboard propulsion final specifications could be drafted : cryogenic propellant storage problems, booster explosion hazards and assessment thereof, spacecraft system abort modes, propulsion system temperature control, propellant leakage, ignition in a confined space, zero suction pump proposals for cryogenic liquid bipropellant main engine systems, and propellant utilization and measurement system.

Minutes of meeting of Apollo Technical Liaison Group, Onboard Propulsion, April 10-12, 1961.

April 10-12

The Apollo Technical Liaison Group for Structures and Materials discussed at STG the preparation of material for the Apollo spacecraft specification. It decided that most of the items proposed for its study could not be specified at that time and also that many of the items did not fall within the structures and materials area. A number of general areas of concern were added to the work plan: heat protection, meteoroid protection, radiation effects, and vibration and acoustics.

Minutes of meeting of Apollo Technical Liaison Group, Structures and Materials, April 10-12, 1961.

April 10-12

The Apollo Technical Liaison Group for Trajectory Analysis met at STG and began preparing material for the Apollo spacecraft specification. It recommended:

- STG should take the initiative with NASA Headquarters in delegating responsibility for setting up and updating a uniform model of astronomical constants.
- The name of the Group should be changed to Mission Analysis to help clarify its purpose.
- A panel should be set up to determine the scientific experiments which could be done on board, or in conjunction with the orbiting laboratory, so that equipment, weight, volumes, laboratory characteristics, etc., might be specified

Minutes of meeting of Apollo Technical Liaison Group, Trajectory Analysis, April 10-12, 1961.

April 10-13

In preparing background material for the Apollo spacecraft specification at STG, the Apollo Technical Liaison Group for Mechanical Systems worked on environmental control systems, reaction control systems, auxiliary power supplies, landing and recovery systems, and space cabin sealing.

Minutes of meeting of Apollo Technical Liaison Group, Trajectory Analysis, April 10-13, 1961.

April 10-14

Meeting at STG, the Guidance and Control Group changed its name to the "Apollo Technical Liaison Group for Navigation, Guidance, and Control." Definitions were established for "navigation" (the determination of position and velocity), "guidance" (velocity vector control), and "control" (control of rotational orientation about the center of gravity - i.e., attitude control). Work was started on the preparation of the navigation, guidance, and control specifications for the Apollo spacecraft.

Minutes of meeting of Apollo Technical Liaison Group, Navigation, Guidance, and Control, April 10-14, 1961.

April 12

NASA Associate Administrator Robert C. Seamans, Jr., established the permanent Saturn Program Requirements Committee. Members were William A. Fleming, Chairman; John L. Sloop, Deputy Chairman; Richard B. Canright; John H. Disher; Eldon W. Hall; A. M. Mayo; and Addison M. Rothrock, all of NASA Headquarters. The Committee would review on a continuing basis the mission

planning for the utilization of the Saturn and correlate such planning with the Saturn development and procurement plans.

Memorandum, Seamans to Program Directors, "Establishment of Saturn Program Requirements Committee," April 12, 1961.

April 12

The Soviet Union launched into orbit the five-ton *Vostok I*, with Yuri A. Gagarin as pilot, the first man to make a successful orbital space flight. The payload included life-support equipment and radio and television to relay information on the condition of the pilot. The spacecraft apogee was 187.8 miles, the perigee was 109.5 miles, inclination 65.07 degrees, and the orbital period 89.1 minutes. After a 108-minute, one-orbit flight, the capsule and pilot reentered and landed safely in the Soviet Union.

New York Times, April 13, 1961; *Instruments and Spacecraft*, p. 170.

April 12

President John F. Kennedy, in his regular press conference, stated that "no one is more tired than I am" of seeing the United States second to Russia in space. "They secured large boosters which have led to their being first in Sputnik, and led to their first putting their man in space. We are, I hope, going to be able to carry out our efforts, with due regard to the problem of the life of the men involved, this year. But we are behind . . . the news will be worse before it is better, and it will be some time before we catch up. . . ."

Washington Post, April 13, 1961.

April 14

Under questioning by the House Committee on Science and Astronautics, NASA Associate Administrator Robert C. Seamans, Jr., stated that a landing on the moon in 1967 might be possible through an all-out crash program at a cost of \$4 to \$5 billion a year instead of the current budget of \$1.236 billion.

Washington Post, April 15, 1961.

April 19

A circular, "Manned Lunar Landing via Rendezvous," was prepared by John C. Houbolt from material supplied by himself, John D. Bird, Max C. Kurbjun, and Arthur W. Vogeley, who were members of the Langley Research Center space station subcommittee on rendezvous. Other members of the subcommittee at various times included W. Hewitt Phillips, John M. Eggleston, John A. Dodgen, and

William D. Mace.

Bird, "Short History of the Development of the Lunar Orbit Rendezvous Plan at Langley Research Center," p. 3.

April 19

John C. Houbolt and members of the Langley Research Center subcommittee on rendezvous outlined the objectives of a rendezvous program that would lead ultimately to a manned lunar landing:

1. establish manned and unmanned orbital operations,
2. establish techniques for accomplishing space missions through the orbital assembly of units.

Three key projects were described which would accomplish these objectives. The first was MORAD (Manned Orbital Rendezvous and Docking), which would require the use of the Mercury-Atlas and Scout in the 1961- 1963 period. Rendezvous in space between the Mercury spacecraft and Scout payload would establish confidence in manned rendezvous techniques and lead to simplification of equipment and increased reliability. The second key project was ARP (Apollo Rendezvous Phases), in which the Atlas, Agena, and Saturn boosters would be used in the 1962-1965 period. This program would accomplish rendezvous with space stations, personnel transfer, resupply of space laboratory, execution of space maneuvers after coupling (steps toward lunar landing), and development of specifications for subsequent orbital and moon missions. The third project was called MALLIR (Manned Lunar Landing Involving Rendezvous), in which Saturn and Apollo components would be used during the 1961-1967 period. After qualification of the Saturn components for rendezvous operations, an early manned lunar landing would take place.

Langley Research Center, "Manned Lunar Landing via Rendezvous," April 19, 1961.

April 19



An early lunar excursion module was proposed by personell of Langley Research Center as the lunar lander for the suggested Project MALLIR.

The booster requirements for Project MALLIR (Manned Lunar Landing Involving Rendezvous) would be satisfied by use of the Saturn C-2 as the basic launch vehicle. The number of boosters needed to

achieve a lunar landing would be substantially reduced by using a combination of earth orbit and lunar orbit rendezvous. In a Project MALLIR configuration, two Saturn C-2's would be required. The first would launch the command module, lunar lander, and propulsion unit for lunar braking. The second would launch a booster which would rendezvous in earth orbit with the spacecraft. This booster would be jettisoned after launching the configuration into a lunar trajectory. After reaching lunar orbit, the lunar lander would separate from the command module and descend to the lunar surface. One man would remain behind in the command module orbiting the moon. After a brief lunar stay, the two men would ascend in the lunar lander and rendezvous with the command module. The command module would then boost to return trajectory, leaving behind the lunar lander, and reenter after jettisoning the propulsion unit. The command module was estimated to weigh 11,000 pounds, and the lunar lander 11,000 pounds.

"Manned Lunar Landing via Rendezvous."

April 19

Recommendations on immediate steps to be taken so that the three key projects - MORAD (Manned Orbital Rendezvous and Docking), ARP (Apollo Rendezvous Phases), and MALLIR (Manned Lunar Landing Involving Rendezvous) - could get under way were:

- Approve the MORAD project and let a study contract to consider general aspects of the Scout rendezvous vehicle design, definite planning and schedules, and tie down cost estimates more exactly.
- Delegate responsibility to STG to give accelerated consideration to rendezvous aspects of Apollo, tailoring developments to fit directly into the MALLIR project.
- Let a study contract to establish preliminary design, scheduling, and cost figures for the three projects.

"Manned Lunar Landing via Rendezvous."

April 20

A conference was held at NASA Headquarters on the relationship between the Prospector and Apollo programs. Representatives of the Jet Propulsion Laboratory (JPL) and STG discussed the possible redirection of Prospector planning to support more directly the manned space program. The Prospector spacecraft was intended to soft-land about 2,500 pounds on the lunar surface with an accuracy of +/- 1 kilometer anywhere on the visible side of the moon. An essential feature of Prospector was the development of an automatic roving vehicle weighing about 1500 pounds which would permit detailed reconnaissance of the lunar surface over a wide area. STG representatives felt that the most useful feature of the Prospector program lay in its planned ability to soft-land cargo in close proximity to a desired site. Many applications could be foreseen, such as the deposit of landing aids and essential material in support of a manned lunar landing or in continuing support for a manned lunar expedition.

However, the Prospector roving vehicle seemed to be a much more complicated and heavier piece of hardware than a manned lunar transport and, for that reason, STG did not support its development. The planning for Prospector involved JPL in-house studies concerning closer integration with manned space flight requirements, definitive decisions on the program within several months, a contractor's study in Fiscal Year 1962, engineering design in Fiscal Year 1963, and a hardware contract at a future date. Future Prospector planning would emphasize its cargo-carrying ability as a prime requirement, JPL representatives stated.

Memorandum, H. Kurt Strass, Apollo Project Office, to Associate Director, STG, "Conference at NASA Headquarters Concerning Relationship Between the Prospector and Apollo Programs, April 20, 1961," May 1, 1961.

April 25

Mercury-Atlas 3 (MA-3) was launched from the Atlantic Missile Range, carrying a "mechanical astronaut" in an intended unmanned orbital flight. Forty seconds after liftoff, MA-3 was destroyed by the range safety officer because the inertial guidance system had failed to pitch the vehicle over toward the horizon. The spacecraft successfully aborted and was recovered a short distance off shore.

Swenson *et al.*, *This New Ocean*, pp. 335-337.

April 25

A conference was held at Lewis Research Center between STG and Lewis representatives to discuss the research and development contract for the liquid-hydrogen liquid-oxygen fuel cell as the primary spacecraft electrical power source. Lewis had been provided funds approximately \$300,000 by NASA Headquarters to negotiate a contract with Pratt & Whitney Aircraft Division of United Aircraft Corporation for the development of a fuel cell for the Apollo spacecraft. STG and Lewis representatives agreed that the research and development should be directed toward the liquid-hydrogen - liquid-oxygen fuel cell. Guidelines were provided by STG:

- Power output requirement for the Apollo spacecraft was estimated at two to three kilowatts.
- Nominal output voltage should be about 27.5 volts.
- Regulation should be within +/- 10 percent of nominal output voltage.
- The fuel cell should be capable of sustained operation at reduced output (10 percent of rated capacity, if possible).
- The fuel cell and associated system should be capable of operation in a space environment.

Lewis planned to request a pilot model of the fuel cell of about 250 watts capacity, capable of unattended operation. Contract negotiations were expected to be completed by May 2 and the model delivered within 12 months of the contract award.

Memorandum, Preston T. Maxwell, Aeronautical Research Engineer, to Associate Director (Research and Development), STG, "Conference with Lewis Research Center Personnel to Discuss R and D Contract for H2-O2 Fuel Cell," April 27, 1961.

April 28

Little Joe 5B was launched from Wallops Island, carrying a production Mercury spacecraft. In spite of an erroneous trajectory which subjected the capsule to much greater dynamic pressures than planned, the spacecraft and escape system performed successfully.

Swenson *et al.*, *This New Ocean*, pp. 337-338.

April 29

The first successful flight qualification test of the Saturn SA-1 booster took place in an eight-engine test lasting 30 seconds.

Saturn Illustrated Chronology, p. 24.

During the Month

The Douglas Aircraft Company reported that air transport of the Saturn C-1 second stage (S-IV) was feasible.

Saturn Illustrated Chronology, p. 22.

May 1

Anticipating the expanded scope of manned space flight programs, STG proposed a manned spacecraft development center. The nucleus for a center existed in STG, which was handling the Mercury project. A program of much greater magnitude would require a substantial expansion of staff and facilities and of organization and management controls.

STG Study, "Manned Spacecraft Development Center, Organizational Concepts and Staffing Requirements," May 1, 1961.

May 2

NASA Associate Administrator Robert C. Seamans, Jr., established the Ad Hoc Task Group for a Manned Lunar Landing Study, to be chaired by William A. Fleming of NASA Headquarters. The study was expected to produce the following information:

- All tasks associated with the mission.
- Interdependent time-phasing of the tasks.
- Areas requiring considerable technological advancements from the current state of the art.
- Tasks for which multiple approach solutions were advisable.
- Important action and decision points in the mission plan.
- A refined estimate by task and by fiscal year of the dollar resources required for the mission.
- Refined estimates of in-house manpower requirements, by task and by fiscal year
- Tentative in-house and contractor task assignments accompanying the dollar and manpower resource requirements.

The study began on May 8 and the final report was submitted on June 16. Guidelines served as a starting point for the study:

- The manned lunar landing target date was 1967.
- Intermediate missions of multiman orbital satellites and manned circumlunar missions were desirable at the earliest possible time.
- Man's mission on the moon as it affected the study was to be determined by the Ad Hoc Task Group - i.e., the time to be spent on the lunar surface and the tasks to be performed while there.
- In establishing the mission plan, the use of the Saturn C-2 launch vehicle was to be evaluated as compared with an alternative launch vehicle having a higher thrust first stage and C-2 upper-stage components.
- The mission plan was to include parallel development of liquid and solid propulsion leading to a Nova vehicle 400,000 pounds in earth orbit and should indicate when the decision should be made on the final Nova configuration.
- Nuclear-powered launch vehicles should not be considered for use in the first manned lunar landing mission.
- The flight test program should be laid out with enough launchings to meet the needs of the program considering the reliability requirements.
- Alternative approaches should be provided in critical areas - e.g., upper stages and mission modes.

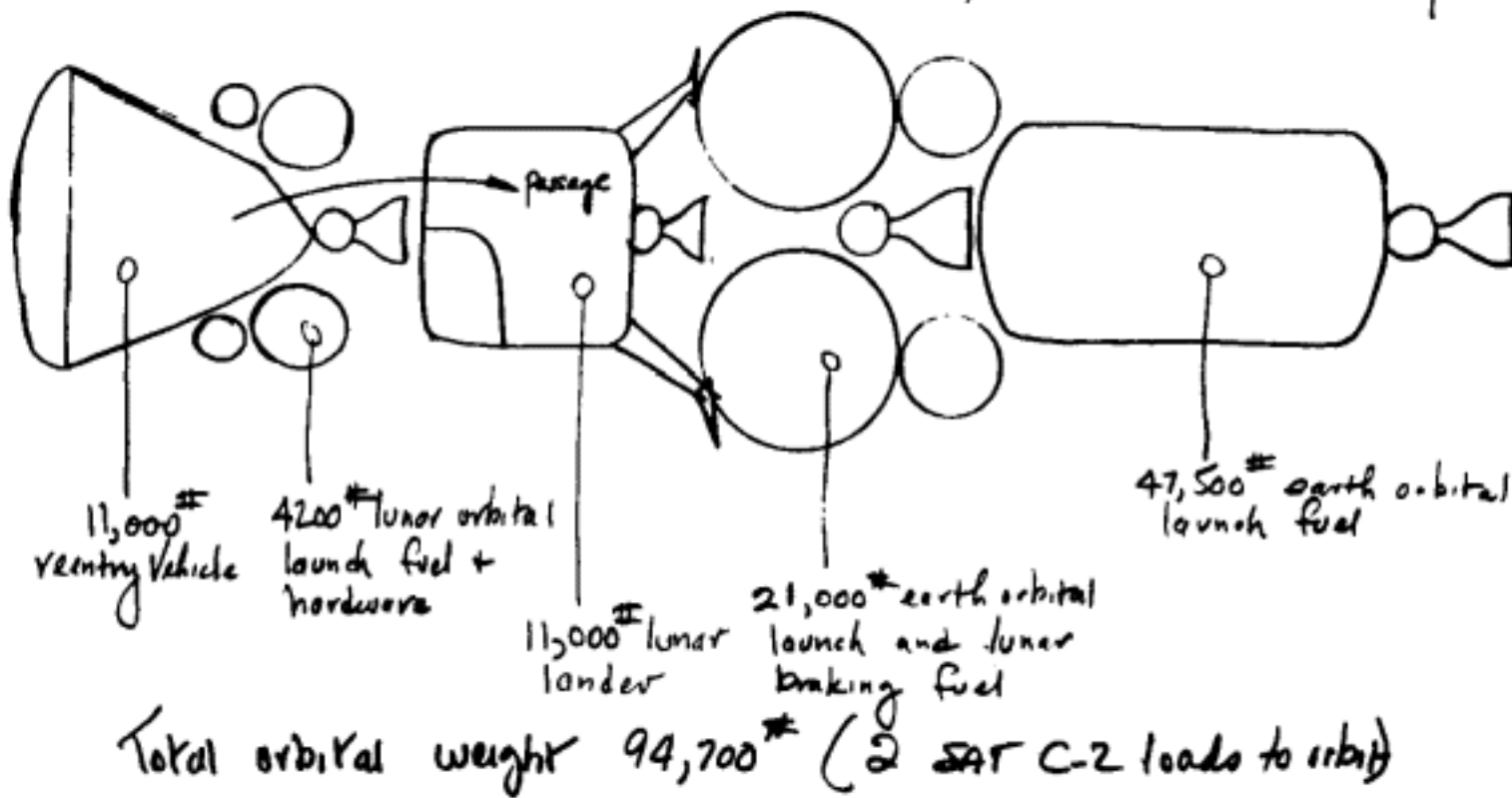
Memorandum, Seamans to Directors, Office of Space Flight Programs, Office of Launch Vehicle Programs, Office of Advanced Research Programs, and Office of Life Sciences Programs, "Establishment of Ad Hoc Task Group for Manned Lunar Landing Study," May 2, 1961.

NASA-LANGLEY
EARTH & LUNAR RENDEZVOUS
(No radiation protection - 60 FT OVERALL LENGTH)

JDB
5/3/61

41,200# One C-2

47,500# one C-2



The engineering sketch drawn by John D. Bird of Langley Research Center on May 3, 1961, indicated the thinking of that period: By launching two Saturn C-2's, the lunar landing mission could be accomplished by using both earth rendezvous and lunar rendezvous at various stages of the mission.

May 5

STG completed the first draft of "Project Apollo, Phase A, General Requirements for a Proposal for a Manned Space Vehicle and System" [Statement of Work], an early step toward the spacecraft specification. A circumlunar mission was the basis for planning.

"Apollo Spacecraft Chronology," p. 8.

May 5

In the first American manned space flight, *Freedom 7*, piloted by Astronaut Alan B. Shepard, Jr., was launched successfully from the Atlantic Missile Range. The Redstone rocket boosted the Mercury capsule to 116.5 miles and a maximum speed of 5,180 miles per hour. After a flight of 15 minutes and 22 seconds, the landing was made 302 miles downrange from the launch site. Recovery operations were perfect; there was no damage to the spacecraft; and Astronaut Shepard was in excellent condition.

Grimwood, *Project Mercury: A Chronology*, p. 137.

May 7

Albert C. Hall of The Martin Company proposed to Robert C. Seamans, Jr., NASA's Associate Administrator, that the Titan II be considered as a launch vehicle in the lunar landing program. Although skeptical, Seamans arranged for a more formal presentation the next day. Abe Silverstein, NASA's Director of Space Flight Programs, was sufficiently impressed to ask Director Robert R. Gilruth and STG to study the possible uses of Titan II. Silverstein shortly informed Seamans of the possibility of using the Titan II to launch a scaled-up Mercury spacecraft.

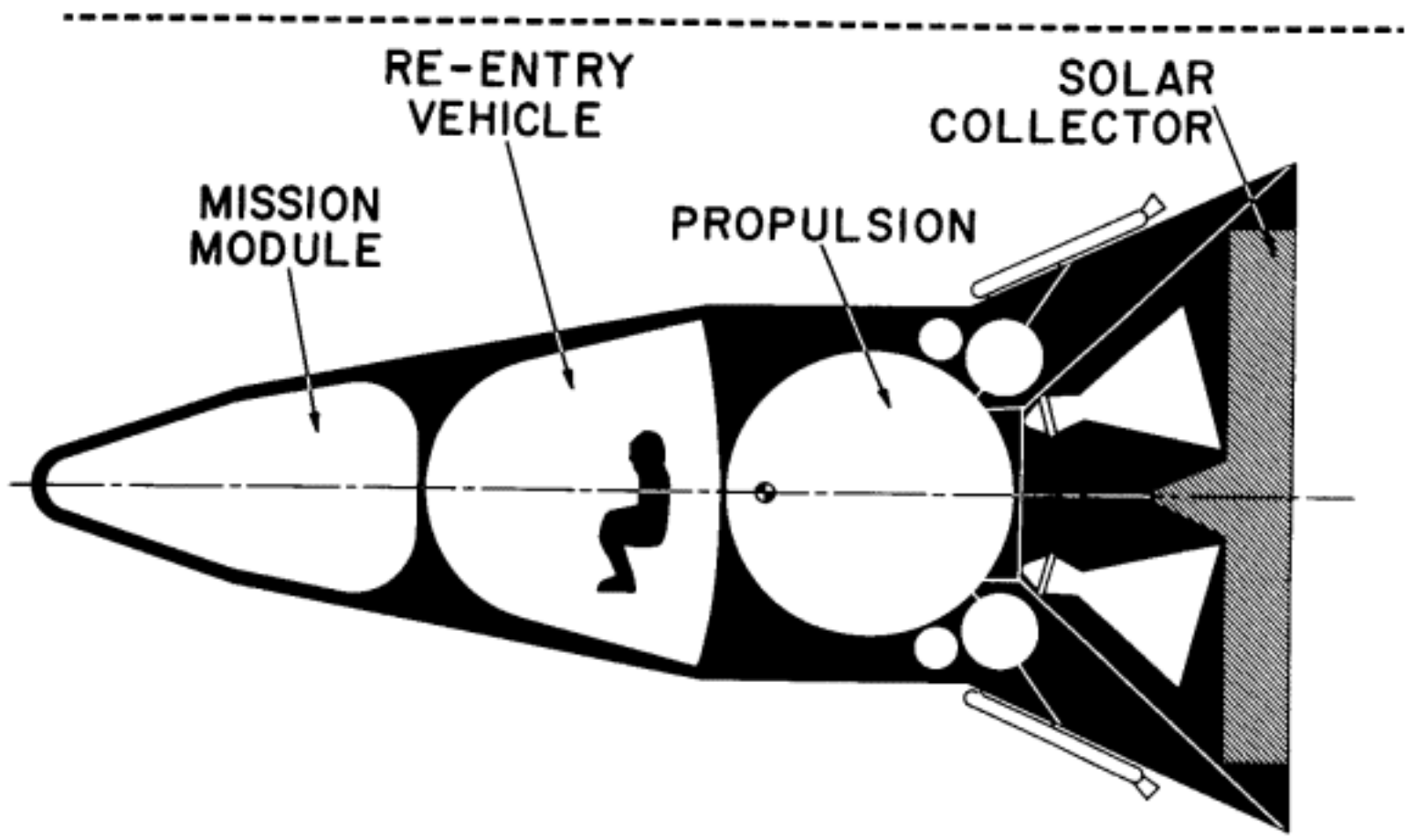
Interview with Seamans, Washington, D.C., May 26, 1966.

May 8

After study and discussion by STG and Marshall Space Flight Center officials, STG concluded that the current 154-inch diameter of the second stage (S-IV) adapter for the Apollo spacecraft would be satisfactory for the Apollo missions on Saturn flights SA-7, SA-8, SA-9, and SA-10.

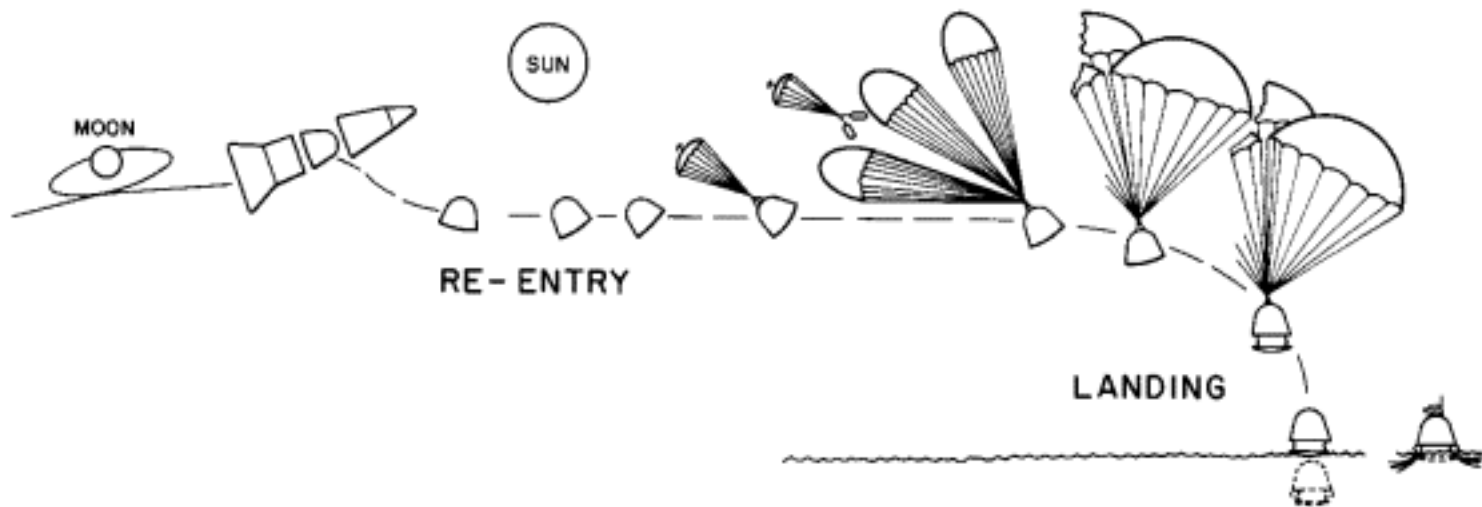
Letter, Robert R. Gilruth, Director, STG, to Marshall Space Flight Center, Attn: W. M. von Braun, Director, "S-IV Adapter and C-1 Two-Stage Report," May 8, 1961.

D-2 CONFIGURATION



A cross-section drawing of the vehicle (D-2) recommended by General Electric's Missile and Space Vehicle Department for the Apollo program during the Apollo feasibility study, completed in May 1961. (G.E. illustration)

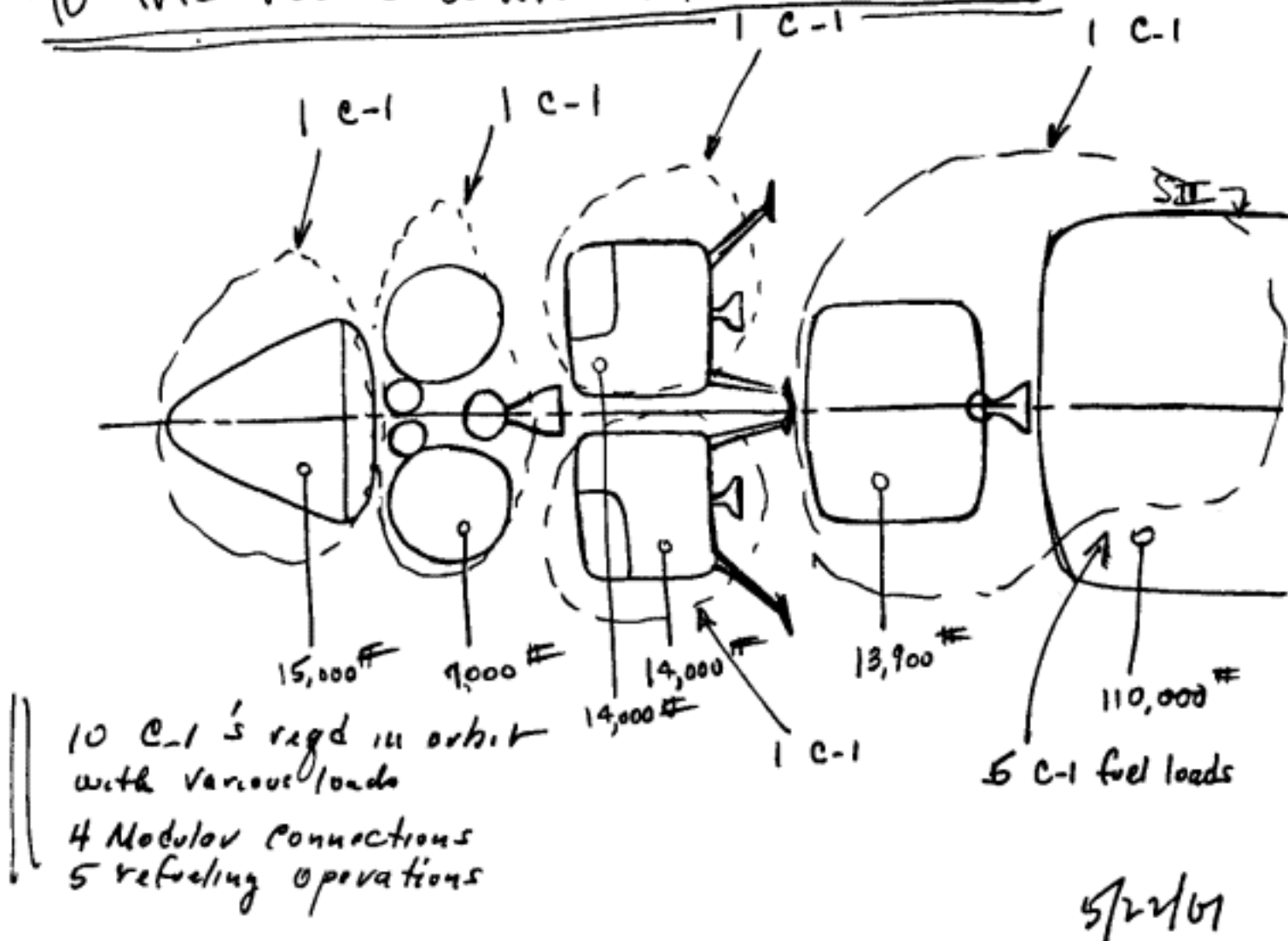
MISSION SEQUENCE TO EARTH



A mission sequence to earth landing, developed by G.E. during its Project Apollo feasibility study, including the planned configuration through the lunar-earth trajectory, reentry, and landing. (G.E. illustration)

NASA-LANGLEY

TO THE MOON WITH C-1'S OR BUST



"TO THE MOON WITH C-1'S OR BUST" was the theme of the day at Langley Research Center May 22, 1961. The sketch by John D. Bird on that day portrays the means of completing the lunar mission by launching ten C-1's.

May 15-17

The final reports on the feasibility study contracts for the advanced manned spacecraft were submitted to STG at Langley Field, Va., by the General Electric Company, Convair Astronautics Division of General Dynamics Corporation, and The Martin Company. These studies had begun in November 1960.

Aeronautical and Astronautical Events of 1961, pp. 20, 23; "Apollo Spacecraft Chronology," p. 9.

May 22

The second draft of a Statement of Work for the development of an advanced manned spacecraft was completed, incorporating results from NASA in-house and contractor feasibility studies.

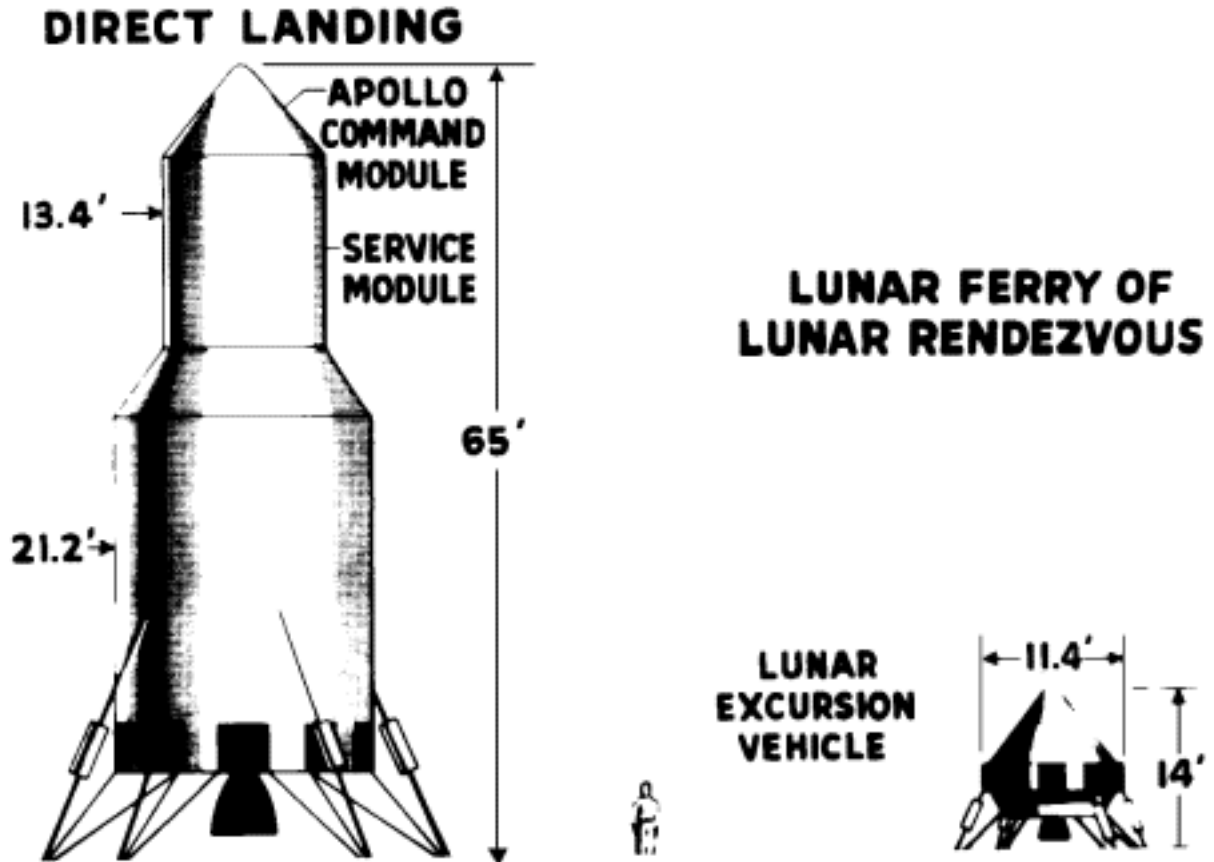
"Apollo Spacecraft Chronology," p. 9.

May 25

In a special message to Congress on urgent national needs, President John F. Kennedy called for new, long-range goals for the space program: "Now it is time to take longer strides - time for a great new American enterprise time for this nation to take a clearly leading role in space achievement, which in many ways may hold the key to our future on earth. . . . I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth. No single space project in this period will be more impressive to mankind, or more important for the long-range exploration of space; and none will be so difficult or expensive to accomplish . . . in a very real sense, it will not be one man going to the moon if we make this judgment affirmatively, it will be an entire nation. For all of us must work to put him there." The President also called for the early development of the Rover nuclear rocket, the acceleration of the use of space satellites for worldwide communications, and the development of a weather satellite system. For these and associated projects in space technology, the President requested additional appropriations totaling \$611 million for NASA and DOD for Fiscal Year 1962.

U.S. Congress, Senate, Committee on Aeronautical and Space Sciences, *Documents on International Aspects of the Exploration and Use of Outer Space, 1954-1962*, Staff Report, 88th Congress, 1st Session (1963), pp. 202, 203.

COMPARISON OF LANDER SIZES



Lunar lander sizes under study in May 1962 as various groups were making determinations on the best way to achieve the lunar landing goal.

May 25

Robert C. Seamans, Jr., NASA's Associate Administrator, requested the Directors of the Office of Launch Vehicle Programs and the Office of Advanced Research Programs to bring together members of their staffs with other persons from NASA Headquarters to assess a wide variety of possible ways of accomplishing the lunar landing mission. This study was to supplement the one being done by the Ad Hoc Task Group for Manned Lunar Landing Study (Fleming Committee) but was to be separate from it. Bruce T. Lundin was appointed Chairman of the study group (Lundin Committee). The following guidelines were suggested :

- All possible approaches for accomplishing the manned lunar landing mission in the 1967-1970 period should be considered.
- Primary emphasis should be placed on the launch vehicle portion of the system: vehicle size and type, the use of rendezvous, etc.

- Nuclear-powered launch vehicles should not be considered for use in the early manned lunar landing missions.
- Advantages, disadvantages, and problems associated with each technique should be indicated and, based on these, a relative rating of the various methods. should be established.
- The time phasing and a rough order of magnitude cost should be indicated for each method considered.
- The study should be completed at about the same time as the one under way by the Ad Hoc Task Group on Manned Lunar Landing Study.

The Lundin Committee report was submitted June 10.

Memorandum, Associate Administrator to Directors, Launch Vehicle Programs and Advanced Research Programs, "Broad Study of Feasible Ways for Accomplishing Manned Lunar Landing Mission," May 25, 1961; Rosholt, *An Administrative History of NASA, 1958-1963*, p. 213.

May 31

STG submitted to NASA Headquarters recommendations on crew selection and training:

- There would be no need to select crews within the next 12 months, Pilots could be chosen as required from the astronaut group, permitting the prospective crewmen to be active in test flying until assigned to Apollo missions.
- Based on extrapolations from the Mercury program, STG expected that 12 months would be ample time for specialized training before a flight.
- A maximum of 18 astronauts in 1965 would be needed to fulfil the requirements of the flight schedule.
- All crew members would be experienced flight personnel; special engineering or scientific capabilities would be provided through crew indoctrination.

Letter, Robert R. Gilruth, Director, STG, to NASA Headquarters, Attn: Abe Silverstein, "Apollo Crew Selection and Training," May 31, 1961.

During the Month

The Marshall Space Flight Center began reevaluation of the Saturn C-2 configuration capability to support circumlunar missions. Results showed that a Saturn vehicle of even greater performance would be desirable.

Saturn Illustrated Chronology, p. 26.

During the Month

Basic concepts of the lunar orbit rendezvous plan were presented to the Lundin Committee by John C. Houbolt of Langley Research Center.

Bird, "Short History of the Development of the Lunar Orbit Rendezvous Plan at the Langley Research Center," p. 3.

June 1

NASA announced a change in the Saturn C-1 vehicle configuration. The first ten research and development flights would have two stages, instead of three, because of the changed second stage (S-IV) and, starting with the seventh flight vehicle, increased propellant capacity in the first stage (S-1) booster.

Senate Staff Report, *Manned Space Flight Program*, p. 199.

June 2

A meeting to discuss Project Apollo plans and programs was held at NASA Headquarters. Abe Silverstein, Warren J. North, John H. Disher, and George M. Low of NASA Headquarters and Robert R. Gilruth, Walter C. Williams, Maxime A. Faget, James A. Chamberlin, and Robert O. Piland of STG participated in the discussions. Six prime contract areas were defined: spacecraft (command center), onboard propulsion, lunar landing propulsion, launch vehicle (probably several prime contracts), tracking and communications network, and launch facilities and equipment. The prime contractor for the spacecraft would be responsible for the design, engineering, and fabrication of the spacecraft; for the integration of the onboard and lunar landing propulsion systems; and for the integration of the entire spacecraft system with the launch vehicle. In connection with the prime contract, STG would:

- Define details for specifications and justify choices
- Prepare a "scope of work" statement for release to industry by July 1
- Prepare spacecraft specifications for release by August 1
- Set up a contract evaluation team, qualified to evaluate the technical, management, design, engineering, and fabrication capabilities of the bidders.

In connection with other projects directly relating to the Apollo program, STG was to:

- Forward to Marshall Space Flight Center, via the Office of Space Flight Programs, the spacecraft systems part of a preliminary development plan for Saturn reentry tests
- Make recommendations on an advanced version of the Mercury capsule
- Designate a liaison member for the Lunar Sciences Subcommittee of the Space Sciences Steering Committee.

The Office of Space Flight Programs would arrange a meeting with the Office of Advanced Research Programs, STG, and Langley Research Center on the Atlas-Agena reentry tests and with the Office of

Advanced Research Programs, Office of Life Sciences Programs, STG, and Ames Research Center on the biomedical flight program.

Memorandum, Low, Assistant Director for Manned Space Flight Programs, to Director of Space Flight Programs, "Report of Meeting with Space Task Group on June 2, 1961," June 6, 1961.

June 5

The Flight Vehicles Integration Branch was organized within STG. Members included H. Kurt Strass, Robert L. O'Neal, and Charles H. Wilson. Maxime A. Faget, Chief, Flight Systems Division, also served as temporary Branch Chief. The Branch was to provide technical aid to STG in solving compatibility requirements for spacecraft and launch vehicles for manned flight missions.

Memorandum, Faget to Staff, STG, "Change in Organization of Flight Systems Division," June 5, 1961.

June 5

Saturn Launch Complex 34 at Cape Canaveral, Fla., was dedicated in a brief ceremony by NASA. The giant gantry, 310 feet high and weighing 2,800 tons, was the largest movable land structure in North America.

Aeronautical and Astronautical Events of 1961, p. 25.

June 7

A preliminary study of a fin-stabilized solid-fuel rocket booster, the Little Joe Senior, was completed by members of STG. The booster would be capable of propelling a full-size Apollo reentry spacecraft to velocities sufficient to match critical portions of the Saturn trajectory. The purpose was to provide a simple and fairly inexpensive means of determining, from flight tests, full-scale configuration concepts, systems hardware performance, and vehicle structural integrity. Of particular importance would be the flight testing of the Apollo spacecraft escape system under simulated maximum conditions. (On April 6, 1962, NASA submitted a Request for Proposal to bidders on the Little Joe Senior, by that time renamed Little Joe II.)

NASA Project Apollo Working Paper No. 1020, "A Preliminary Study of a Fin-Stabilized Solid-Fuel Rocket Booster for Use with the Apollo Spacecraft," June 7, 1961.

June 10

'The Lundin Committee completed its study of various vehicle systems for the manned lunar landing mission, as requested on May 25 by NASA associate Administrator Robert C. Seamans, Jr. The Committee had considered alternative methods of rendezvous: earth orbit, lunar orbit, a combination of

earth and lunar orbit, and lunar surface. Launch vehicles studied were the Saturn C-2 and C-3. The concept of a low- altitude earth orbit rendezvous using two or three C-3's was clearly preferred by the Committee. Reasons for this preference were the small number of launches and orbital operations required and the fact that the Saturn C- 3 was considered to be an efficient launch vehicle of great utility and future growth.

Lundin Committee, "A Survey of Various Vehicle Systems for the Manned Lunar Landing Mission," June 10, 1961.

June 16

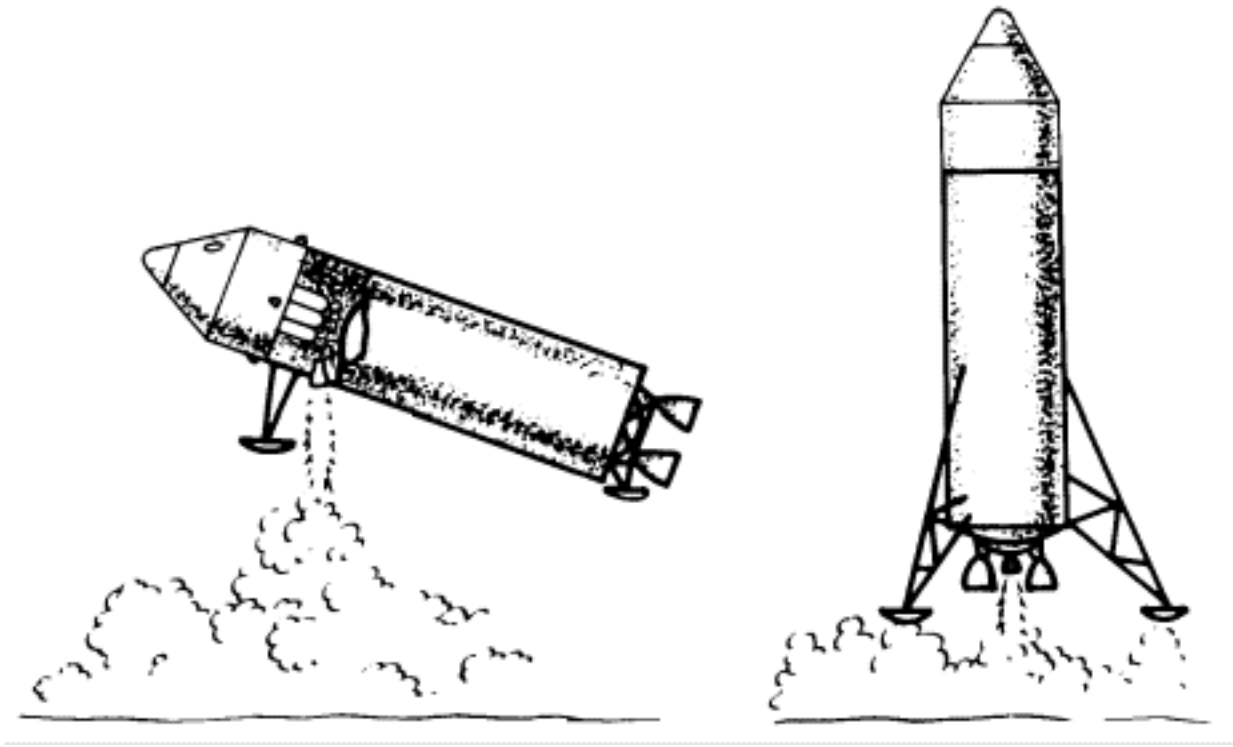
The Fleming Committee, which had been appointed on May 2, submitted its report to NASA associate Administrator Robert C. Seamans, Jr., on the feasibility of a manned lunar landing program. The Committee concluded that the lunar mission could be accomplished within the decade. Chief pacing items were the first stage of the launch vehicle and the facilities for testing and launching the booster. It also concluded that information on solar flare radiation and lunar surface characteristics should be obtained as soon as possible, since these factors would influence spacecraft design. Special mention was made of the need for a strong management organization.

Ad Hoc Task Group, *A Feasible Approach for an Early Manned Lunar Landing*, Part I, "Summary Report of Ad Hoc Task Group Study," June 16, 1961, pp. 95-96.

June 20

Robert C. Seamans, Jr., NASA Associate Administrator, notified the Directors of Launch Vehicle Program, Space Flight Programs, Advanced Research Programs, and Life Sciences Programs that Donald H. Heaton had been appointed Chairman of an Ad Hoc Task Group. It would establish program plans and supporting resources necessary to accomplish the manned lunar landing mission by the use of rendezvous techniques, using the Saturn C-3 launch vehicle, with a target date of 1967. Guidelines and operating methods were similar to those of the Fleming Committee. Members of the Task Group would be appointed from the Offices of Launch Vehicle Programs, Space Flight Program, Advanced Research Programs, and Life Sciences Programs. The work of the Group (Heaton Committee) would be reviewed weekly. The study was completed during August.

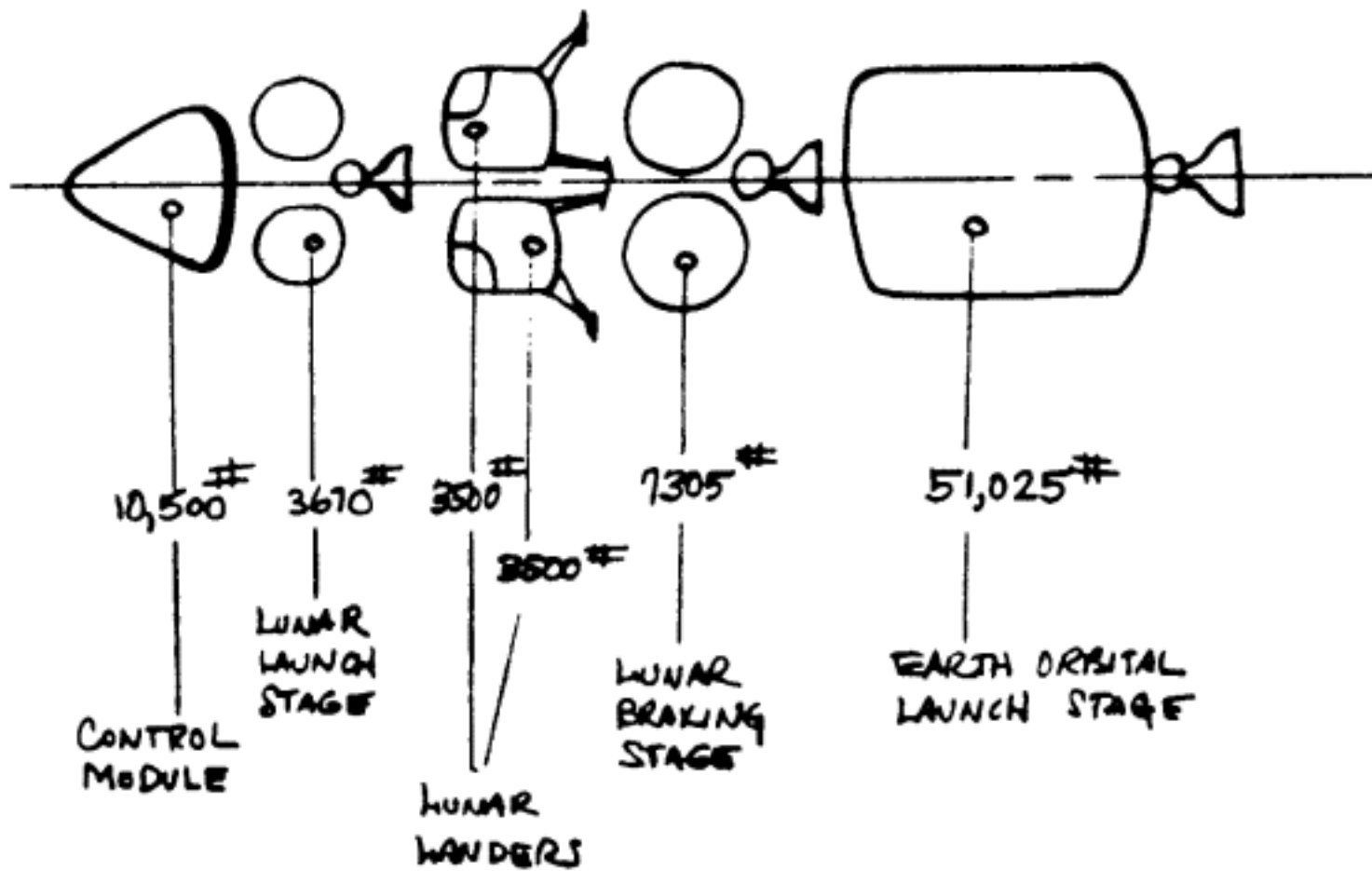
Memorandum, Seamans to Director, Launch Vehicle Programs, Director, Space Flight Programs, Director, Advanced Research Programs, and Acting Director, Life Sciences Programs, "Establishment of Ad Hoc Task Group for Manned Lunar Landing by Rendezvous Technique." June 20. 1961.



Two methods of landing techniques proposed for the direct ascent moon mission.

(C-3 LUNAR MISSION)

LUNAR MISSION - ONE VEHICLE FROM EARTH
LAUNCHED OUT OF COASTING ORBIT - THREE
MEN - RENDEZVOUS AT MOON - 79,500# TOTAL WT.



NASA-LANGLEY

Another John D. Bird engineering sketch shows the potential of the Saturn C-3 for a Lunar mission as visualised in June 1961.

June 23

NASA Associate Administrator Robert C. Seamans, Jr., requested Kurt H. Debus, Director of the NASA Launch Operations Directorate, and Maj. Gen. Leighton I. Davis, Commander of the Air Force Missile Test Center, to make a joint analysis of all major factors regarding the launch requirements, methods, and procedures needed in support of an early manned lunar landing. The schedules and early requirements were to be considered in two phases:

1. in line with the Fleming Report, a direct flight to the moon would be assumed, using the Saturn C-1 and C-3 launch vehicles in early support phases and liquid- or solid-fueled Nova launch vehicles for the lunar landing;
2. as a possible alternative or parallel program, orbital rendezvous operations using Saturn C-3 and liquid- fueled Nova.

The analysis should include recommendations on mutual NASA-DOD range responsibilities, authority, management structures, and other allied subjects. On June 30, Seamans notified Debus and Davis that the evaluation of tracking and command stations should not be included in the study. He stressed that the factors of immediate concern with regard to launch operations were those of launch site locations, land acquisition requirements, spacecraft and launch vehicle preparation facilities, vehicle launch facilities, and other facilities and requirements at the launch site. (Phase I of the Report was submitted on July 31.)

Memorandum, Seamans to Commander, AFMTC, and Director, LOD, MSFC, "National Space Program Range Facilities and Resources Planning," June 23, 1961; letter, Seamans to Gen. Davis and Dr. Debus, "National Space Program Range Facilities and Resources Planning," June 30, 1961.

June 23

NASA announced that the Saturn C-1 launch vehicle, which could place ten-ton payloads in earth orbit, would be operational in 1964.

Senate Staff Report, *Manned Space Flight Program*, p. 200.

June 23

NASA announced that further engineering design work on the Saturn C-2 configuration would be discontinued and that effort instead would be redirected toward clarification of the Saturn C-3 and Nova concepts. Investigations were specifically directed toward determining capabilities of the proposed C-3 configuration in supporting the Apollo mission.

Saturn Illustrated Chronology, pp. 31-32.

June 26

Maxime A. Faget, Paul E. Purser, and Charles J. Donlan of STG met with Arthur W. Vogeley, Clinton E. Brown, and Laurence K. Loftin, Jr., of Langley Research Center on a "lunar landing" paper. Faget's outline was to be used, with part of the information to be worked up by Vogeley.

Memorandum, Purser to Robert R. Gilruth, "Log for the Week of June 26, 1961."

During the Month

STG completed a detailed assessment of the results of the Project Apollo feasibility studies submitted by the three study contractors: the General Electric Company, Convair/Astronautics Division of the General Dynamics Corporation, and The Martin Company. (Their findings were reflected in the Statement of Work sent to prospective bidders on the spacecraft contract on July 28.)

"Apollo Spacecraft Chronology," p. 9.

During the Month

Members of Langley Research Center briefed the Heaton Committee on the lunar orbit rendezvous method of accomplishing the manned lunar landing mission.

Manned Lunar-Landing through use of Lunar-Orbit Rendezvous, p. 5.

Summer

Construction began at Langley Research Center of facilities specifically oriented toward the Apollo program, including a lunar landing simulator. Interview with Charles J. Donlan, Langley Research Center, June 20, 1966.

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July 6

At NASA Headquarters, the first meeting was held of the Manned Lunar Landing Coordination Group, attended by NASA Associate Administrator Robert C. Seamans, Jr., Ira H. Abbott, Don R. Ostrander, Charles H. Roadman, William A. Fleming, DeMarquis D. Wyatt (part-time), and George M. Low (in place of Abe Silverstein). This Headquarters Group, appointed by Seamans, was to coordinate problems that jointly affected several NASA Offices, during the interim period while the manned space flight organization was being formed. Members of the steering group included NASA program directors, with participation by Wernher von Braun of Marshall Space Flight Center, Robert R. Gilruth of STG, and Wyatt and Abraham Hyatt of NASA Headquarters, as required. Fleming acted as Secretary of the Group. A list of decisions and actions required to implement an accelerated lunar landing program was drawn up as a tentative agenda for the next meeting:

- Begin Nova systems integration studies and develop the general arrangement of second and third stages. The studies should include spacecraft propulsion stages and spacecraft.
- Begin Saturn C-3 systems integration studies.
- Begin developing Nova and C-3 first-stage specifications in preparation to letting contracts
- Continue Launch Operations Directorate-Air Force Missile Test Center studies of Nova and C-3 launch sites at Atlantic Missile Range (AMR).
- Take steps to bring the contractor aboard as soon as possible for Nova and C-3 launch facility and test stand designs.

- Accelerate F-1 engine funding to provide adequate production engines for the Nova and C-3.
- Examine the Marshall Space Flight Center (MSFC) proposal for static test facilities for large vehicle stages with a view toward beginning detailed site examination.
- Accelerate funding of the J-2 engine to provide acceptance test stands.
- Determine the necessity for a one-million-pound-thrust liquid- hydrogen - liquid-oxygen engine.
- Begin design studies on spacecraft propulsion systems and develop specifications. Define management responsibilities.
- Begin preparations for letting the contract for a spacecraft operations facility at AMR.
- Determine the relationships and responsibilities of MSFC and STG on guidance and control.

Memoranda, Low, Assistant Director for Manned Space Flight Programs, to Director of Space Flight Programs, "Meeting of Manned Lunar Landing Coordination Group," July 8, 1961; Ostrander, Director, Launch Vehicle Programs, to Staff, "Manned Lunar Landing Program," July 10, 1961.

July 7

The NASA Administrator and the Secretary of Defense concluded an agreement to study development of large launch vehicles for the national space program. For this purpose, the DOD-NASA Large Launch Vehicle Planning Group was created, reporting to the Associate Administrator of NASA and to the Assistant Secretary of Defense (Deputy Director of Defense Research and Engineering).

Memorandum, Associate Administrator to the Administrator, "Planning of a DOD - NASA Program for Development of Large Launch Vehicles," July 7, 1961; letters, James E. Webb to Robert S. McNamara, July 7, 1961; McNamara to Webb, July 7, 1961.

July 12

Jet Propulsion Laboratory announced that construction was under way on the first large space simulator in the United States capable of testing full-scale spacecraft of the Ranger and Mariner classes. Three primary space effects could be simulated: solar radiation, cold space heat sink, and a high vacuum equivalent to about one part in a billion of the atmospheric pressure at sea level.

Aeronautical and Astronautical Events of 1961, p. 32.

July 18-26

A NASA-Industry Apollo Technical Conference was held in Washington, D.C., for representatives of about 300 potential Project Apollo contractors. Scientists from NASA, the General Electric Company, The Martin Company, and General Dynamics/Astronautics presented the results of studies on Apollo requirements. Within the next four to six weeks NASA was expected to draw up the final details and specifications for the Apollo spacecraft.

Wall Street Journal, July 18, 1961; *Aeronautical and Astronautical Events of 1961*, p. 33; "Apollo Spacecraft Chronology," p. 10.

July 20

The Large Launch Vehicle Planning Group, established on July 7, 1961, began its formal existence with seven DOD and seven NASA members and alternates. The members of the Group included : Nicholas E. Golovin, Director of the Group, Technical Assistant to the Associate Administrator of NASA; Lawrence L. Kavanau, Deputy Director of the Group, Special Assistant (Space) in the Office of the Director of Defense Research and Engineering; Warren Amster and Edward J. Barlow, Aerospace Corporation; Aleck C. Bond, STG; Lt. Col. David L. Garter and Col. Otto J. Glasser, Air Force Systems Command; Col. Matthew R. Collins, Jr., U.S. Army, Office of Chief of Ordnance; Eldon W. Hall, Harvey Hall, and Milton W. Rosen, NASA Office of Launch Vehicle Programs; Wilson B. Schramm and Francis L. Williams, Marshall Space Flight Center; Rear Adm. Levering Smith, U.S. Navy, Special Projects Office ; Capt. Lewis J. Stecher, Jr., U.S. Navy, Office of the Chief of Naval Operations; H. J. Weigand, Headquarters, U.S. Air Force; Kurt R. Stehling, NASA Office of Program Planning and Evaluation; and William W. Wolman, NASA Office of Programs.

The Group, frequently called the Golovin Committee, was to concern itself only with large launch vehicle systems, including propulsion elements, guidance and control, and instrumentation. It was to suggest launch vehicle configurations and operational procedures, taking into consideration not only the manned lunar landing program but other anticipated needs of DOD and NASA. Report of DOD-NASA Large Launch Vehicle Planning Group, Vol. 1, 1961.

July 21

Liberty Bell 7, manned by Astronaut Virgil I. Grissom, was launched successfully from the Atlantic Missile Range. The Mercury capsule, boosted by a Redstone rocket, reached a peak altitude of 118.26 miles and a speed of 5,168 miles per hour. After a flight of 15 minutes and 37 seconds, the landing was made 302 miles downrange from the launch site. The spacecraft was lost during recovery operations, but Astronaut Grissom was rescued and was reported in excellent condition.

Swenson *et al.*, *This New Ocean*, pp. 370-377, 640-641.

July 24

Changes in Saturn launch vehicle configurations were announced :

- C-1:
Stages S-I (1.5 million pounds of thrust) and S-IV
- C-2:
Stages S-I, S-II, and S-IV

C-3:
Stages S-IB (3 million pounds of thrust), S-II, and S-IV.

Senate Staff Report, Manned Space Flight Program, p. 200.

July 24

NASA issued a letter contract to the Astro-Electronic Division of Radio Corporation of America to develop and fabricate the high-resolution television system (including associated communication and electronic equipment) for the Ranger program.

Sixth Semiannual Report of the National Aeronautics and Space Administration, July 1, 1961, through December 31, 1961 (1962), p. 66.

July 28

NASA invited 12 companies to submit prime contractor proposals for the Apollo spacecraft by October 9: The Boeing Airplane Company, Chance Vought Corporation, Douglas Aircraft Company, General Dynamics/Convair, the General Electric Company, Goodyear Aircraft Corporation, Grumman Aircraft Engineering Corporation, Lockheed Aircraft Corporation, McDonnell Aircraft Corporation, The Martin Company, North American Aviation, Inc., and Republic Aviation Corporation.

In the Statement of Work sent to each prospective bidder, three phases of the Apollo program were described:

Phase A:

Manned low-altitude earth orbital flights of up to two weeks' duration and unmanned reentry flights from superorbital velocities. The spacecraft designed for these missions should be capable of development for the lunar landing and return. The objectives of Phase A were to qualify the spacecraft systems and features for the lunar landing mission within the constraints of the earth orbital environment, to qualify the heat protection and other systems for the lunar mission through reentry tests from superorbital velocities, to study the physiological and psychological reactions and capabilities of human beings under extended periods in the space environment, to develop flight and ground operational techniques and equipment for space flights of extended duration, and to conduct experimental investigations to acquire information for the lunar mission. The Saturn C-1 would be used for Phase A missions.

Phase B:

Circumlunar, lunar orbital, and parabolic reentry test flights employing the Saturn C-3 launch vehicle for furthering the development of the spacecraft and operational techniques and for lunar reconnaissance.

Phase C:

Manned lunar landing and return missions using either the Nova class or Saturn C-3 launch

vehicles and using rendezvous techniques for the purpose of lunar observation and exploration.

The contractor was to design and manufacture the command module, service module, and spacecraft adapter with associated ground support equipment, excluding the navigation and guidance system, research and development instrumentation, and scientific instrumentation; to design and manufacture the "test" spacecraft for use with Saturn C-1 research and development launch vehicles; to integrate the spacecraft modules and to integrate these modules with their ground support equipment and ensure compatibility of spacecraft with launch vehicle and with the ground operational support system; and to design and manufacture spacecraft mockups.

The contractor was to prepare the spacecraft for flight, man the systems monitoring positions in the ground operational support system, and support the operation of the overall space vehicle.

STG had prepared the Statement of Work, using both contractor and in-house studies. Included in the Statement of Work was a description of the major command and service module systems.

Guidance and control system

Navigation and guidance subsystem components:

- Stable platform
- Space sextant
- Radar altimeter
- Secondary inertial elements
- Computer
- Periscope
- Sun trackers
- Associated electronics
- Displays and controls
- Cabling

Stabilization and control subsystem to provide:

- Flight-path control during the thrusting period of atmospheric abort and stability augmentation after launch escape system separation
- Orientation, attitude control, and reentry stabilization and control during extra-atmospheric abort
- Stabilization of the spacecraft plus the final stage of the launch vehicle while in a parking orbit
- Stabilization and control during translunar and transearth midcourse flight
- Rendezvous and docking with the space laboratory module
- Attitude control for accomplishing landings and takeoffs from the moon and for entering and departing from lunar orbits
- Control requirements for reentry guidance
- Stabilization and control of the command module flight direction in the landing configuration, as well as the landing system suspension members

Vernier propulsion system

The system would be included in the service module to provide longitudinal velocity control not supplied by the reaction control system, mission propulsion system, or lunar landing module; and to furnish effective thrust-vector control during operation of the mission propulsion system. It would be pressure-fed, using storable hypergolic bipropellants.

Mission propulsion system

Representing the major portion of propulsion for translunar abort, lunar orbit injection and rejection, and velocity increment for lunar launch, the system would comprise a number of identical solid-propellant rocket motors and would be included in the service module.

Reaction control system

The system would provide attitude control, stabilization, ullage for the vernier propulsion system, and minor velocity corrections. For both the command and service modules, the system would be pulse-modulated, pressure-fed, and would use storable hypergolic fuel identical with that in the vernier propulsion system. The fuel tanks would be the positive expulsion type.

Launch escape system

During failure or imminent failure of the launch vehicle during all atmospheric mission phases, the system would separate the command module from the launch vehicle. The basic propulsion system would be a solid-fuel rocket motor with "step" or regressive burning characteristics.

Earth landing system

The system would consist of a ribbon drogue parachute and a cluster of three simultaneously deployed landing parachutes, sized so that satisfactory operation of any two of the three would satisfy the vertical velocity requirement. The command module would hang in a canted position

from the parachute risers and be oriented through roll control to favor impact attenuation.

Structural system

In addition to fundamental load-carrying structures, the command and service modules would carry meteoroid protection, radiation protection inherent in the structure, and passive heat protection systems.

Crew systems

Included were:

- Three couches, the center one stowable
- Support and restraint systems at each duty station
- Shock mitigation devices for individual crew support and restraint systems
- Pressure suits for each crewman
- Sleeping area
- Sanitation area

Environmental control system

To provide a shirtsleeve environment in the command module, the system would consist of:

- Cabin atmosphere - an oxygen-nitrogen mixture stabilized at 7.0 psia
- Removal of carbon dioxide by lithium hydroxide
- Removal of noxious gases by activated charcoal and a catalytic burner
- Heat-exchanger water-separation system for control of temperature and humidity
- Potable water from the fuel cells
- Controls for pressure, humidity, and temperature

Electrical power system

The system would be composed of nonregenerative hydrogen-oxygen Bacon- type fuel-cell batteries carried, with their fuel supply, in the service module; silver-zinc primary batteries required during reentry and postlanding carried, with their associated fuel, distribution, and control equipment, in the command module.

Communication and instrumentation system

Communication subsystems:

- Deep-space communication
- Telemetry
- VHF transmitter and receiver
- Intercommunication system
- Near-field transceiver
- Television
- C-band transponder
- Altimeter and rendezvous radar
- Minitrack beacon
- HF/VHF recovery subsystem
- Antennas

Instrumentation subsystem:

- Sensors
- Data disposition (telemetry and onboard recorders)
- Subsystem calibration
- Auxiliary instrumentation (clock, cameras, telescope)

Scientific equipment

The equipment was unspecified but would be fitted into ten cubic feet and weigh 250 pounds.

In addition to the description of the major command and service module systems, the Statement of Work outlined the general concepts of the lunar landing module and space laboratory module.

Lunar landing module

The basic systems comprised :

Lunar touchdown system to arrest impact, support the spacecraft during its period on the moon,

and provide a launching base

Guidance and control, provided by the command and service modules

Main propulsion system, for translunar velocity control and the gross velocity decrement required for lunar landing, using liquid-hydrogen - liquid-oxygen propellant

Terminal propulsion system, to provide propulsion and attitude reaction control to perform the terminal descent maneuver, including hovering and translation

Structural system, to meet the same requirements as specified for the command and service modules

Space laboratory module

The module would be used in earth orbital flights for special experiments. It would provide its own power supply, environmental control system, etc., without demand on the command and service module systems and could support two of the three Apollo crewmen except for their food and water.

NASA, *Project Apollo Spacecraft Development Statement of Work, Phase A* (STG, July 28, 1961), pp. 1-1 to 1-3, A-2 to A-21; *New York Times*, July 29, 1961.

July 28

NASA Associate Administrator Robert C. Seamans, Jr., appointed members to the Source Evaluation Board to evaluate contractors' proposals for the Apollo spacecraft. Walter C. Williams of STG served as Chairman, and members included Robert O. Piland, Wesley L. Hjernevik, Maxime A. Faget, James A. Chamberlin, Charles W. Mathews, and Dave W. Lang, all of STG; George M. Low, Brooks C. Preacher, and James T. Koppenhaver (nonvoting member) from NASA Headquarters; and Oswald H. Lange from Marshall Space Flight Center. On November 2, Faget became the Chairman, Kenneth S. Kleinknecht was added as a member, and Williams was relieved from his assignment.

Memoranda, Robert R. Gilruth to Member, Source Evaluation Board, "Instructions for Members of the Source Evaluation Board for Evaluation of Proposals for Project Apollo Spacecraft, RFP No. 9-150," September 1, 1961; Seamans to STG, "Redesignation of Source Evaluation Board Members," November 2, 1961.

July 31

Phase I of a joint NASA-DOD report on facilities and resources required at launch sites to support the manned lunar landing program was submitted to Associate Administrator Robert C. Seamans, Jr., by Kurt H. Debus, Director, Launch Operations Directorate, and Maj. Gen. Leighton I. Davis, Commander of the Air Force Missile Test Center. The report, requested by Seamans on June 23, was based on the

use of Nova- class launch vehicles for the manned lunar landing in a direct ascent mode, with the Saturn C-3 in supporting missions. Eight launch sites were considered: Cape Canaveral (on-shore); Cape Canaveral (off- shore); Mayaguana Island (Atlantic Missile Range downrange); Cumberland Island, Ga.; Brownsville, Tex.; White Sands Missile Range, N. Mex.; Christmas Island, Pacific Ocean; and South Point, Hawaii. On the basis of minimum cost and use of existing national resources, and taking into consideration the stringent time schedule, White Sands Missile Range and Cape Canaveral (on-shore) were favored. White Sands presented serious limitations on launch azimuths because of first-stage impact hazards on populated areas.

NASA-DOD, *Phase I Report: Joint Report on Facilities and Resources Required at Launch Site to Support NASA Manned Lunar Landing*, July 31, 1961.

During the Month

Langley Research Center simulated spacecraft flights at speeds of 8,200 to 8,700 feet per second in approaching the moon's surface. With instruments preset to miss the moon's surface by 40 to 80 miles, pilots with control of thrust and torques about all three axes of the craft learned to establish orbits 10 to 90 miles above the surface, using a graph of vehicle rate of descent and circumferential velocity, an altimeter, and vehicle attitude and rate meters, as reported by Manuel J. Queijo and Donald R. Riley of Langley.

Aeronautical and Astronautical Events of 1961, p. 36.

During the Month

James A. Chamberlin and James T. Rose of STG proposed adapting the improved Mercury spacecraft to a 35,000-pound payload, including a 5,000-pound "lunar lander." This payload would be launched by a Saturn C-3 in the lunar orbit rendezvous mode. The proposal was in direct competition with the Apollo proposals that favored direct landing on the moon and involved a 150,000-pound payload launched by a Nova-class vehicle with approximately 12 million pounds of thrust.

Interviews with Chamberlin, Houston, Tex., June 9, 1966; Rose, St. Louis, Mo., April 13, 1966.

During the Month

Ralph Ragan of the MIT Instrumentation Laboratory, former director of the Polaris guidance and navigation program, in cooperation with Milton B. Trageser of the Laboratory and with Robert O. Piland, Robert C. Seamans, Jr., and Robert G. Chilton, all of NASA, had completed a study of what had been done on the Polaris program in concept and design of a guidance and navigation system and the documentation necessary for putting such a system into production on an extremely tight schedule. Using this study, the group worked out a rough schedule for a similar program on Apollo.

Interview with Ralph Ragan, Instrumentation Laboratory, MIT, April 27, 1966.

July-September

The MIT Instrumentation Laboratory and NASA completed the work statements for the Laboratory's program on the Apollo guidance and navigation system and the request for quotation for industrial support was prepared.

Interview with Ralph Ragan, Instrumentation Laboratory, MIT, April 27, 1966.

August 2

NASA Headquarters announced that it was making a worldwide study of possible launching sites for lunar spacecraft. The size, power, noise, and possible hazards of Saturn or Nova rockets would require greater isolation for public safety than currently available at NASA launch sites.

Washington Post, August 3, 1961.

August 6

The Soviet Union successfully launched *Vostok II* into orbit with Gherman S. Titov as pilot. The spacecraft, which weighed 10,430 pounds, carried life-support equipment, radio and television for monitoring the condition of the cosmonaut, tape recorder, telemetry system, biological experiments, and automatic and manual control equipment. After 17.5 orbits, the spacecraft reentered on August 7 and landed safely. Titov made a separate parachute landing in an ejector couch.

New York Times, August 7 and 8, 1961; *Instruments and Spacecraft*, p. 194.

August 7

STG appointed members to the Technical Subcommittee and to the Technical Assessment Panels for evaluation of industry proposals for the development of the Apollo spacecraft.

Memoranda, Wesley L. Hjernevik for Walter C. Williams to Member, Technical Subcommittee, "Instruction for Members of the Technical Subcommittee for the Evaluation of Contractors' Proposals for Project Apollo Spacecraft RFP-9-150," August 7, 1961; Hjernevik for Williams to Member, Technical Assessment Panel, "Instruction for Members of the Technical Assessment Panels for the Evaluation of Contractors Proposals for Project Apollo Spacecraft RFP-9-150," August 7, 1961.

August 9

NASA selected the Instrumentation Laboratory of MIT to develop the guidance and navigation system for the Apollo spacecraft. This first major Apollo contract had a long lead-time, was basic to the overall Apollo mission, and would be directed by STG.

Memorandum, William W. Petynia to Associate Director, STG, "Visit to MIT Instrumentation laboratory on September 12-13, 1961, regarding Apollo Navigation and Guidance Contract," September 21, 1961.

August 14

STG requested that a program be undertaken by the U.S. Navy Air Crew Equipment Laboratory, Philadelphia, Penna., to validate the atmospheric composition requirement for the Apollo spacecraft. On November 7, the original experimental design was altered by the Manned Spacecraft Center (MSC). The new objectives were:

- Establish the required preoxygenation time for a rapid decompression (80 seconds) from sea level to 35,000 feet.
- Discover the time needed for equilibrium (partial denitrogenation) at the proposed cabin atmosphere for protection in case of rapid decompression to 35,000 feet.
- Investigate the potential hazard associated with an early mission decompression - i.e., before the equilibrium time was reached, preceded by the determined preoxygenation period.
- Conduct any additional tests suggested by the results of the foregoing experiments.

Letter, Robert R. Gilruth, Director, MSC, to Director, Air Crew Equipment Laboratory, November 7, 1961.

August 14-15

STG held a pre-proposal briefing at Langley Field, Va., to answer bidders' questions pertaining to the Request for Proposal for the development of the Apollo spacecraft.

"Apollo Spacecraft Chronology," p. 11.

August 16

STG appointed members to the Business Subcommittee and to the Business Assessment Panels for evaluation of industry proposals for the development of the Apollo spacecraft.

Memoranda, Walter C. Williams to Member, Business Subcommittee, "Instructions for Members of the Business Subcommittee for Evaluation of Proposals for Project Apollo Spacecraft, RFP No. 9-150," August 16, 1961; Williams to Member, Business Assessment Panels, "Instructions for Members of the Business Assessment Panels for Evaluation of Proposals for the Project Apollo Spacecraft, RFP No. 9-

150," undated.

August 23

Ranger I, a test version of the spacecraft which would attempt an unmanned crash landing on the moon, was launched from the Atlantic Missile Range by an Atlas-Agena B booster. The 675-pound spacecraft did not attain the scheduled extremely elongated orbit because of the misfiring of the Agena B rocket. Although the spacecraft systems were tested successfully, only part of the eight project experiments could be carried out. Ranger I reentered on August 29 after 111 orbits.

New York Times, August 24, 1961; *Aeronautical and Astronautical Events of 1961*, pp. 41, 42, 84.

August 23

The Large Launch Vehicle Planning Group (Golovin Committee) notified the Marshall Space Flight Center (MSFC), Langley Research Center, and the Jet Propulsion Laboratory (JPL) that the Group was planning to undertake a comparative evaluation of three types of rendezvous operations and direct flight for manned lunar landing. Rendezvous methods were earth orbit, lunar orbit, and lunar surface. MSFC was requested to study earth orbit rendezvous, Langley to study lunar orbit rendezvous, and JPL to study lunar surface rendezvous. The NASA Office of Launch Vehicle Programs would provide similar information on direct ascent. Emphasis was to be placed on developmental problems, exclusive of vehicle design which would be handled separately.

In each case, environmental conditions peculiar to the particular mode of rendezvous, and their effects on equipment design, were to be considered so that the problems characteristic of the different rendezvous modes could be separated and compared as quantitatively as possible. Examples of problem areas were automatic versus manual operation, mission profile, and lunar surface conditions. All rendezvous modes would assume that the reentry capsule(s) should be capable of supporting three men and weigh within the range specified by STG (about 8,500 pounds).

The preliminary results of the study were to be ready in 30 days.

TWX from Harvey Hall, NASA Coordinator, NASA-DOD Large Launch Vehicle Planning Group, to MSFC, Langley Research Center, and JPL, August 23, 1961.

August 24

Expanded facilities in the Cape Canaveral area would be the site for the launch of manned lunar flights and other missions requiring the use of Saturn and Nova vehicles, NASA announced. The site of the new facilities, north and west of the Air Force Missile Test Center, had been chosen after months of NASA-DOD surveys of proposed launch areas.

Washington Post, August 25, 1961.

August 29

NASA announced that planned Ranger launchings would be increased from five to nine. These additional spacecraft would be equipped with six high-resolution television cameras. They would be programmed to begin operating at about 800 miles above the lunar surface and continue until moments before the spacecraft crash-landed. The final pictures would record features no more than eight inches across. About 1,600 photographs were expected from each spacecraft, which would no longer carry previously planned instrumented capsules. The objective of these spacecraft now was to provide information on the lunar surface in support of the manned lunar landing mission.

Sixth NASA Semiannual Report, p. 67.

August 31

C. Stark Draper, Director of the MIT Instrumentation Laboratory, at a meeting with NASA Administrator James E. Webb, Deputy Administrator Hugh L. Dryden, and Associate Administrator Robert C. Seamans, Jr., at NASA Headquarters proposed that at least one of the Apollo astronauts should be a scientifically trained individual since it would be easier to train a scientist to perform a pilot's function than vice versa. (In a letter to Seamans on November 7, Draper further proposed that he be that individual.)

Ralph Ragan and David G. Hoag, personal notes of meeting, August 31, 1961 ; letter, Draper to Seamans, November 7, 1961.

During the Month

The Ad Hoc Task Group for Study of Manned Lunar Landing by Rendezvous Techniques, Donald H. Heaton, Chairman, reported its conclusions: rendezvous offered the earliest possibility for a successful lunar landing, the proposed Saturn C-4 configuration should offer a higher probability of an earlier successful manned lunar landing than the C-3, the rendezvous technique recommended involved rendezvous and docking in earth orbit of a propulsion unit and a manned spacecraft, the cost of the total program through first lunar landing by rendezvous was significantly less than by direct ascent.

Summary report of Ad Hoc Task Group Study, "Earth Orbital Rendezvous for an Early Manned Lunar Landing," Part I, August 1961.

During the Month

John C. Houbolt of Langley Research Center made a presentation to STG on rendezvous and the lunar orbit rendezvous plan. At this time James A. Chamberlin of STG requested copies of all of Houbolt's

material because of the pertinence of this work to the Mercury Mark II program and other programs then under consideration.

Bird, "Short History of the Development of the Lunar Orbit Rendezvous Plan at the Langley Research Center," p. 3.

During the Month

The deep-space tracking station at Hartebeesthoek, South Africa, was completed. Dedication took place on September 8. NASA thus gained the capacity for continuous line-of-sight communication with lunar and interplanetary probes despite the earth's rotation. The other deep-space tracking stations were at Goldstone, Calif., and Woomera, Australia.

Sixth NASA Semiannual Report, p. 76; *Aeronautical and Astronautical Events of 1961*, p. 45.

During the Month

The Jet Propulsion Laboratory selected the Blaw Knox Company of Pittsburgh, Penna., for second-phase feasibility and design studies of an antenna in the 200-to 250-foot diameter class. The first of these antennas, which were to be used in acquiring data from advanced lunar and planetary exploration programs, would be operational at Goldstone, Calif., by early 1965.

Sixth NASA Semiannual Report, p. 76.

September 7

NASA announced that the government-owned Michoud Ordnance Plant near New Orleans, La., would be the site for fabrication and assembly of the Saturn C-3 first stage as well as larger vehicles.

St. Louis Post-Dispatch, September 7, 1961.

September 11

NASA selected NAA to develop the second stage (S-II) for the advanced Saturn launch vehicle. The cost, including development of at least ten vehicles, would total about \$140 million. The S-II configuration provided for four J-2 liquid-oxygen - liquid-hydrogen engines, each delivering 200,000 pounds of thrust.

Wall Street Journal, September 12, 1961.

September 12-13

Representatives of STG and NASA Headquarters visited the Instrumentation Laboratory of MIT to discuss the contract awarded to the Laboratory on August 9 and progress in the design and development of the Apollo spacecraft navigation and guidance system. They mutually decided that a draft of the final contract should be completed for review at Instrumentation Laboratory by October 2 and the contract resolved by October 9. Revisions were to be made in the Statement of Work to define more clearly details of the contract. Milton B. Trageser of the Laboratory, in the first month's technical progress report, gave a brief description of the first approach to the navigation and guidance equipment and the arrangement of the equipment within the spacecraft. He also presented the phases of the lunar flight and the navigation and guidance functions or tasks to be performed. Other matters discussed were a space sextant and making visual observations of landmarks through cloud cover.

Memorandum, William W. Petynia to Associate Director, STG, September 21, 1961.

September 13

Mercury-Atlas 4, carrying an astronaut simulator, was launched from the Atlantic Missile Range in the first earth orbital test of the Mercury spacecraft. After one orbit, the spacecraft reentered and was recovered safely. With minor deviations, the flight was highly successful.

Grimwood, *Project Mercury: A Chronology*, pp. 148-149.

September 14

In a memorandum to the Large Launch Vehicle Planning Group (LLVPG) staff, Harvey Hall of NASA described the studies being done by the Centers on rendezvous modes for accomplishing a manned lunar landing. These studies had been requested from Langley Research Center, Marshall Space Flight Center, and the Jet Propulsion Laboratory on August 23. STG was preparing separate documentation on the lunar orbit rendezvous mode. An LLVPG team to undertake a comparative evaluation of rendezvous and direct ascent techniques had been set up. Members of the team included Hall and Norman Rafel of NASA and H. Braham and L. M. Weeks of Aerospace Corporation.

The evaluation would consider:

- Effect of total flight time on specifications and reliability of equipment and on personnel.
- Effect of vehicle system reliability in each case, including the number of engine starts and restarts.
- Dependence on data, data-rate, and distance from ground station for control of assembly and refueling operations
- Launch and injection windows
- Effect of differences in the total weight propelled to earth escape velocity
- Relative merits of lunar gravity and of a lunar base in general versus an orbital station for rendezvous and assembly purposes.

Reliability estimates on vehicles would be based on LLVPG data; estimates on equipment would rely on experience with similar types in known applications.

Memorandum, Hall to Large Launch Vehicle Planning Group Staff, "Comparison of Mission Alternatives (Rendezvous versus Direct Flight)," September 14, 1961.

September 17

NASA invited 36 companies to bid on a contract to produce the first stage of the advanced Saturn launch vehicle. Representatives of interested companies would attend a pre-proposal conference in New Orleans, La., on September 26. Bids were to be submitted by October 16 and NASA would then select the contractor, probably in November.

Wall Street Journal, September 18, 1961.

September 19

NASA announced that a site near Houston, Tex., had been selected for the manned space flight research center which would design, develop, evaluate, and test Apollo spacecraft in addition to training the astronauts for lunar flights and other space missions. The laboratory would be the command center for the manned lunar landing mission and subsequent space flight missions. Selection had followed a nationwide study by NASA of prospective sites.

Washington Post, September 20, 1961.

September 24

A major reorganization of NASA Headquarters was announced by Administrator James E. Webb. Four new program offices were to be formed, effective November 1: the Office of Advanced Research and Technology, Ira H. Abbott, Director; the Office of Space Sciences, Homer E. Newell, Director; the Office of Manned Space Flight, D. Brainerd Holmes, Director; and the Office of Applications, directorship vacant. Holmes' appointment had been announced on September 20. He had been General Manager of the Major Defense Systems Division of the Radio Corporation of America. The new Directors would report to Robert C. Seamans, Jr., NASA's Associate Administrator.

At the same time, Robert R. Gilruth was named Director of the Manned Spacecraft Center to be located in Houston, Tex. The Directors of NASA's nine field centers would, like the newly appointed program Directors, report to Seamans.

Washington Post, September 24, 1961; *Washington Daily News*, September 21, 1961.

During the Month

Richard H. Battin published MIT Instrumentation Laboratory Report R-341, "A Statistical Optimizing Navigation Procedure for Space Flight," describing the concepts by which Apollo navigation equipment could make accurate computations of position and velocity with an onboard computer of reasonable size.

Battin, *Astronautical Guidance* (1964).

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October 3

The Charter of the MSFC-STG Space Vehicle Board, prepared jointly by Marshall Space Flight Center (MSFC) and STG, was approved at the first meeting of the Board at NASA Headquarters. The purpose of the Space Vehicle Board was to assure complete coordination and cooperation between all levels of the MSFC and STG management for the NASA manned space flight programs in which both Centers had responsibilities. Members of the Board were the Directors of MSFC and STG (Wernher von Braun and Robert R. Gilruth), the Deputy Director for Research and Development, MSFC (Eberhard F. M. Rees), and the STG Associate Director (Walter C. Williams). The Board was responsible for:

- Management of the SFC-STG Apollo-Saturn program.
- Resolution of all space vehicle problems, such as design systems, research and development tests, planning, schedules, and operations.
- Approval of mission objectives.
- Direction of the respective organizational elements in the conduct of the MSFC-STG Apollo-Saturn program, including approval of the Sub- Board and of the Coordination Panels.
- Formation of the Advanced Program Coordination Board consisting of top personnel from MSFC and STG. This Board would consider policy and program guidelines.

A Sub-Board would comprise the Director, Saturn Systems Office, MSFC (H. H. Koelle), the Apollo Project Manager, STG (Robert O. Piland), the Board Secretary, and alternate Board Secretary.

The Sub-Board would :

- Resolve space-vehicle coordination and integration problems and assign these to the Coordination Panels, if required.
- Prepare briefs in problem areas not resolved by the Board or Sub- Board.
- Act as a technical advisory group to the Board.
- Channel the decisions of the Board through the respective organizational elements of MSFC or STG for proper action.
- Ensure that the Saturn-Apollo Coordination Panels were working adequately and within the scope of their charters.
- Recommend to the Board modifications of the Panels.
- Define or resolve systems or integration problems of the Saturn launch vehicle and the Apollo spacecraft.
- Define mission objectives of the Saturn-Apollo space vehicle.
- Analyze and report progress of the Saturn-Apollo space vehicle.
- Initiate and guide studies for the selection of optimum Saturn- Apollo space vehicle systems.
- Define and establish reliability criteria.
- Establish and document flight safety philosophy.

The Secretariat set up under the Charter was to be responsible for the orderly conduct of business and meetings.

Four Saturn-Apollo Coordination Panels were established to make available the technical competence of MSFC and STG for the solution of interrelated problems of the launch vehicle and the spacecraft. The four included the Launch Operations, Mechanical Design, Electrical and Electronics Design, and Flight Mechanics, Dynamics, and Control Coordination Panels. Although these Panels were designated as new Panels, the members selected by STG and MSFC represented key technical personnel who had been included in the Mercury-Redstone Panels, the Mercury-Atlas Program Panels, the Apollo Technical Liaison Groups, and the Saturn working groups. The Charter was signed by von Braun and Gilruth. Charter of the MSFC-STG Space Vehicle Board, October 3, 1961.

October 3

The MSFC-STG Space Vehicle Board at NASA Headquarters discussed the S- IVB stage, which would be modified by the Douglas Aircraft Company to replace the six LR-115 engines with a single J-2 engine. Funds of \$500,000 were allocated for this study to be completed in March 1962. The status of orbital launch operations studies at Marshall Space Flight Center (MSFC) were reviewed and the Board agreed that an ad hoc study group should be formed to consider such operations and the S-IVB as the orbital launch vehicle. Other matters discussed were the mission plans for SA-5 through SA-10, a review of the Apollo flight program schedule, planned MSFC participation in the Dyna-Soar program, the agenda for the first meeting of the Advanced Program Coordination Board, and joint MSFC-STG study of post-Apollo programs.

Minutes, Marshall Space Flight Center-Manned Spacecraft Center Space Vehicle Board Meeting No. 1, November 7, 1961; Senate Staff Report, *Manned Space Flight Program*, p. 202.

October 4

Representatives of STG visited the Instrumentation Laboratory of MIT for the second monthly progress report meeting on the Apollo spacecraft guidance and navigation contract. A number of technical topics were presented by Laboratory speakers: space sextant visibility and geometry problems, gear train analysis, vacuum environmental approach, midcourse guidance theory, inertial measurement unit, and gyro. The organization of the Apollo effort at the Laboratory was also discussed. A preliminary estimate of the cost for both Laboratory and industrial support for the Apollo navigation and guidance system was presented: \$158.4 million through Fiscal Year 1966.

Memorandum, William W. Petynia, Apollo Project Office, to Associate Director, "Second Apollo Monthly Meeting at MIT, Instrumentation Laboratory, on October 4, 1961," October 10, 1961.

October 11

Officials of STG heard oral reports from representatives of five industrial teams bidding on the contract for the Apollo spacecraft: General Dynamics/Astronautics in conjunction with the Avco Corporation; General Electric Company, Missile and Space Vehicle Department, in conjunction with Douglas Aircraft Company, Grumman Aircraft Engineering Corporation, and Space Technology Laboratories, Inc.; McDonnell Aircraft Corporation in conjunction with Lockheed Aircraft Corporation, Hughes Aircraft Company, and Chance Vought Corporation of Ling-Temco-Vought, Inc.; The Martin Company; and North American Aviation, Inc. Written proposals had been received from the contractors on October 9. The presentations were made in the Virginia Room of the Chamberlain Hotel at Old Point Comfort, Va. Following the reports, 11 panels, under the direction of the Business and Technical Subcommittees, began studying the proposals. The Panels established were: Systems Integration; Propulsion; Flight Mechanics; Structures, Materials, and Heating; Human Factors; Instrumentation and Communications; Onboard Systems; Ground Operational Support Systems and Operations; Technical Development Plan; Reliability; and Manufacturing. The Technical Assessment Panels completed their evaluation October 20 and made their final report to the Technical Subcommittee on October 25. The Technical Subcommittee made its final report to the Source Evaluation Board on November 1.

MSC *Space News Roundup*, November 1, 1961, p. 8; December 13, 1961, p. 7; "Apollo Spacecraft Chronology," p. 12.

October 20

The MSFC-STG Advanced Program Coordination Board met at STG and discussed the question of the development of an automatic checkout system which would include the entire launch vehicle program from the Saturn C-1 through the Nova. It agreed that the Apollo contractor should be instructed to make the spacecraft electrical subsystems compatible with the Saturn complex.

In further discussion, Paul J. DeFries of Marshall Space Flight Center MSFC presented a list of proposed guidelines for use in studying early manned lunar landing missions:

- The crew should draw on its own resources only when absolutely necessary. Equipment and service personnel external to the spacecraft should be used as much as possible.
- Early lunar expeditions would receive active external support only up to the time of the launch from earth orbit.
- The crew would board the spacecraft only after it was checked out and ready for final countdown and launch.
- The first Apollo crews should have an emergency shelter available on the moon which could afford several months of lift: support and protection.
- The capability for clocking an orbital launch vehicle with a propulsion stage - the "connecting mode" - should be possible.
- The capability of fueling an orbital launch vehicle should be made available - "fueling mode."
- The capability of making repairs, replacements, or adjustments in orbit should be developed.
- For repairs, replacements, and adjustments on the orbital launch vehicle in earth orbit, two support vehicles would be necessary. These would be a Saturn C-1 launch vehicle manned by Apollo technicians and an unmanned Atlas-Centaur launch vehicle carrying repair kits.
- Development of docking, testing of components, and techniques for docking and training of man in orbital operations could be carried out by a space ferry loaded with a Mercury capsule.

Some of the points discussed in connection with these suggestions were:

- Orbital launch operations were just as complex, if not more complex, than earth-launched operations.
- A question existed as to how complex the orbital launch facility could be and what its function should be.
- There was a possibility that the crew could do most of the checkout and launch operations. Studies should be made to define the role of the crew versus the role of a proposed MSFC auxiliary checkout and maintenance crew.

After the discussion on orbital launch operations, the Board agreed that contemporary technology was inadequate to support such operations. Both STG and MSFC would need to study and develop both refueling and connector techniques.

Memorandum, J. Thomas Markley, Acting Secretary, to Distribution Members of the MSFC-STG Space Vehicle Board, "Minutes of MSFC-MSC Advanced Program Coordination Board," December 11, 1961.

October 25

NASA selected the Pearl River site in southwestern Mississippi, about 35 miles from the Michoud plant near New Orleans, La., as a static-test facility for Saturn- and Nova-class launch vehicles. The completed facility would operate under the direction of the Marshall Space Flight Center.

Washington *Daily News*, October 26, 1961; *Aeronautical and Astronautical Events of 1961*, p. 58.

October 27

The Saturn SA-1 first-stage booster was launched successfully from Cape Canaveral. The 925,000-pound launch vehicle, the largest known to be tested up to that time, carried water-filled dummy upper stages to an altitude of 84.8 miles and 214.7 miles down the Atlantic Missile Range. The booster's eight clustered H-1 engines developed 1.3 million pounds of thrust.

Washington *Evening Star*, October 28, 1961; *Aeronautical and Astronautical Events of 1961*, p. 58.

October 31

Under the direction of John C. Houbolt of Langley Research Center, a two-volume work entitled "Manned Lunar-Landing through use of Lunar-Orbit Rendezvous" was presented to the Golovin Committee (organized on July 20). The study had been prepared by Houbolt, John D. Bird, Arthur W. Vogeley, Ralph W. Stone, Jr., Manuel J. Queijo, William H. Michael, Jr., Max C. Kurbjun, Roy F. Brissenden, John A. Dodgen, William D. Mace, and others of Langley. The Golovin Committee had requested a mission plan using the lunar orbit rendezvous concept. Bird, Michael, and Robert H. Tolson appeared before the Committee in Washington to explain certain matters of trajectory and lunar stay time not covered in the document.

Bird, "Short History of the Development of the Lunar Orbit Rendezvous Plan at the Langley Research Center," p. 3.

October 31

Robert G. Chilton of STG gave the MIT Instrumentation Laboratory new information based on NASA in-house studies on the Apollo spacecraft roll inertia, pitch and yaw inertia, and attitude jets.

David G. Hoag, MIT, personal notes, October 1961.

LUNAR LANDER-ONE MAN



	<u>LB</u>
1 MAN AND LIFE SUPPORT	220
CONTROLS	50
STRUCTURE	230
ENGINE AND TANKAGE	220
FUEL AND OXIDIZER	2500
	<hr/>
TOTAL	3220

An artist's concept of a small lunar lander during descent to the lunar surface, as proposed by personnel of Langley Research Center in October 1961.

November 1

The Space Task Group was formally redesignated the Manned Spacecraft Center, Robert R. Gilruth, Director.

Grimwood, *Project Mercury: A Chronology*, p. 152.

November 6

Marshall Space Flight Center directed NAA to redesign the advanced Saturn second stage (S-II) to incorporate five rather than four J-2 engines, to provide a million pounds of thrust.

Saturn Illustrated Chronology, p. 46.

November 6

An Apollo Egress Working Group, consisting of personnel from Marshall Space Flight Center, Launch Operations Directorate, and Atlantic Missile Range, was formed on November 2. Meetings on that date and on November 6 resulted in publication of a seven-page document, "Apollo Egress Criteria." The Group established ground rules, operations and control procedures criteria, and space vehicle design criteria and provided requirements for implementation of emergency egress system.

Memorandum, Walter C. Williams, Associate Director, MSC, to Apollo Office, Attn: Bob Piland; Chief, Flight Operations Division; and Chief, Preflight Operations Division, "Apollo Emergency Egress Requirements," December 11, 1961.

November 6

In a memorandum to D. Brainerd Holmes, Director, Office of Manned Space Flight (OMSF), Milton W. Rosen, Director of Launch Vehicles and Propulsion, OMSF, described the organization of a working group to recommend to the Director a large launch vehicle program which would meet the requirements of manned space flight and which would have broad and continuing national utility for other NASA and DOD programs. The group would include members from the NASA Office of Launch Vehicles and Propulsion (Rosen, Chairman, Richard B. Canright, Eldon W. Hall, Elliott Mitchell, Norman Rafel, Melvyn Savage, and Adelbert O. Tischler); from the Marshall Space Flight Center (William A. Mrazek, Hans H. Maus, and James B. Bramlet); and from the NASA Office of Spacecraft and Flight Missions (John H. Disher). (David M. Hammock of MSC was later added to the group.) The principal background material to be used by the group would consist of reports of the Large Launch Vehicle Planning Group (Golovin Committee), the Fleming Committee, the Lundin Committee, the Heaton Committee, and the Debus-Davis Committee. Some of the subjects the group would be considering were:

1. an assessment of the problems involved in orbital rendezvous,
2. an evaluation of intermediate vehicles (Saturn C-3, C-4, and C-5),
3. an evaluation of Nova-class vehicles,
4. an assessment of the future course of large solid-fuel rocket motor development,
5. an evaluation of the utility of the Titan III for NASA missions, and
6. an evaluation of the realism of the spacecraft development program (schedules, weights, performances).

Rosen set November 20 as a target date for a recommended program.

Memoranda, Rosen to Holmes, "Large Launch Vehicle Program," November 6, 1961; Rosen to Holmes, "Recommendations for NASA Manned Space Flight Vehicle Program," November 20, 1961.

November 7-9

Representatives of MSC and NASA Headquarters visited the MIT Instrumentation Laboratory to discuss clauses in the contract for the Apollo navigation and guidance system, technical questions proposed by MSC, and work in progress. Topics discussed included the trajectories for the SA-7 and SA-8 flights and the estimated propellant requirements for guidance attitude maneuvers and velocity changes for the lunar landing mission. Presentations were made on the following subjects by members of the Laboratory staff: the spacecraft gyro, Apollo guidance computer logic design, computer displays and interfaces, guidance computer programming, horizon sensor experiments, and reentry guidance.

Memoranda, Jack Barnard, Apollo Project Office, to Associate Director, MSC, "Visit to MIT Instrumentation Laboratory Concerning the Apollo Navigation and Guidance System," November 15, 1961; William W. Petynia, Apollo Project Office, to Associate Director, MSC, "Third Apollo Monthly Meeting at MIT Instrumentation Laboratory on November 8-9," November 15, 1961.

November 8

The four MSC-MSFC Coordination Panels held their first meeting at Marshall Space Flight Center (MSFC). A significant event was the decision to modify the Electrical and Electronics Design Panel by creating two new Panels: the Electrical Systems Integration Panel and the Instrumentation and Communications Panel. In succeeding months, the Panels met at regular intervals.

MSF Management Council Minutes, June 25, 1963, Agenda Item 6.

November 15

In a letter to NASA Associate Administrator Robert C. Seamans, Jr., John C. Houbolt of Langley Research Center presented the lunar orbit rendezvous (LOR) plan and outlined certain deficiencies in the national booster and manned rendezvous programs. This letter protested exclusion of the LOR plan from serious consideration by committees responsible for the definition of the national program for lunar exploration.

Letter, Houbolt to Seamans, November 15, 1961.

November 17

NASA announced that the Chrysler Corporation had been chosen to build 20 Saturn first-stage (S-1) boosters similar to the one tested successfully on October 27 . They would be constructed at the Michoud facility near New Orleans, La. The contract, worth about \$200 million, would run through 1966, with delivery of the first booster scheduled for early 1964.

Washington Post, November 18, 1961.

November 18

Ranger II was launched into near-earth orbit from the Atlantic Missile Range by an Atlas-Agena B booster.

The scheduled deep-space trajectory of the spacecraft was not achieved when the Agena engine failed to restart in orbit.

Washington *Evening Star*, November 18, 1961.

November 20

Milton W. Rosen, Director of Launch Vehicles and Propulsion, NASA Office of Manned Space Flight (OMSF), submitted to D. Brainerd Holmes, Director, OMSF, the report of the working group which had been set up on November 6. The recommendations of the group were :

- The United States should undertake a program to develop rendezvous capability on an urgent basis.
- To exploit the possibilities of accomplishing the first manned lunar landing by rendezvous, an intermediate vehicle with five F-1 engines in the first stage, four or five J-2 engines in the second stage, and one J-2 engine in the third stage should be developed (Saturn C-5). The vehicle should be so designed that it could be modified to use a three- engine first stage. The three-engine vehicle provided a better match with a large number of NASA and DOD requirements and earlier flights in support of the manned lunar program.
- The United States should place primary emphasis on the direct flight mode for achieving the first manned lunar landing. This mode gave greater assurance of accomplishment during this decade. To implement the direct flight mode, a Nova vehicle consisting of an eight F-1 engine first stage, a four M-1 engine second stage, and a one J-2 engine third stage should be developed on a top priority basis.
- Large solid-fuel rockets should not be considered as a requirement for manned lunar landing. If these rockets were developed for other purposes, the manned space flight program should support a solid-fuel first-stage development to provide a backup capability for Nova.
- Development of the S-IVB stage (one J-2) engine should be started, aiming toward flight tests on a Saturn C-1 in late 1964. It should be used as the third stage of both Saturn C-5 and Nova and also as the escape stage in the single earth orbit rendezvous mode.
- NASA had no present requirement for the Titan III vehicle. If the Titan III were developed by DOD, NASA should maintain continuous liaison with DOD development to ascertain if the vehicle could be used for future NASA needs.

Memorandum, Rosen to Holmes, "Recommendations for NASA Manned Space Flight Vehicle Program," November 20, 1961.

November 27

The original Apollo spacecraft Statement of Work of July 28 had been substantially expanded.

The requirements for the spacecraft navigation and guidance system were defined:

Control of translunar injection of the spacecraft and monitoring capability of injection guidance to the crew both for direct ascent and for injection from an earth parking orbit.

Data and computation for mission abort capability en route to the moon and for guidance to a point from which a safe lunar landing could be attempted.

Guidance of the command module to a preselected earth landing site after safe reentry.

Guidance for establishing lunar orbit and making lunar landings; mission abort capability from the lunar landing maneuver.

Control of launch from the lunar surface into transearth trajectory by both direct ascent and from lunar parking orbit.

Rendezvous in earth orbit between the spacecraft and space laboratory module or other space vehicle.

Components of the navigation and guidance system now clearly identified were:

Inertial platform

Space sextant

Computer

Controls and displays

Electronics assembly

Chart and star catalog

Range or velocity measuring equipment for terminal control in rendezvous and lunar landing

Backup inertial components for emergency operation

The stabilization and control system requirements were revised:

Roll control as well as flight path control during the thrusting period of atmospheric abort and stability augmentation after launch escape system separation

Stabilization of the spacecraft and the lunar injection configuration while in earth parking orbit

Rendezvous and docking with the space laboratory module or other space vehicle

Attitude control and hovering for lunar landings and launchings and for entering and leaving lunar orbit

Basic components of the stabilization and control system were defined:

Attitude reference

Rate sensors

Control electronics assembly

Manual controls

Attitude and rate displays

Power supplies

A single-engine service module propulsion system would replace the earlier vernier and mission propulsion systems.

The new system would be capable of:

Abort propulsion after jettison of the launch escape system

All major velocity increments and midcourse velocity corrections for missions prior to the lunar landing attempt

Lunar launch propulsion and transearth midcourse velocity correction.

Earth-storable, hypergolic propellants would be used by the new system, which would include single- or multiple-thrust chambers with a thrust- to-weight ratio of at least 0.4 for all chambers operating (based on the lunar launch configuration) and would have a pressurized propellant feed system.

The reaction control systems for the command and service modules would now each consist of two independent system, both capable of meeting the total torque and propellant requirements. The fuel would be monomethylhydrazine and the oxidizer would be a mixture of nitrogen tetroxide and nitrous oxide.

The parachute system for the earth landing configuration was revised to include two FIST-type drogue parachutes deployed by mortars.

The command module structure was specified: a ring-reinforced, single- thickness aluminum shell pressure vessel separated from the outer support structure of relatively rigid brazed or welded sandwich construction. The ablative heatshield would be bonded to this outer structure.

Service module structure was also detailed: an aluminum honeycomb sandwich shell compatible with noise and buffet and with meteoroid requirements. The structural continuity would have to be maintained with adjoining modules and be compatible with the overall bending stiffness requirements of the launch vehicle.

The duties of the three Apollo crewmen were delineated :

Commander

Control of the spacecraft in manual or automatic mode in all phases of the mission

Selection, implementation, and monitoring of the navigation and guidance modes

Monitoring and control of key areas of all systems during time-critical periods

Station in the left or center couch

Co-Pilot

Second in command of the spacecraft

Support of the pilot as alternative pilot or navigator

Monitoring of certain key parameters of the spacecraft and propulsion systems during critical mission phases

Station in the left or center couch

Systems Engineer

Responsibility for all systems and their operation

Primary monitor of propulsion systems during critical mission phases

Responsibility for systems placed on board primarily for evaluation for later Apollo spacecraft

Station in the right-hand couch.

During launch, reentry, or similar critical mission phases, the crew would be seated side by side. At other times, at least one couch would be stowed.

One crew member would stand watch during noncritical mission phases at either of the two primary duty stations. Areas for taking navigation fixes, performing maintenance, food preparation, and certain scientific observations could be separate from primary duty stations. Arrangements of displays and controls would reflect the duties of each crewman. They would be so arranged that one crewman could return the spacecraft safely to earth. All crewmen would be cross-trained so that each could assume the others' duties.

Radiation shielding for the crew would be provided by the mass of the spacecraft modules.

A description of crew equipment was added:

The couch for each crewman would give full body and head support during all normal and emergency acceleration conditions. It would be adjustable to permit changes in body and leg angles and would be so constructed as to allow crewmen to interchange positions and to accommodate a crewman wearing a back or seat parachute. A restraint system would be provided with each couch for adequate restraint during all flight phases. Each support and restraint system would furnish

vibration attenuation beyond that needed to maintain general spacecraft integrity. This system would keep crew vibration loads within tolerance limits and also enable the crew to exercise necessary control and monitoring functions.

Pressure suits would be carried for extravehicular activity and for use in the event of cabin decompression.

The spacecraft would be equipped with toilet facilities which would include means for disinfecting the human waste sufficiently to render it harmless and unobjectionable to the crew. Personal hygiene needs, such as shaving, the handling of nonhuman waste, and the control of infectious germs would be provided for.

Food would be dehydrated, freeze-dried, or of a similar type that could be reconstituted with water if necessary. Heating and chilling of the foods would be required. The primary source of potable water would be the fuel cells. In addition, sufficient water would have to be on board at launch for use during the 72-hour landing requirement in case of early abort. Urine would not have to be recycled for potable water.

Emergency equipment would include:

- Personal parachutes

- Post-landing survival equipment:

 - one three-man liferaft, food, location aids, first aid supplies, and accessories to support the crew outside the spacecraft for three days in any emergency landing area. In addition, a three-day water supply would be removed from the spacecraft after landing; provision for purifying a three-day supply of sea water would be included.

The crew would be furnished "shirtsleeve" garments, lightweight cap, and exercise and recreation equipment.

Medical instrumentation would be used to monitor the crew during all flights, especially during stressful periods of early flights, and for special experiments to be performed in the space laboratory module and during extravehicular activity and lunar exploration. Each crewman would carry a radiation dosimeter.

The environmental control system would comprise two air loops, a gas supply system, and a thermal control system.

- One air loop would supply the conditioned atmosphere to the cabin or pressure suits. The other would remove sensible heat and provide cabin ventilation during all phases of the mission including postlanding.

- The primary gas supply would be stored in the service module as supercritical cryogenics. The supply would be 50 percent excess capacity over that required for normal metabolic needs, two complete cabin repressurization, a minimum of 18 airlock operations, and leakage. Recharging of self-contained extravehicular suit support systems would be possible.

Thermal control would be achieved by absorbing heat with a circulating coolant and rejecting this heat from a space radiator. During certain mission modes, other cooling systems would supplement or relieve the primary system.

Water collected from the separator and the fuel cells would be stored separately in positive expulsion tanks. Manual closures, filters, and relief valves would be used where needed as safety devices.

Metabolic requirements for the environmental control system were:

Total cabin pressure (oxygen and nitrogen mixture): 7 +/- 0.2 psia

Relative humidity: 40 to 70 percent

Partial pressure carbon dioxide - maximum 7.6 mm Hg

Temperature: 75 degrees F +/- 5 degrees F

The major components of the electrical power system were described more fully:

Three nonregenerative hydrogen-oxygen fuel cell modules characterized by low pressure, intermediate temperature, Bacon-type, utilizing porous nickel, unactivated electrodes, and aqueous potassium as the electrolyte

Mechanical accessories, including control components, reactant tankage, piping, etc.

Three silver-zinc primary batteries, each having a normal 28-volt output and a minimum capacity of 3,000 watt-hours (per battery) when discharged at the ten-hour rate at 80 degrees F

A display and control panel, sufficient to monitor the operation and status of the system and for distribution of generated power to electrical loads as required

The fuel cell modules and control, tanks (empty), radiators, heat exchangers, piping, valves, total reactants plus reserves would be located in the service module. The silver-zinc batteries anti electrical power distribution and controls would be placed in the command module.

Under normal operation, the entire electrical power requirements would be supplied by the three fuel cell modules operating in parallel. The primary storage batteries would be maintained fully charged under this condition of operation.

If one fuel cell module failed, the unit involved would automatically be electrically and mechanically isolated from the system and the entire electrical load assumed by the two remaining fuel cells. The primary batteries would remain fully charged.

If two fuel cell modules failed, they would be isolated from the system and the spacecraft electrical loads would immediately be reduced by the crew and manually programmed to hold within the generating capacities of the remaining fuel cell.

At reentry, the fuel cell modules and accessories would be jettisoned. All subsequent electrical power requirements would be provided by the primary storage batteries.

Each fuel cell module would have a normal capacity of 1,200 watts at an output voltage of 28 volts and a current density conservatively assigned so that 50 percent overloads could be continuously supplied. The normal fuel cell operating pressure and temperature would be about 60 psia and 425 degrees F to 500 degrees F respectively. Under normal conditions of operation, the specific fuel (hydrogen and oxygen) consumption should not exceed a total of 0.9 lb/kw-hr.

Self-sustaining operation within the fuel cell module should begin at a temperature of about 275 degrees F. A detection system would be provided with each fuel cell module to prevent contamination of the collected potable water supply.

The degree of redundancy provided for mechanical and electrical accessory equipment would be 100 percent.

The distribution portion of the electrical power system would contain all necessary buses, wiring protective devices, and switching and regulating equipment.

Sufficient tankage would be supplied to store all reactants required by the fuel cell modules and environmental controls for a 14-day mission. The reactants would be stored supercritically at cryogenic temperatures and the tankage would consist of two equal volume storage vessels for each reactant. The main oxygen and nitrogen storage would supply both the environmental control system and the fuel cells.

The communication and instrumentation system was further detailed:

The equipment was to be constructed to facilitate maintenance by ground personnel and by the crew and to be as nearly self-contained as possible to facilitate removal from the spacecraft. Flexibility for incorporation of future additions or modifications would be stressed throughout the design. A patch and programming panel would be included which would permit the routing of signal inputs from sensors to any selected signal conditioner and from this to any desired commutator channel. Panel design would provide the capability of "repatching" during a mission. The equipment and system should be capable of sustained undegraded operation with supply voltage variation of +15 percent to -20 percent of the normal bus voltage.

A circuit quality analysis for each radiating electrical system would be required to show exactly how ranging, telemetry, voice, and television data modulated all transmitters with which they were used.

The equipment and associated documentation would be engineered for comprehensive and logical fault tracing.

Components of the communication subsystem would include:

Voice communication

Telemetry

Tracking transponders

Television

Radio recovery aids

Antenna subsystems

Radar altimeter (if required by the guidance system)

The instrumentation system would be required to detect, measure, and display all parameters needed by the crew for monitoring and evaluating the integrity and environment of the spacecraft and performance of the spacecraft systems.

Data would be transmitted to ground stations for assessment of spacecraft performance and for failure analysis. Information needed for abort decisions and aid in the selection of lunar landing sites would also be provided. The mission would be documented through photography and recording.

Included in the components of the instrumentation system were:

Sensors

Data disposition

Tape recorders

Panel display indicators

Calibration

Clock

Telescope

Cameras

In addition to the description of the major command and service module systems, the Statement of Work

also included sections on the lunar landing module, space laboratory module, mission control center and ground operational support system, and the engineering and development test plan.

The propulsion system for the lunar landing module would now comprise a composite propulsion system: multiple lunar retrograde engines for the gross velocity increments required for lunar orbiting and lunar landing; and a lunar landing engine for velocity vector control, midcourse velocity control, and the lunar hover and touchdown maneuver. The lunar retrograde engines would use liquid-oxygen and liquid-hydrogen propellants. The single lunar landing engine would require the same type of propellant, would be throttleable over a ratio of +/- 50 percent about the normal value, and would be capable of multiple starts within the design operating life of the engine.

No additions or changes had been made in the space laboratory module systems description.

Overall control of all Apollo support elements throughout all phases of a mission would be exercised by the Mission Control Center. Up to the time of liftoff, mission launch activities would be conducted from the launch control center at Cape Canaveral. Remote stations would be used to support near-earth and lunar flights and track the command module during reentry.

Five major phases of a development and test plan were identified:

1. Design information and development tests
2. Qualification, reliability, and integration tests
3. Major ground tests
4. Major development flight tests
5. Flight missions.

NASA, *Project Apollo Spacecraft Development Statement of Work* (STG, November 27, 1961), Part 3, Technical Approach, pp. 35-96.

November 28



A team and a goal - officials of North American Aviation, Inc., study a replica of the moon shortly after the announcement that the firm had been selected by NASA as the prime contractor for the Apollo command and service modules. From left to right are Harrison A. Storms, president of North American's Space and Information Systems Division; John W. Paup, program manager of Apollo; and Charles H. Feltz, Apollo program engineer. (NAA photo)

NASA announced that the Space and Information Systems Division of North American Aviation, Inc., had been selected to design and build the Apollo spacecraft. The decision by NASA Administrator James E. Webb followed a comprehensive evaluation of five industry proposals by nearly 200 scientists and engineers representing both NASA and DOD. Webb had received the Source Evaluation Board findings on November 24. Although technical evaluations were very close, NAA had been selected on the basis of experience, technical competence, and cost. NAA would be responsible for the design and development of the command module and service module. NASA expected that a separate contract for the lunar landing system would be awarded within the next six months. The MIT Instrumentation Laboratory had previously been assigned the development of the Apollo spacecraft guidance and navigation system. Both the NAA and MIT contracts would be under the direction of MSC.

NAA Space and Information Systems Division, News Release SP3-0610, November 28, 1961; *Wall Street Journal*, November 29, 1961; U.S. Congress, Senate, Committee on Aeronautical and Space Sciences, *Apollo Accident*, Hearings, 90th Congress, 1st Session (1967), Part 6, p. 513; TWX, NASA Headquarters to Ames, Langley, Lewis, and Flight Research Centers, Goddard and Marshall Space Flight Centers, Jet Propulsion Laboratory, Launch Operations Center, Space Task Group, Wallops Station, and Western Operations Office, November 28, 1961.

November 29

The *Mercury-Atlas 5* launch from the Atlantic Missile Range placed a Mercury spacecraft carrying chimpanzee Enos into orbit. After a two-orbit flight of 3 hours and 21 minutes, the capsule reentered and was recovered 1 hour and 25 minutes later. Enos was reported in excellent condition. No additional unmanned or primate flights were considered necessary before attempting the manned orbital mission scheduled for early 1962.

MSC *Space News Roundup*, December 13, 1961, p. 1; Swenson *et al.*, *This New Ocean*, pp. 402-407.

November 29-30

On a visit to Marshall Space Flight Center by MIT Instrumentation Laboratory representatives, the possibility was discussed of emergency switchover from Saturn to Apollo guidance systems as backup for launch vehicle guidance.

David G. Hoag, personal notes, November 29-30, 1961.

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PART 3 (A)

Lunar Orbit Rendezvous: Mode and Module

December 1961

1961

December 4

The Project Apollo Statement of Work for development of the Apollo spacecraft was completed. A draft letter based on this Statement of Work was presented to NAA for review. A prenegotiation conference on the development of the Apollo spacecraft was held at Langley Field, Va.

"Apollo Spacecraft Chronology," p. 13.

December 4

NASA Associate Administrator Robert C. Seamans, Jr., commented to D. Brainerd Holmes, Director, Office of Manned Space Flight, on the report of the Rosen working group on launch vehicles, which had been submitted on November 20. Seamans expressed himself as essentially in accord with the group's recommendations. Memorandum, Seamans to Holmes,

"Recommendations for NASA Manned Space Flight Vehicle Program," December 4, 1961.

December 5-20

NASA negotiations with NAA on the Apollo spacecraft contract were held at Williamsburg, Va. Nine Technical Panels met on December 11 and 12 to review Part 3, Technical Approach, of the Statement of Work. These Panels reported their recommended changes and unresolved questions to the Technical Subcommittee for action. Later in the negotiations, NASA and NAA representatives agreed on changes intended to clarify the original Statement of Work. Among these was the addition of the boilerplate program. Two distinct types of boilerplates were to be fabricated: those of a simple cold-rolled steel construction for drop impact tests and the more complex models to be used with the Little Joe II and Saturn launch vehicles. The Little Joe II, originally conceived in June 1961, was a solid-fuel rocket booster which would be used to man-rate the launch escape system for the command module.

In addition, the Apollo Project Office, which had been part of the MSC Flight Systems Division, would now report directly to the MSC Director and would be responsible for planning and directing all activities associated with the completion of the Apollo spacecraft project. Primary functions to be performed by the Office would include:

- Monitor the work of the Apollo Principal Contractor NAA and Associate Contractors.
- Resolve technical problems arising between the Principal Contractor and Associate Contractors which were not directly resolved between the parties involved.
- Maintain close liaison with all Apollo contractors to keep fully and currently informed on the status of contract work, potential schedule delays, or technical problems which might impede progress.

[On January 15, 1962, the Apollo Spacecraft Project Office was established at MSC.]

Letter contract No. NAS 9-150, authorizing work on the Apollo development program to begin on January 1, 1962, was signed by NASA and NAA on December 21. Under this contract, NAA was assigned the design and development of the command and service modules, the spacecraft adapter, associated ground support equipment, and spacecraft integration. Formal signing of the contract followed on December 31.

Project Apollo, "Minutes of Technical Panel Meetings for Negotiation of Spacecraft Development," December 12-15, 1961; Oakley, *Historical Summary, S&ID Apollo Program*, pp. 4, 27; *Project Apollo Quarterly Status Report No. 1 for Period Ending September 30, 1962*, p. 9; MSC, *Project Apollo Spacecraft Development Statement of Work* (December 18, 1961), Part 4, pp. 1-2.

December 6

D. Brainerd Holmes, NASA Director of Manned Space Flight, outlined the preliminary project development plan for the Mercury Mark II program in a memorandum to NASA Associate Administrator Robert C. Seamans, Jr. The primary objective of the program was to develop rendezvous techniques; important secondary objectives were long-duration flights, controlled land recovery, and astronaut training. The development of rendezvous capability, Holmes stated, was essential:

- It offered the possibility of accomplishing a manned lunar landing earlier than by direct ascent.
- The lunar landing maneuver would require the development of rendezvous techniques regardless of the operational mode selected for the lunar mission.
- Rendezvous and docking would be necessary to the Apollo orbiting laboratory missions planned for the 1965-1970 period.

The plan was approved by Seamans on December 7. The Mercury Mark II program was renamed "Gemini" on January 3, 1962.]

Memorandum, Holmes to Associate Administrator, "Mercury Mark II Preliminary Project Development Plan," December 6, 1961.

December 7

Plans for the development of a two-man Mercury spacecraft were announced by Robert R. Gilruth, MSC Director. The two-man spacecraft, to be built by McDonnell Aircraft Corporation, would be similar in shape to the Mercury spacecraft but slightly larger and two to three times heavier. Its booster rocket would be a modified Air Force Titan II, scheduled for flight test in early 1962. One of the major objectives in the program would be a test of orbital rendezvous, in which the two-man spacecraft would be launched into orbit by the Titan II and attempt to rendezvous with an Agena stage launched by an Atlas rocket. The total cost for a dozen two-man spacecraft plus boosters and other equipment was estimated at \$500 million.

Aeronautical and Astronautical Events of 1961, p. 71.

December 7

NASA Associate Administrator Robert C. Seamans, Jr., and DOD Deputy Director of Defense Research and Engineering John H. Rubel recommended to Secretary of Defense Robert S. McNamara and NASA Administrator James E. Webb that detailed arrangements for support of the Mercury Mark II spacecraft and the Atlas-Agena vehicle used in rendezvous experiments be planned directly between NASA's Office of Manned Space Flight and the Air Force and other DOD organizations. NASA's primary responsibilities would be the overall management and direction for the Mercury Mark II/ Agena rendezvous development and experiments. The Air Force responsibilities would include acting as NASA contractor for the Titan II launch vehicle and for the Atlas-Agena vehicle to be used in rendezvous experiments. DOD's responsibilities would include assistance in the provision and selection of astronauts and the provision of launch, range, and recovery support, as required by NASA.

Memorandum, Deputy Director of Defense Research and Engineering, DOD, and Associate Administrator, NASA, to The Secretary of Defense and the Administrator, NASA, "Recommendation Relative to the Division of Effort between the NASA and DOD in the Development of Space Rendezvous and Capabilities," December 7, 1961.

December 15

NASA announced that The Boeing Company had been selected for negotiations as a possible prime contractor for the first stage (S-IC) of the advanced Saturn hunch vehicle. The S-IC stage, powered by five F-1 engines, would be 35 feet in diameter and about 140 feet high. The \$300-million contract, to run through 1966, called for the development, construction, and testing of 24 flight stages and one ground test stage. The booster would be assembled at the NASA Michoud Operations Plant near New Orleans, La., under the direction of the Marshall Space Flight Center.

Saturn Illustrated Chronology, pp. 49-50.

December 18-19

Fred T. Pearce, Jr., of MSC visited the MIT Instrumentation Laboratory to discuss the first design-study space sextant produced at the Laboratory, The instrument was intended to be used with the guidance computer. The working mockup was demonstrated and the problem of the effect of the vehicle motion on the sextant was discussed.

Memorandum, Pearce to Associate Director, STG, "Visits to Instrument Laboratory and Ames Research Center to Discuss the Apollo Navigational Instrument," December 22, 1961.

December 20

The General Assembly of the United Nations unanimously adopted Resolution 1721 (XIV) on international cooperation in the peaceful uses of outer space.

Kemp, *Evolution Toward a Space Treaty: An Historical Analysis*, p. 55.

December 20

The Douglas Aircraft Company was selected by NASA for negotiation of a contract to modify the Saturn S-IV stage by installing a single J-2 Rocketdyne engine of 200,000 pounds of thrust. The contract would be under the direction of the Marshall Space Flight Center.

Saturn Illustrated Chronology, p. 50.

December 21

D. Brainerd Holmes, Director of the NASA Office of Manned Space Flight, announced the formation of the Manned Space Flight Management Council. The Council, which was to meet at least once a month, was to identify and resolve difficulties and to coordinate the interface problems in the manned space flight program. Members of the Council, in addition to Holmes, were: from MSC, Robert R. Gilruth and Walter C. Williams, Director and Associate Director; from Marshall Space Flight Center, Wernher von Braun, Director, and Eberhard F. M. Rees, Deputy Director for Research and Development; from NASA Headquarters, George M. Low, Director of Spacecraft and Flight Missions; Milton W. Rosen, Director of Launch Vehicles and Propulsion; Charles H. Roadman, Director of Aerospace Medicine; William E. Lilly, Director of Program Review and Resources Management; and Joseph F. Shea, Deputy Director for Systems Engineering, Shea, formerly Space Programs Director for Space Technology Laboratories, Inc., Los Angeles, Calif., had recently joined NASA.

MSC *Space News Roundup*, January 10, 1962, p. 1; Senate Staff Report, *Manned Space Flight Program*, p. 205.

December 21

The Manned Space Flight Management Council decided at its first meeting that the Saturn C-5 launch vehicle would have a first stage configuration of five F-1 engines and a second stage configuration of five J-2 engines. The third stage would be the S-IVB with one J-2 engine. It recommended that the contractor for stage integration of the Saturn C-1 be Chrysler Corporation and that the contractor for stage integration of the Saturn C-5 be The Boeing Company. Contractor work on the Saturn C-5 should proceed immediately to provide a complete design study and a detailed development plan before letting final contracts and assigning large numbers of contractor personnel to Marshall Space Flight Center or Michoud.

MSF Management Council Minutes, December 21, 1961, pp. 1-2.

December 21

NAA's Space and Information Systems Division selected four companies as subcontractors to design and build four of the major Apollo spacecraft systems. The Collins Radio Company, Cedar Rapids, Iowa, received the telecommunications systems contract, worth more than \$40 million; Minneapolis-Honeywell Regulator Company, Minneapolis, Minn., received the stabilization and control systems contract, \$30 million; AiResearch Manufacturing Company, division of The Garrett Corporation, Los Angeles, Calif., was awarded the environmental control system contract, \$10 million; and Radioplane Division of Northrop Corporation, Van Nuys, Calif., was selected for the parachute landing system contract, worth more than \$1 million. The total cost for the initial phase of the NAA contract was expected to exceed \$400 million.

MSC *Space News Roundup*, December 27, 1961.

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PART 3 (B)

Lunar Orbit Rendezvous: Mode and Module

January 1962 through March 1962

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1962

January 5

NASA made public the drawings of the three-man Apollo spacecraft to be used in the lunar landing development program, On January 9, NASA announced its decision that the Saturn C-5 would be the lunar launch vehicle.

Washington *Evening Star*, January 5, 1962; *Washington Post*, January 10, 1962.

January 11

In his State of the Union message to the Congress, President John F. Kennedy said: "With the approval of this Congress, we have undertaken in the past year a great new effort in outer space. Our aim is not simply to be first on the moon, any more than Charles Lindbergh's real aim was to be first to Paris. His aim was to develop the techniques and the authority of this country and other countries in the field of the air and the atmosphere, and our objective in making this effort, which we hope will place one of our citizens on the moon, is to develop in a new frontier of science, commerce and cooperation, the position of the United States and the free world. This nation belongs among the first to explore it. And among the first - if not the first - we shall be."

Senate Staff Report, *Documents on International Aspects of the Exploration and Use of Outer Space, 1954- 1962*, p. 228.

January 15

The Apollo Spacecraft Project Office (ASPO) was established at MSC. Charles W. Frick was selected as Manager of the new Office, to assume his duties in February. Frick had been Chief of Technical Staff for General Dynamics Convair. Robert O. Piland was appointed Deputy Manager of ASPO and would serve as Acting Manager until Frick's arrival. ASPO would be responsible for the technical direction of NAA and other industrial contractors assigned to work on the Apollo spacecraft. All technical coordination with NAA or with other contractors on the Apollo project would be coordinated through this Office. The Manager of ASPO would be responsible for keeping the Director and Associate Director of MSC fully advised on the status of the program.

MSC Announcement No. 10, Establishment of the Apollo Spacecraft Project Office, January 15, 1962.

January 22

The first Apollo engineering order was issued to fabricate mockups of the Apollo command and service modules.

Oakley, *Historical Summary, S&ID Apollo Program*, p. 5.

January 26

Ranger III was launched toward the moon from the Atlantic Missile Range by an Atlas-Agena B booster. Because of a malfunction in the Agena guidance system, the spacecraft missed its target by 22,862 miles and eventually went into solar orbit. Of four scientific experiments only one was partially completed: gamma-ray readings of the lunar surface. Attempts to relay television pictures of the moon and to bounce radar signals off the moon at close range were unsuccessful.

New York Times, January 29, 1962.

During the Month

NAA engineers began preliminary layouts to define the elements of the command module (CM) configuration. Additional requirements and limitations imposed on the CM included reduction in diameter, paraglider compatibility, 250 pounds of radiation protection water, redundant propellant tankage for the attitude control system, and an increase in system weight and volume.

Layouts were also being prepared to identify equipment requirements in the CM aft compartment, while layouts depicting the position and orientation of the three crewmen during various phases of the lunar flight were complete.

Basic load paths for the CM inner structure, an access door through the outer structure, and the three side wall hatches for crew entrance and exit had been tentatively defined. The CM inner structure was currently of bonded aluminum honeycomb, the outer structure of high-temperature, brazed steel honeycomb.

NAA, *Apollo Monthly Progress Report*, SID 62-300-1, January 31, 1962, pp. 15-16.

During the Month

Command module heatshield requirements, including heating versus time curves, were established by NAA for several design trajectories. A computer program method of analyzing the charring ablation process had been developed. By this means, it was possible to calculate the mass loss, surface char layer temperature, amount of heat conducted through the uncharred ablation material and insulation into the cabin, and temperature profile through the ablator and insulation layers. In February, NAA determined that a new and more refined computer program would be needed.

Apollo Monthly Progress Report, SID 62-300-1, p. 1.

During the Month

The solid propellant called for in the original NAA proposal on the service module propulsion system was replaced by a storable, hypergolic propellant. Multitank configurations under study appeared to present offloading capabilities for alternative missions.

Apollo Monthly Progress Report, SID 62-300-1, p. 18.

January-February

The Requests for Quotation on production contracts for major components of the Apollo spacecraft guidance and navigation system, comprising seven separate items, were released to industry by the MIT Instrumentation Laboratory. (The Source Evaluation Board, appointed on January 31, began its work during the week of March 5 and contractors were selected on May 8.)

Interview with Ralph Ragan, Instrumentation Laboratory, MIT, April 27, 1966; Apollo Spacecraft Project Office, MSC, Weekly Activity Report, March 5-10, 1962; memorandum, Robert C. Seamans, Jr., to MSC, Attn: Robert R. Gilruth, "Appointment of Source Evaluation Board," January 31, 1962.

January-June

The Grumman Aircraft Engineering Corporation developed a detailed, company-funded study on the lunar orbit rendezvous technique: characteristics of the system (relative cost of direct ascent, earth orbit rendezvous, and lunar orbit rendezvous); developmental problems (communications, propulsion); and

elements of the system (tracking facilities, etc.). Joseph M. Gavin was appointed in the spring to head the effort, and Robert E. Mullaney was designated program manager.

Interview with Saul Ferdman, Director of Space Vehicle Development, Grumman Aircraft Engineering Corporation, May 2, 1966.

February 6

John C. Houbolt of Langley Research Center and Charles W. Mathews of MSC made a presentation of lunar orbit rendezvous versus earth orbit rendezvous to the Manned Space Flight Management Council.

MSF Management Council Minutes, February 6, 1962, p. 1.

February 7

At his regular press conference, President John F. Kennedy was asked for his "evaluation of our progress in space at this time" and whether the United States had changed its "timetable for landing a man on the moon." He replied: "As I said from the beginning, we have been behind . . . and we are running into the difficulties which came from starting late, We, however, are going to proceed by making a maximum effort. As you know, the expenditures in our space program are enormous . . . the time schedule, at least our hope, has not been changed by the recent setbacks [Ranger failures]."

Washington Post, February 8, 1962.

February 7

On the basis of a study by NAA, a single-engine configuration was chosen as the optimum approach for the service module propulsion subsystem. The results of the study were presented to MSC representatives and NAA was authorized to issue a work statement to begin procurement of an engine for this configuration. Agreement was also reached at this meeting on a vacuum thrust level of 20,000 pounds for the engine. This would maintain a thrust-to-weight ratio of 0.4 and allow a considerable increase in the lunar liftoff weight of the spacecraft.

NAA, *Apollo Monthly Progress Report*, SID 62-300-2, February 28, 1962, p. 46.

February 9

Robert R. Gilruth, MSC Director, in a letter to NASA Headquarters, described the Ad Hoc Lunar Landing Module Working Group which was to be under the direction of the Apollo Spacecraft Project Office. The Group would determine what constraints on the design of the lunar landing module were applicable to the effort of the Lewis Research Center. Gilruth asked that Eldon W. Hall represent NASA

Headquarters in this Working Group. [At this time, the lunar landing module was conceived as being that part of the spacecraft which would actually land on the moon and which would contain the propulsion system necessary for launch from the lunar surface and injection into transearth trajectory. Pending a decision on the lunar mission mode, the actual configuration of the module was not yet clearly defined.]

Letter, Gilruth, MSC, to NASA Headquarters, Attn: Mr. Rosen, "Formation of Lunar Landing Module Ad Hoc Working Group," February 9, 1962.

February 9

NASA announced that the General Electric Company had been selected for a major supporting role in the Apollo project, to provide integration analysis of the total space vehicle (including booster-spacecraft interface), ensure reliability of the entire space vehicle, and develop and operate a checkout system.

U.S. Congress, House, Committee on Science and Astronautics, *Astronautical and Aeronautical Events of 1962*, Report of the National Aeronautics and Space Administration, 88th Congress, 1st Session (1963), p. 15.

February 13

A contract for the escape rocket of the Apollo spacecraft launch escape system was awarded to the Lockheed Propulsion Company by NAA. The initial requirements were for a 200,000-pound-thrust solid-propellant rocket motor with an active thrust-vector-control subsystem. After extensive study, Lockheed was directed to remove the control subsystem. A letter contract change was subsequently made with Lockheed to develop and manufacture a pitch-control motor to replace the thrust-vector-control subsystem. In conjunction with the use of the pitch-control motor, the escape-motor thrust was reduced to 155,000 pounds.

Apollo Quarterly Status Report No. 1, p. 10; Oakley, *Historical Summary, S&ID Apollo Program*, p. 6; TWX, NAA to MSC, February 12, 1962.

February 13-15

A meeting on the technical aspects of earth orbit rendezvous was held at NASA Headquarters. Representatives from various NASA offices attended: Arthur L. Rudolph, Paul J. DeFries, Fred L. Digesu, Ludie G. Richard, John W. Hardin, Jr., Ernst D. Geissler, and Wilson B. Schramm of Marshall Space Flight Center (MSFC); James T. Rose of MSC; Friedrich O. Vonbun, Joseph W. Siry, and James J. Donegan of Goddard Space Flight Center (GSFC); Douglas R. Lord, James E. O'Neill, Richard J. Hayes, Warren J. North, and Daniel D. McKee of the NASA Office of Manned Space Flight (OMSF). Joseph F. Shea, Deputy Director for Systems, OMSF, who had called the meeting, defined in general

terms the goal of the meeting: to achieve agreement on the approach to be used in developing the earth orbit rendezvous technique. After two days of discussions and presentations, the Group approved conclusions and recommendations:

- Gemini rendezvous operations could and must provide substantial experience with rendezvous techniques pertinent to Apollo.
- Incorporation of the Saturn guidance equipment in a scaled-down docking module for the Agenas in the Gemini program was not required.
- Complete development of the technique and equipment for Apollo rendezvous and docking should be required before the availability of the Saturn C-5 launch vehicle.
- Full-scale docking equipment could profitably be developed by three- dimensional ground simulations. MSFC would prepare an outline of such a program.
- The Apollo rendezvous technique and actual hardware could be flight- tested with the Saturn C-1 launch vehicle. MSFC would prepare a proposed flight test program.
- The choice of connecting or tanking modes must be made in the near future. The MSFC Orbital Operations Study program should be used to provide data to make this decision.
- The rendezvous technique which evolved from this meeting would place heavy requirements on the ground tracking network. GSFC should provide data relating the impact of detailed trajectory considerations to ground tracking station requirements.

[This meeting was part of a continuing effort to select the lunar mission mode.]

Minutes, Earth Orbital Rendezvous Meeting, February 13-15, 1962, pp. 2-4.

February 14

NASA signed a contract with The Boeing Company for indoctrination, familiarization, and planning, expected to lead to a follow-on contract for design, development, manufacture, test, and launch operations of the first stage S-IC of the Saturn C-5 launch vehicle.

Senate Staff Report, *Manned Space Flight Program*, p. 205.

February 18

NASA announced Project Fire, a high-speed reentry heat research program to obtain data on materials, heating rates, and radio signal attenuation on spacecraft reentering the atmosphere at speeds of about 24,500 miles per hour. Information from the program would support technology for manned and unmanned reentry from lunar missions. Under the management of the Langley Research Center, Project Fire would use Atlas D boosters and the reentry package would be powered by an Antares solid-fuel motor (third stage of the Scout).

Astronautical and Aeronautical Events of 1962, p. 17.

February 20

The Mercury spacecraft *Friendship 7*, with Astronaut John H. Glenn, Jr., as pilot, was launched into orbit from the Atlantic Missile Range by an Atlas booster. After a three-orbit flight of 4 hours, 55 minutes, and 23 seconds, *Friendship 7* splashed down in the Atlantic Ocean about 800 miles southeast of Bermuda. The spacecraft was recovered within minutes, and Astronaut Glenn was reported to be in excellent condition. With this flight, the basic objectives of Project Mercury had been achieved.

Grimwood, *Project Mercury: A Chronology*, pp. 159-160.

February 27

The preparation of schedules based on the NASA Fiscal Year 1962 budget (including the proposed supplemental appropriation), the Fiscal Year 1963 budget as submitted to Congress, and Fiscal Year 1964 and subsequent funding was discussed at the Manned Space Flight Management Council meeting. Program assumptions as presented by Wernher von Braun, Director, Marshall Space Flight Center (MSFC), were approved for use in preparation of the schedules :

- The Saturn C-5 launch vehicle and earth orbital rendezvous were considered the primary mode for the lunar landing.
- Full-scale orbit operations development, including ground testing, would be accomplished, using S-I boosters and orbital upper stages. This development would be planned so that upper stages and rendezvous techniques would be developed by the time the C-5 was operational. Planning would consider both connecting and fueling modes.
- The development of a two-stage Nova with liquid-propellant engines in both stages would be activated as early as realistically feasible. This would provide an alternative, direct flight mode carrying the same orbital launch vehicle as developed for the C-5.
- There would be no solid-propellant vehicle development.

Charles W. Frick of MSC and Hans H. Maus of MSFC would coordinate schedule assumptions between the Centers.

MSF Management Council Minutes, February 27, 1962, Erratum Sheet, Agenda Item 3.

During the Month

A NASA Apollo Office was established at NAA's Space and Information Systems Division, under the direction of J. Thomas Markley of MSC. The Office would serve primarily as liaison between the prime contractor and the Apollo Spacecraft Project Office at MSC.

MSC *Space News Roundup*, February 21, 1962, p. 8.

During the Month

The command module crew couch was repositioned and redesigned because of numerous problems. In the new design, an adjustable hand controller, similar to that used on the X-15, would be attached to an adjustable arm rest. The head rest could be regulated for an approximate four-inch movement, while the side head support was limited in movement for couch-module clearance. The adjustable leg support included a foot controller which could be folded up.

The center couch, including the crewman parachute and survival kit, could be folded out to a sleep position and stowed under either remaining couch. Allowance was made for the crewman to turn over.

Principal problems remaining were the difficulty of removing the center couch and providing the clearances needed for the couch positions specified for various phases of the lunar mission.

Apollo Monthly Progress Report, SID 62-300-2, p. 43.

During the Month

NASA wind tunnel data on the adaptation of the Project Mercury Little Joe booster to the Apollo launch escape system were analyzed. The booster fins were ineffective in maintaining the stability of the configuration and the project was canceled. The later Little Joe II depended on the inherent stability of the total vehicle to attain a successful ballistic trajectory to test altitude.

Apollo Monthly Progress Report, SID 62-300-2, p. 1; Convair Division of General Dynamics, *Little Joe II Test Launch Vehicle*, *NASA Project Apollo: Final Report* (May 1966), Vol. 1, p. 117.

March 1

NASA Headquarters selected the Chance Vought Corporation of Ling-Temco-Vought, Inc., as a contractor to study spacecraft rendezvous. A primary part of the contract would be a flight simulation study exploring the capability of an astronaut to control an Apollo-type spacecraft.

Astronautical and Aeronautical Events of 1962, p. 27.

March 2

The Marquardt Corporation was selected by NAA's Space and Information Systems Division to design and build the reaction control rocket engines for the Apollo spacecraft. The contract was signed during April.

Oakley, *Historical Summary, S&ID Apollo Program*, p. 6; *Apollo Quarterly Status Report No. 1*, p. 17;

Apollo Spacecraft Project Office, MSC, Weekly Activity Report, February 25-March 3, 1962.

March 3

The Aerojet-General Corporation was named by NAA as a subcontractor for the Apollo service module propulsion system.

Oakley, *Historical Summary, S&ID Apollo Program*, p. 6.

March 6

The organizational elements and staffing for the MSC Apollo Spacecraft Project Office was announced:

Office of Project Manager

Charles W. Frick, Project Manager

Robert O. Piland, Deputy Project Manager

Command and Service Module

Caldwell C. Johnson, Chief

William F. Rector, Special Assistant

Calvin H. Perrine, Flight Technology

Lee N. McMillion, Crew Systems

David L. Winterhalter, Sr., Power Systems

Wallace D. Graves, Mechanical Systems

Milton C. Kingsley, Electrical Systems

(Vacant), Ground Support Equipment

Lunar Landing Module

Robert O. Piland, Acting Chief

Guidance and Control Development

David W. Gilbert, Chief

Jack Barnard, Apollo Office at MIT

Systems Integration

Paul F. Weyers, Chief

(Vacant), Reliability and Quality Control

Emory F. Harris, Operations Requirements

Robert P. Smith, Launch Vehicle Integration

Owen G. Morris, Mission Engineering

Marion R. Franklin, Ground Operational Support Systems

Apollo Office at NAA

Herbert R. Ash, Acting Manager

Alan B. Kehlet, Engineering

Alan B. Kehlet, Acting Manager, Quality Control and Engineering

Herbert R. Ash, Acting Manager, Business Administration

Planning and Resources

Thomas F. Baker, Chief

MSC Announcement No. 30, Personnel Assignments for Apollo Spacecraft Project Office. March 6, 1962.

March 8

NAA awarded a development contract for the Apollo spacecraft fuel cell to Pratt & Whitney Aircraft Division of United Aircraft Corporation.

Oakley, *Historical Summary, S&ID Apollo Program*, p. 5.

March 12

Primary MSC activities for the Apollo program were relocated from Langley Field, Va., to the Manned Spacecraft Center, Houston, Tex.

MSC Announcement No. 21, Relocation of MSC Headquarters, February 26, 1962.

March 12-13

A NASA Headquarters-MSD management meeting was held to discuss the general status of the Apollo

project, Apollo Spacecraft Project Office organization, mission and engineering studies, and budgets and schedules. Participants at the meeting agreed that a staged lunar landing propulsion module would be studied.

Apollo Spacecraft Project Office, MSC, Weekly Activity Report, March 11-17, 1962.

March 13

James E. Webb, NASA Administrator, recommended to President John F. Kennedy that the Apollo program be given DX priority [highest priority in the procurement of critical materials]. He also sent a memorandum to Vice President Lyndon B. Johnson, Chairman of the National Aeronautics and Space Council, requesting that the Council consider advising the President to add the Apollo program to the DX priority list.

Letter, Webb to The President, March 13, 1962; memorandum, Webb to Chairman, National Aeronautics and Space Council, "Request for Highest National Priority for the Apollo Program," March 13, 1962.

March 14

NASA and the Jet Propulsion Laboratory announced the selection of the Military Electronics Division of Motorola, Inc., as the contractor to manufacture and test radio equipment in the first two phases of a program to augment the Deep Space Instrumentation Facility (DSIF) by providing "S" band capability for stations at Goldstone, Calif., Woomera, Australia, and near Johannesburg, South Africa. With these stations located some 120 degrees apart around the earth, DSIF would have a high-gain, narrow-beam-width, high-frequency system, with very little interference from cosmic noise and would provide much improved telemetering and tracking of satellites as far out as the moon and nearby planets.

Astronautical and Aeronautical Events of 1962, p. 35.

March 15-16

Charles W. Frick, Manager of the MSC Apollo Spacecraft Project Office, together with Maxime A. Faget, Charles W. Mathews, Christopher C. Kraft, Jr., John B. Lee, Owen E. Maynard, and Alan B. Kehlet of MSC and George M. Low of the NASA Office of Manned Space Flight, visited NAA at Downey, Calif. This was the first monthly meeting of the Apollo design and review team to survey NAA's progress in various areas, including the Apollo spacecraft heatshield, fuel cells, and service module.

MSF Management Council Minutes, March 27, 1962, Agenda Item 4.

March 18

Marshall Space Flight Center's latest schedule on the Saturn C-5 called for the first launch in the last quarter of 1965 and the first manned launch in the last quarter of 1967. If the C-5 could be man-rated on the eighth research and development flight in the second quarter of 1967, the spacecraft lead time would be substantially reduced.

MSFC Consolidated Program Schedules and Funding, M-CP-R2, March 18, 1962.

March 23

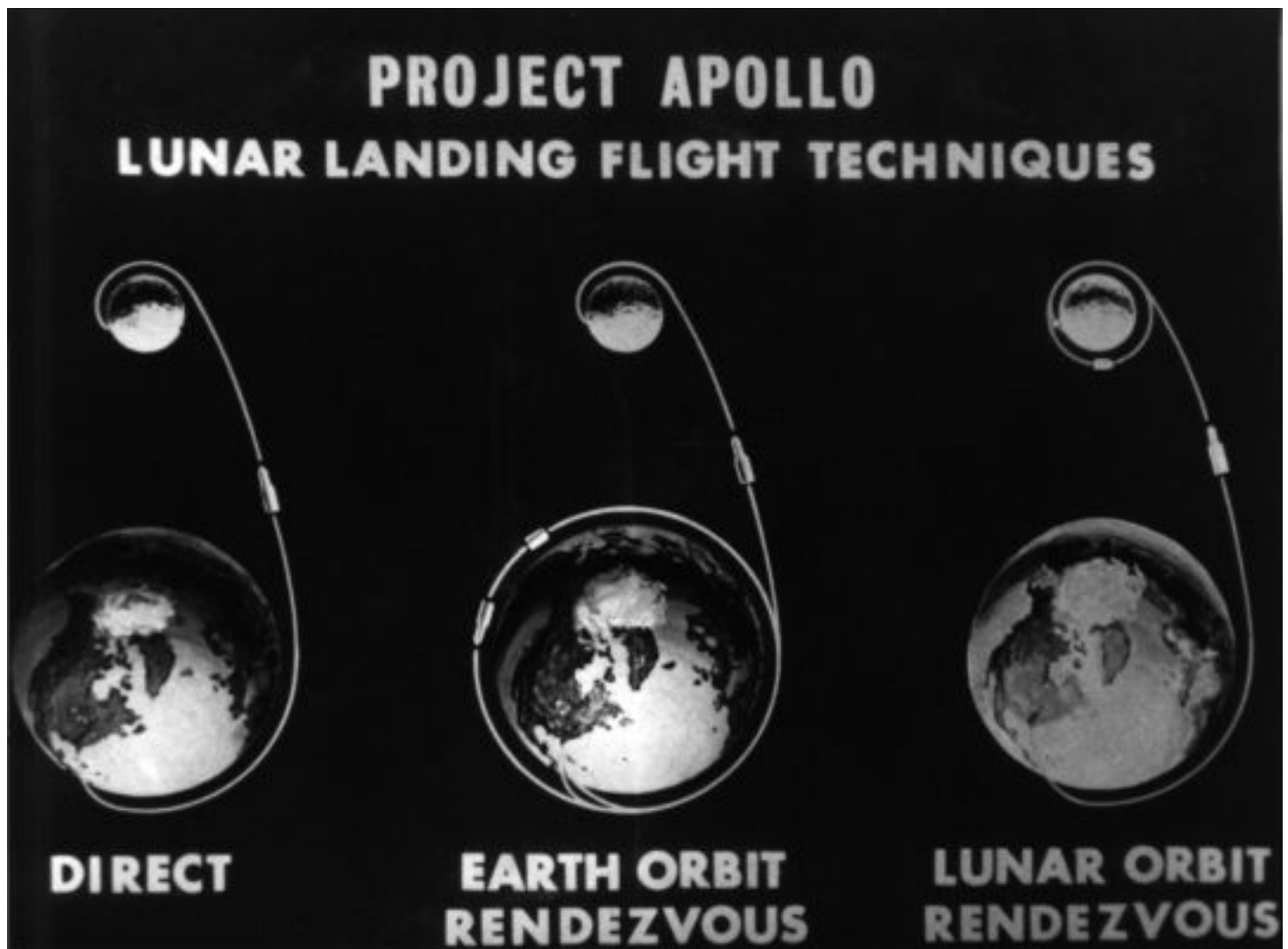
The Avco Corporation was selected by NAA to design and install the ablative material on the Apollo spacecraft outer surface.

Oakley, *Historical Summary, S&ID Apollo Program*, p. 6; Apollo Spacecraft Project Office, MSC, Weekly Activity Report, March 18-24, 1962.

March 23

Wind tunnel tests were completed at the Jet Propulsion Laboratory and at Langley Research Center on two early configurations of Apollo spacecraft models.

Oakley, *Historical Summary, S&ID Apollo Program*, p. 6.



These illustrations were used by D. Brainerd Holmes, Director, Manned Space Flight, NASA, in testimony before the House of Representatives Committee on Science and Astronautics, Subcommittee on Manned Space Flight, March 26, 1962.

March 25-31

NASA Headquarters approved plans for the development of the Little Joe II test launch vehicle. Prospective bidders were notified of a briefing to be held at MSC on April 6, at which time Requests for Proposals would be distributed.

Apollo Spacecraft Project Office, MSC, Weekly Activity Report, March 25-31, 1962.

March 29

Members of Langley Research Center briefed representatives of the Chance Vought Corporation of

Ling- Temco-Vought, Inc., on the lunar orbit rendezvous method of accomplishing the lunar landing mission. The briefing was made in connection with the study contract on spacecraft rendezvous awarded by NASA Headquarters to Chance Vought on March 1.

John D. Bird, "Short History of the Development of the Lunar Orbit Rendezvous Plan at the Langley Research Center," p. 4.

March 29

NASA announced that a \$5 million contract would be awarded to Republic Aviation Corporation for the construction of two experimental reentry spacecraft. Republic was selected from eight companies that submitted bids on March 12. The contract was part of Project Fire, to develop a spacecraft capable of withstanding reentry into the earth's atmosphere from a lunar mission. Plans called for the spacecraft to be tested during the second half of 1963.

New York Times, March 30, 1962.

During the Month

A small group within the MSC Apollo Spacecraft Project Office developed a preliminary program schedule for three approaches to the lunar landing mission: earth orbit rendezvous, direct ascent, and lunar orbit rendezvous. The exercise established a number of ground rules :

- Establish realistic schedules that would "second guess" failures but provide for exploitation of early success.
- Schedule circumlunar, lunar orbit, and lunar landing missions at the earliest realistic dates.
- Complete the flight development of spacecraft modules and operational techniques, using the Saturn C-1 and C-1B launch vehicles, prior to the time at which a "man-rated" C-5 launch vehicle would become available.
- Develop the spacecraft operational techniques in "buildup" missions that would progress generally from the simple to the complex.
- Use the spacecraft crew at the earliest time and to the maximum extent, commensurate with safety considerations, in the development of the spacecraft and its subsystems.

The exercise also provided a basis for proceeding with the development of definitive schedules and a program plan.

Memorandum, Thomas F. Baker, Chief, Planning and Resources, to Manager, Apollo Spacecraft Project Office, March 23, 1962.

March-November

The Apollo guidance and navigation system was defined in more detail as more information from NASA MIT studies was received on new requirements for the system. As a result, the scope of the component development tasks given to all the guidance and navigation subcontractors was substantially increased.

Interview with Ralph Ragan, MIT Instrumentation Laboratory, April 27, 1966.

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PART 3 (C)

Lunar Orbit Rendezvous: Mode and Module

April 1962 through June 1962

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1962

April 1-7

NAA was directed by the MSC Apollo Spacecraft Project Office to begin a study to define the configuration and design criteria of the service module which would make the lunar landing maneuver and touchdown.

Apollo Spacecraft Project Office, MSC, Weekly Activity Report, April 1-7, 1962.

April 2-3

A meeting to review the lunar orbit rendezvous (LOR) technique as a possible mission mode for Project Apollo was held at NASA Headquarters. Representatives from various NASA offices attended: Joseph F. Shea, Eldon W. Hall, William A. Lee, Douglas R. Lord, James E. O'Neill, James Turnock, Richard J. Hayes, Richard C. Henry, and Melvyn Savage of NASA Headquarters; Friedrich O. Vonbun of Goddard Space Flight Center (GSFC); Harris M. Schurmeier of Jet Propulsion Laboratory; Arthur V. Zimmeman of Lewis Research Center; Jack Funk, Charles W. Mathews, Owen E. Maynard, and William F. Rector of MSC; Paul J. DeFries, Ernst D. Geissler, and Helmut J. Horn of Marshall Space Flight Center (MSFC); Clinton E. Brown, John C. Houbolt, and William H. Michael, Jr., of Langley Research Center; and Merrill H. Mead of Ames Research Center. Each phase of the LOR mission was discussed separately.

The launch vehicle required was a single Saturn C-5, consisting of the S-IC, S-II, and S-IVB stages. To provide a maximum launch window, a low earth parking orbit was recommended. For greater reliability, the two-stage-to-orbit technique was recommended rather than requiring reignition of the S-IVB to escape from parking orbit.

The current concepts of the Apollo command and service modules would not be altered. The lunar excursion vehicle (LEV), under intensive study in 1961, would be aft of the service module and in front of the S-IVB stage. For crew safety, an escape tower would be used during launch. Access to the LEV would be provided while the entire vehicle was on the launch pad.

Both Apollo and Saturn guidance and control systems would be operating during the launch phase. The Saturn guidance and control system in the S-IVB would be "primary" for injection into the earth parking orbit and from earth orbit to escape. Provisions for takeover of the Saturn guidance and control system should be provided in the command module. Ground tracking was necessary during launch and establishment of the parking orbit, MSFC and GSFC would study the altitude and type of low earth orbit.

The LEV would be moved in front of the command module "early" in the translunar trajectory. After the S-IVB was staged off the spacecraft following injection into the translunar trajectory, the service module would be used for midcourse corrections. Current plans were for five such corrections. If possible, a symmetric configuration along the vertical center line of the vehicle would be considered for the LEV. Ingress to the LEV from the command module should be possible during the translunar phase. The LEV would have a pressurized cabin capability during the translunar phase. A "hard dock" mechanism was considered, possibly using the support structure needed for the launch escape tower. The mechanism for relocation of the LEV to the top of the command module required further study. Two possibilities were discussed: mechanical linkage and rotating the command module by use of the attitude control system. The S-IVB could be used to stabilize the LEV during this maneuver.

The service module propulsion would be used to decelerate the spacecraft into a lunar orbit. Selection of the altitude and type of lunar orbit needed more study, although a 100-nautical-mile orbit seemed desirable for abort considerations.

The LEV would have a "point" landing ($\pm\frac{1}{2}$ mile) capability. The landing site, selected before liftoff, would previously have been examined by unmanned instrumented spacecraft. It was agreed that the LEV would have redundant guidance and control capability for each phase of the lunar maneuvers. Two types of LEV guidance and control systems were recommended for further analysis. These were an automatic system employing an inertial platform plus radio aids and a manually controlled system which could be used if the automatic system failed or as a primary system.

The service module would provide the prime propulsion for establishing the entire spacecraft in lunar orbit and for escape from the lunar orbit to earth trajectory. The LEV propulsion system was discussed and the general consensus was that this area would require further study. It was agreed that the propulsion system should have a hover capability near the lunar surface but that this requirement also

needed more study.

It was recommended that two men be in the LEV, which would descend to the lunar surface, and that both men should be able to leave the LEV at the same time. It was agreed that the LEV should have a pressurized cabin which would have the capability for one week's operation, even though a normal LOR mission would be 24 hours. The question of lunar stay time was discussed and it was agreed that Langley should continue to analyze the situation. Requirements for sterilization procedures were discussed and referred for further study. The time for lunar landing was not resolved.

In the discussion of rendezvous requirements, it was agreed that two systems be studied, one automatic and one providing for a degree of manual capability. A line of sight between the LEV and the orbiting spacecraft should exist before lunar takeoff. A question about hard-docking or soft-docking technique brought up the possibility of keeping the LEV attached to the spacecraft during the transearth phase. This procedure would provide some command module subsystem redundancy.

Direct link communications from earth to the LEV and from earth to the spacecraft, except when it was in the shadow of the moon, was recommended. Voice communications should be provided from the earth to the lunar surface and the possibility of television coverage would be considered.

A number of problems associated with the proposed mission plan were outlined for NASA Center investigation. Work on most of the problems was already under way and the needed information was expected to be compiled in about one month.

[This meeting, like the one held February 13-15, was part of a continuing effort to select the lunar mission mode.]

Minutes, Lunar Orbit Rendezvous Meeting, April 2-3, 1962.

April 4



Two views of a preliminary mockup command module build by North American's Space and Information Systems Division.

A mockup of the Apollo command module, built by the Space and Information Systems Division of NAA, was made public for the first time during a visit to NAA by news media representatives.

Oakley, *Historical Summary, S&ID Apollo Program*, p. 6.

April 5

The X-15 was flown to a speed of 2,830 miles per hour and to an altitude of 179,000 feet in a test of a new automatic control system to be used in the Dyna-Soar and Apollo spacecraft. NASA's Neil A. Armstrong was the pilot. The previous electronic control system had been automatic only while the X-

15 was in the atmosphere; the new system was automatic in space as well.

Baltimore *Sun*, April 6, 1962.

April 6

The Thiokol Chemical Corporation was selected by NAA to build the solid-fuel rocket motor to be used to jettison the Apollo launch escape tower following a launch abort or during a normal mission.

Oakley, *Historical Summary, S&ID Apollo Program*, p. 6.

April 6

The request for a proposal on the Little Joe II test launch vehicle was submitted to bidders by a letter from MSC, together with a Work Statement. Five launches, which were to test boilerplate models of the Apollo spacecraft command module in abort situations, were called for: three in 1963 and two in 1964. The first two launches in 1963 were to be max q abort tests and the third was to be a high-altitude atmospheric abort. The first launch in 1964 was to be a very-high-altitude abort and the final launch a confirming max q abort [max q - the point in the exit trajectory at which the launch vehicle and spacecraft are subjected to the severest aerodynamic load]. (Evaluation of the proposals took place from April 23 to 27, and the contractor was selected on May 11).

Apollo Spacecraft Project Office, MSC, Monthly Activity Report, April 1-30, 1962, p. 3; *Little Joe II Test Launch Vehicle, NASA Project Apollo: Final Report*, Vol. I, pp 1-2, 4-1.

April 11

President John F. Kennedy designated the Apollo program including essential spacecraft, launch vehicles, and facilities as being in the highest national priority category (DX) for research and development and for achieving operational capability.

National Security Action Memorandum No. 144, McGeorge Bundy to the Vice President (as Chairman, National Aeronautics and Space Council); The Secretary of Defense; the Secretary of Commerce; Administrator, NASA; Director, Bureau of the Budget; Director, Office of Emergency Planning, "Assignment of Highest National Priority to the APOLLO Manned Lunar Landing Program," April 11, 1962.

April 16

Representatives of MSC made a formal presentation at Marshall Space Flight Center on the lunar orbit rendezvous technique for accomplishing the lunar mission.

Apollo Spacecraft Project Office, MSC, Weekly Activity Report, April 15- 21, 1962.

April 19-20

Discussions at the monthly NAA-NASA Apollo spacecraft design review included:

- Results of an NAA study on environmental control system (ECS) heating capabilities for lunar night operations were presented. The study showed that the system could not provide enough heating and that the integration of ECS and the fuel cell coolant system was the most promising source for supplemental heating.
- The launch escape system configuration was approved. It embodied a 120inch tower, symmetrical nose cone, jettison motor located forward of the launch escape motor, and an aerodynamic skirt covering the escape motor nozzles. This configuration change in the escape rocket nozzle cant angle was intended to prevent impingement of hot gases on the command module.
- MSC senior personnel directed NAA to study the technical penalties and scheduling effects of spacecraft design capabilities with direct lunar landing and lunar rendezvous techniques.

NAA, *Apollo Monthly Progress Report*, SID 62-300-3, April 30, 1962, pp. 19, 59; Apollo Spacecraft Project Office, MSC, Weekly Activity Report, April 15-21, 1962.

April 23

Ranger IV was launched by an Atlas-Agena B booster from the Atlantic Missile Range, attained a parking orbit, and was fired into the proper lunar trajectory by the restart of the Agena B engine. Failure of a timer in the spacecraft payload caused loss of both internal and ground control over the vehicle. The Goldstone Tracking Station maintained contact with the spacecraft until it passed behind the left edge of the moon on April 26. It impacted at a speed of 5,963 miles per hour, the first American spacecraft to land on the lunar surface. The Agena B second stage passed to the right of the moon and later went into orbit around the sun. Lunar photography objectives were not achieved.

Astronautical and Aeronautical Events of 1962, pp. 59, 61; *New York Times*, April 24, 1962; *Washington Post*, April 26, 1962.

April 24

Milton W. Rosen, NASA Office of Manned Space Flight Director of Launch Vehicles and Propulsion, recommended that the S-IVB stage be designed specifically as the third stage of the Saturn C-5 and that the C-5 be designed specifically for the manned lunar landing using the lunar orbit rendezvous technique. The S-IVB stage would inject the spacecraft into a parking orbit and would be restarted in space to place the lunar mission payload into a translunar trajectory. Rosen also recommended that the S-IVB stage be used as a flight test vehicle to exercise the command module (CM), service module

(SM), and lunar excursion module (LEM) [previously referred to as the lunar excursion vehicle (LEV)] in earth orbit missions. The Saturn C-1 vehicle, in combination with the CM, SM, LEM, and S-IVB stage, would be used on the most realistic mission simulation possible. This combination would also permit the most nearly complete operational mating of the CM, SM, LEM, and S-IVB prior to actual mission flight.

MSF Management Council Minutes, April 24, 1962, Agenda Item 1.

April 24

MSC Associate Director Walter C. William reported to the Manned Space Flight Management Council that the lack of a decision on the lunar mission mode was causing delays in various areas of the Apollo spacecraft program, especially the requirements for the portions of the spacecraft being furnished by NAA.

MSF Management Council Minutes, April 24, 1962, Agenda Item 2.

April 24

The Manned Space Flight Management Council decided to delay the awarding of a Nova launch vehicle study contract until July 1 at the earliest to allow time for an in-house study of bids submitted and for further examination of the schedule for a manned lunar landing using the direct ascent technique.

MSF Management Council Minutes, April 24, 1962, Agenda Item 4.

April 25

The Saturn SA-2 first stage booster was launched successfully from Cape Canaveral. The rocket was blown up intentionally and on schedule about 2.5 minutes after liftoff at an altitude of 65 miles, dumping the water ballast from the dummy second and third stages into the upper atmosphere. The experiment, Project Highwater, produced a massive ice cloud and lightning-like effects. The eight clustered H-1 engines in the first stage produced 1.3 million pounds of thrust and the maximum speed attained by the booster was 3,750 miles per hour. Modifications to decrease the slight fuel sloshing encountered near the end of the previous flight test were successful.

New York Times, April 26, 1962; *Astronautical and Aeronautical Events of 1962*, p.61.

April 30

The contract for the Apollo service module propulsion engine was awarded by NAA to Aerojet-General Corporation. The estimated cost of the contract was \$12 million. NAA had given Aerojet-General authority April 9 to begin work.

Apollo Quarterly Status Report No. 1, p. 19; *MSC Space News Roundup*, May 2, 1962, p. 8; Aerojet-General Corporation, *Apollo Service Module Rocket Engine Monthly Progress Report*, October 1962, p. 1.

During the Month

John C. Houbolt of Langley Research Center, writing in the April issue of *Astronautics*, outlined the advantages of lunar orbit rendezvous for a manned lunar landing as opposed to direct flight from earth or earth orbit rendezvous. Under this concept, an Apollo-type spacecraft would fly directly to the moon, go into lunar orbit, detach a small landing craft which would land on the moon and then return to the mother craft, which would then return to earth. The advantages would be the much smaller craft performing the difficult lunar landing and takeoff, the possibility of optimizing the smaller craft for this one function, the safe return of the mother craft in event of a landing accident, and even the possibility of using two of the small craft to provide a rescue capability.

Houbolt, "Lunar-Orbit Rendezvous and Manned Lunar Landing," *Astronautics*, 7 (April 1962), pp.26-29, 70, 72.

During the Month

The basic design configuration of the command module forward compartment was changed by the relocation of two attitude control engines from the lower to the upper compartment area, where less heat flux would be experienced during reentry.

Apollo Monthly Progress Report, SID 62-300-3, p. 79.

During the Month

Three major changes were made by NAA in the Apollo space-suit circuit:

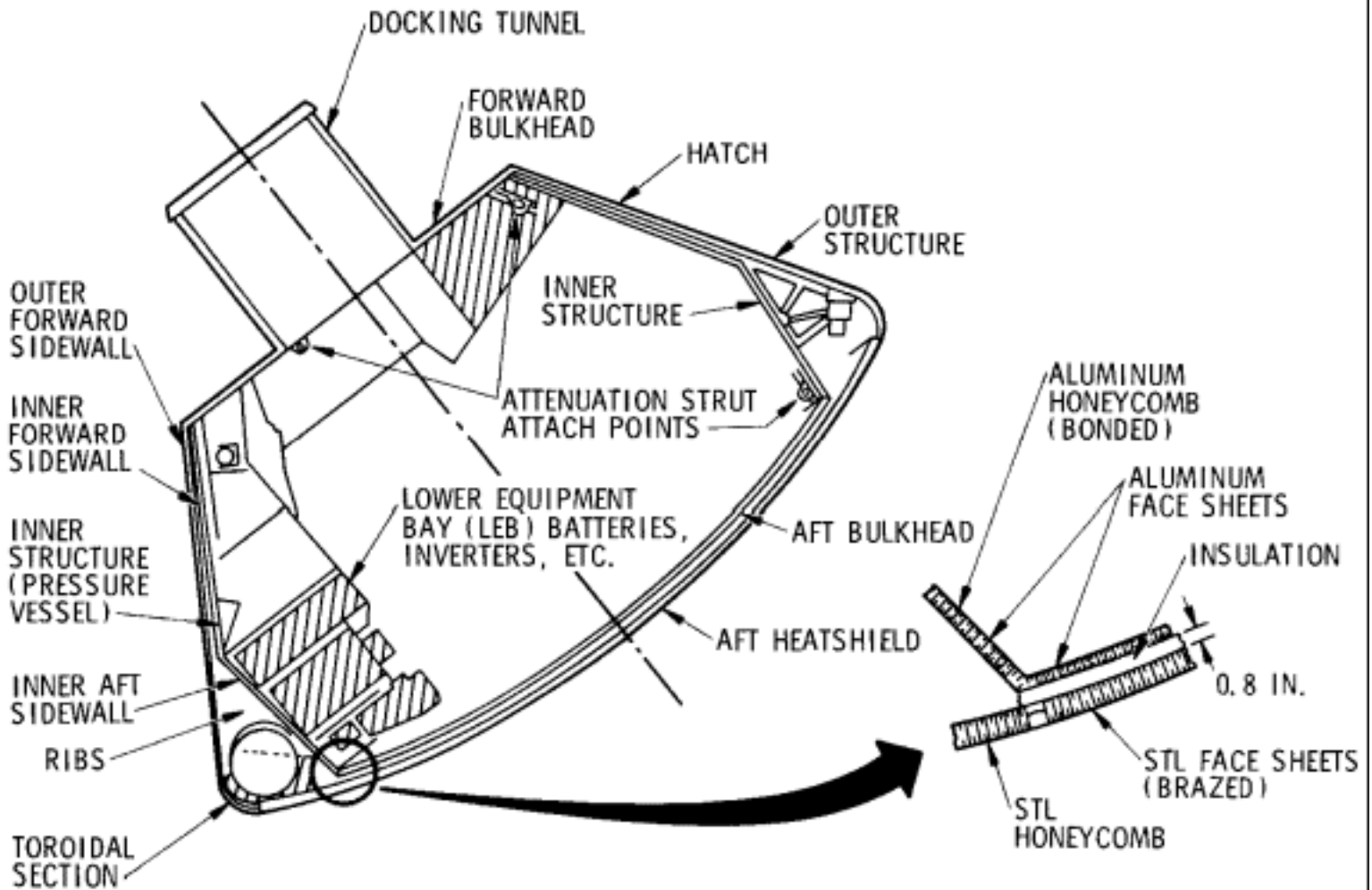
1. The demand oxygen regulator was moved downstream of the crew to prevent a sudden drop of pressure when a crewman opened his face plate.
2. The suit manifold would now have a pressure-controlled bypass to prevent variable flow to other crew members if one crewman increased or decreased oxygen flow. The manifold would also include a venturi in each suit-inlet connection to prevent a loss of oxygen flow to other crew members if the suit of one crewman should rupture. In this situation, the venturi would prevent the damaged suit flow out from exceeding the maximum flow of demand regulators.
3. The circuit water evaporator and coolant loop heat exchanger of the suit were integrated into one by fluid exchange to make it smaller. A coolant-temperature control was also provided for sunlight operation on the moon.

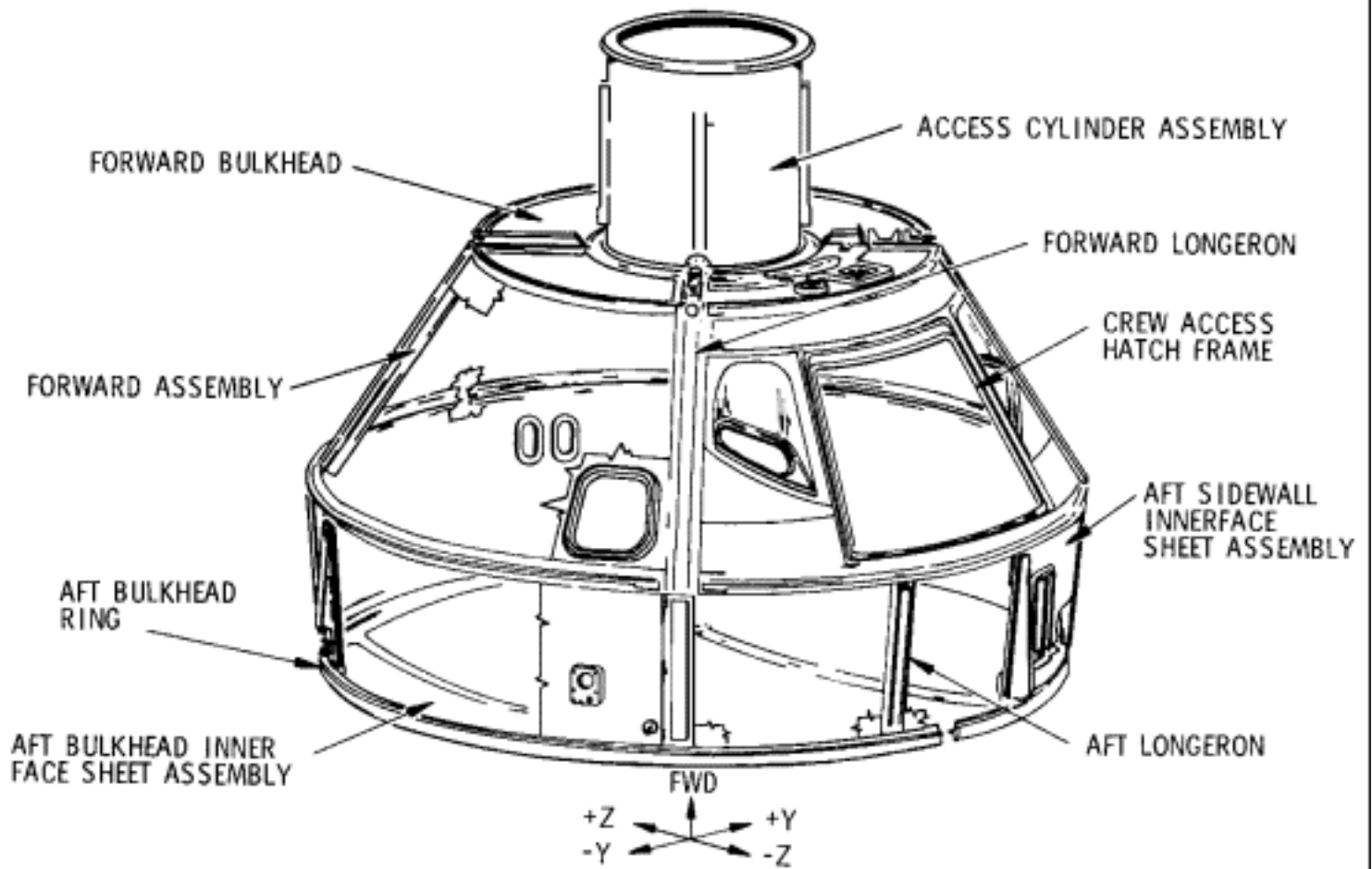
In addition, a suit inlet-outlet was added to the command module sleeping quarters, and the cabin fan was shifted so that it would operate as an intake fan during the post-landing phase.

Apollo Monthly Progress Report, SID 62-300-3, pp. 17-18, 65.

During the Month

NAA developed a concept for shock attenuation along the command module Y-Y axis by the use of aluminum honeycomb material.





Cylinders mounted on the outboard edge of the left and right couches would extend mechanically to bear against the side compartment walls.

Apollo Monthly Progress Report, SID 62-300-3, p. 68.

During the Month

NAA studies resulted in significant changes in the command module environmental control system (ECS).

1. Among modifications in the ECS schematic were included:
 1. Reduction in the cooling water capacity
 2. Combining into one command module tank the potable water and cooling water needed during boost
 3. Elimination of the water blanket for radiation protection.
2. More water would be generated by the fuel cells than necessary and could be dumped to decrease lunar landing and lunar takeoff weight.
3. Airlock valving requirements would permit two or more crewmen to perform extravehicular

operation simultaneously. Area control of the space radiator to prevent coolant freezing was specified.

4. A new concept to integrate heat rejection from the spacecraft power system and the ECS into one space radiator subsystem was developed. This subsystem would provide full versatility for both lunar night and lunar day conditions and would decrease weight and complexity.
5. Because of the elimination of the lunar supplemental refrigeration system and deployable radiators, the water-glycol coolant system was modified:
 1. Removal from the service module of the coolant loop regenerative heat exchanger
 2. Replacement by a liquid valving arrangement of the gas-leak check provision at the radiator panels
 3. Changeover to a completely cascaded system involving the suit-circuit heat exchanger, cabin heat exchanger, and electronic component coldplate.

In addition, a small, regenerative heat exchanger was added in the command module to preheat the water-glycol. A separate coolant branch to the inertial measurement unit section of the electronic system provided for the more critical cooling task required in that area.

Apollo Monthly Progress Report, SID 62-300-3, pp. 15, 17, 21, 64-65.

During the Month

NAA determined that preliminary inflight nuclear radiation instrumentation would consist of an onboard system to detect solar x-ray or ultraviolet radiation and a ground visual system for telemetering solar flare warning signals to the command module. The crew would have eight to ten minutes warning to take protective action before the arrival of solar flare proton radiation.

Apollo Monthly Progress Report, SID 62-300-3, p. 22.

May 3

A presentation on the lunar orbit rendezvous technique was made to D. Brainerd Holmes, Director, NASA Office of Manned Space Flight, by representatives of the Apollo Spacecraft Project Office. A similar presentation to NASA Associate Administrator Robert C. Seamans, Jr., followed on May 31.

Apollo Spacecraft Project Office, MSC, Monthly Activity Report, May 1-31, 1962.

May 4

The Source Evaluation Board for selecting Apollo navigation and guidance components subcontractors completed its evaluation of bids and technical proposals and submitted its findings to NASA Headquarters. Preliminary presentation of the Board's findings had been made to NASA Administrator James E. Webb on April 5.

Apollo Spacecraft Project Office, MSC, Weekly Activity Report, April 1- 7, 1962; MSC, Weekly Activity Report for the Office of the Director, Manned Space Flight, April 29-May 5, 1962, p. 12.

May 4-5

At the monthly Apollo spacecraft design review meeting at NAA, MSC representatives recommended that NAA and Avco Corporation prepare a comprehensive test plan for verifying the overall integrity of the heatshield including flight tests deemed necessary, without regard for anticipated hunch vehicle availability.

Apollo Spacecraft Project Office, MSC, Weekly Activity Report, June 3-9, 1962.

May 6

A preliminary Statement of Work for a proposed lunar excursion module was completed, although the mission mode had not yet been selected.

MSC, Weekly Activity Report for the Office of the Director, Manned Space Flight, April 29-May 5, 1962, p. 12.

May 3

A purchase request was being prepared by NASA for wind tunnel support services from the Air Force's Arnold Engineering Development Center in the amount of approximately \$222,000. These wind tunnel tests were to provide design parameter data on static stability, dynamic stability, pressure stability, and heat transfer for the Apollo program. The funds were to cover tests during June and July 1962. Approximately \$632,000 would be required in Fiscal Year 1963 to fund the tests scheduled to December 1962.

MSC, Weekly Activity Report for the Office of the Director, Manned Space Flight, April 29-May 5, 1962, p. 13.

May 5

MSC processed a purchase request to increase NAA's spacecraft letter contract from \$32 million to \$55 million to cover NAA's costs to June 30, 1962. [Pending the execution of a definitive contract (signed August 14, 1963), actions of this type were necessary].

MSC, Weekly Activity Report for the Office of the Director, Manned Space Flight, April 29-May 5, 1962, p. 13; Oakley, *Historical Summary, S&ID Apollo Program*, p. 9.

May 8

NASA announced the selection of three companies for the negotiation of production contracts for major components of the Apollo spacecraft guidance and navigation system under development by the MIT Instrumentation Laboratory. The largest of the contracts, for \$16 million, would be negotiated with AC Spark Plug Division of General Motor Corporation for fabrication of the inertial, gyroscope-stabilized platform of the Apollo spacecraft; for development and construction of ground support and checkout equipment; and for assembling and testing all parts of the system. The second contract, for \$2 million, would be negotiated with the Raytheon Company to manufacture the digital computer aboard the spacecraft. Under the third contract, for about \$2 million, Kollsman Instrument Corporation would build the optical subsystems, including a space sextant, sunfinders, and navigation display equipment.

Apollo Spacecraft Project Office, MSC, Weekly Activity Report, May 5-11, 1962; *Washington Evening Star*, May 9, 1962.

May 11

NASA awarded a letter contract to General Dynamics/Convair to design and manufacture the Little Joe II test launch vehicle which would be used to boost the Apollo spacecraft on unmanned suborbital test flights. The Little Joe II would be powered by clustered solid-fuel engines. At the same time, a separate 30-day contract was awarded to Convair to study the control system requirements. White Sands Missile Range, N. Mex., had been selected for the Little Joe II max q abort and high-altitude abort missions.

Apollo Spacecraft Project Office, MSC, Weekly Activity Report, May 13-19, 1962; *Little Joe II Test Launch Vehicle, NASA Project Apollo: Final Report*, Vol. I, pp. 1-2, 4-1; *Aeronautical and Aeronautical Events of 1962*, p. 82.

May 24

The *Aurora 7* spacecraft, with Astronaut M. Scott Carpenter as pilot, was launched successfully by an Atlas booster from Atlantic Missile Range. After a three-orbit flight, the spacecraft reentered the atmosphere. Yaw error and late retrofire caused the landing impact point to be over 200 miles beyond the intended area and beyond radio range of the recovery forces. Landing occurred 4 hours and 56 minutes after liftoff. Astronaut Carpenter was later picked up safely by a helicopter.

Grimwood, *Project Mercury: A Chronology*, pp. 164-165.

May 25

D. Brainerd Holmes, NASA's Director of Manned Space Flight, requested the Directors of Launch Operations Center, Manned Spacecraft Center, and Marshall Space Flight Center (MSFC) to prepare supporting component schedules and cost breakdowns through Fiscal Year 1967 for each of the

proposed lunar landing modes: earth orbit rendezvous, lunar orbit rendezvous, and direct ascent. For direct ascent, a Saturn C-8 launch vehicle was planned, using a configuration of eight F-1 engines, eight J-2 engines, and one J-2 engine. MSFC was also requested to submit a proposed schedule and summary of costs for the Nova launch vehicle, using the configuration of eight F-1 engines, two M-1 engines, and one J-2 engine. Each Center was asked to make an evaluation of the schedules as to possibilities of achievement, major problem areas, and recommendations for deviations.

Memorandum, Holmes to Director, Launch Operations Center; Director, Manned Spacecraft Center; and Director, Marshall Space Flight Center, "The Manned Lunar Landing Program," May 25, 1962.

May 26

The F-1 engine was first fired at full power (more than 1.5 million pounds of thrust) for 2.5 minutes at Edwards Rocket Site, Calif.

Rocketdyne *Skywriter*, June 1, 1962, p. 1.

May 29

A schedule for the letting of a contract for the development of a lunar excursion module was presented to the Manned Space Flight Management Council by MSC Director Robert R. Gilruth in anticipation of a possible decision to employ the lunar rendezvous technique in the lunar landing mission.

MSF Management Council Minutes, May 29, 1962, Agenda Item 12.

May 29

The Manned Space Flight Management Council approved the mobile launcher concept for the Saturn C-5 at Launch Complex 39, Merritt Island, Fla.

MSF Management Council Minutes, May 29, 1962, Agenda Item 9.

During the Month

NAA completed a preliminary requirement outline for spacecraft docking. The outline specified that the two spacecraft be navigated to within a few feet of each other and held to a relative velocity of less than six inches per second and that they be steered to within a few inches of axial alignment and parallelism. The crewman in the airlock was assumed to be adequately protected against radiation and meteoric bombardment and to be able to grasp the docking spacecraft and maneuver it to the sealing faces for final clamp.

NAA, *Apollo Monthly Progress Report*, SID 62-300 4, May 31, 1962, p. 66.

During the Month

A feasibility study was completed by NAA on the ballistic (zero-lift) maneuver as a possible emergency flight mode for lunar mission reentry. Based upon single-pass and 12 g maximum load-factor criteria, the guidance corridor would be nine nautical miles. When atmospheric density deviations were considered (+/- 50 percent from standard), the allowable corridor would be reduced to four nautical miles. Touchdown dispersions within the defined corridor exceeded 2500 nautical miles.

Apollo Monthly Progress Report, SID 62-300-4, p. 17.

During the Month

Telescope requirements for the spacecraft were modified after two study programs had been completed by NAA.

A study on the direct vision requirement for lunar landing showed that, to have a simultaneous direct view of the lunar landing point and the landing feet without changing the spacecraft configuration, a periscope with a large field of view integrated with a side window would be needed. A similar requirement on the general-purpose telescope could thus be eliminated, reducing the complexity of the telescope design.

Another study showed that, with an additional weight penalty of from five to ten pounds, an optical drift indicator for use after parachute deployment could easily be incorporated into the general-purpose telescope.

Apollo Monthly Progress Report, SID 62-300-4, pp. 29-30.

During the Month

The first reliability prediction study for the Apollo spacecraft was completed by NAA. Assuming all systems as series elements and excluding consideration of alternative modes, redundancies, or inflight maintenance provisions, the study gave a reliability estimate of 0.731. This analysis provided a basis from which means of improving reliability would be evaluated and formulated.

Apollo Monthly Progress Report, SID 62-300-4, p. 26.

During the Month

Layouts of three command module observation window configurations were made by NAA. A study

disclosed that sufficient direct vision for lunar landing was not feasible and that windows could not be uncovered during reentry.

Apollo Monthly Progress Report, SID 62-300-4, p. 66.

During the Month

NAA began compiling a list of command module materials to be classified selectively for potentially toxic properties. These materials would be investigated to determine location (related to possible venting of gases), fire resistance, exposure to excessive temperatures, gases resulting from thermal decomposition, and toxicity of gases released under normal and material-failure conditions. Although a complete examination of every material was not feasible, materials could be grouped according to chemical constituency and quantity of gases released.

Apollo Monthly Progress Report, SID 62-300-4, p. 10,

During the Month

The basic spacecraft adapter structure was defined as consisting of six aluminum honeycomb panels, six longerons, and forward and aft bulkheads. The design of the honeycomb panels for the test requirements program was complete.

Apollo Monthly Progress Report, SID 62-300-4. v. 89.

During the Month

NAA decided to retain the inward-opening pull-down concept for the spacecraft crew hatch, which would use plain through bolts for lower sill attachment and a manual jack-screw device to supply the force necessary to seat and unseat the hatch.

Concurrently, a number of NAA latching concepts were in preparation for presentation to NASA, including that of an outward-opening, quick-opening crew door without an outer emergency panel. This design, however, had weight and complexity disadvantages, as well as requiring explosive charges.

Apollo Monthly Progress Report, SID 62-300-4, p. 68.

During the Month

The command module reaction control system (RCS) selected by NAA was a dual system without interconnections. Either would be sufficient for the entire mission.

For the service module RCS, a quadruple arrangement was chosen which was basically similar to the command module RCS except that squib valves and burst discs were eliminated.

Apollo Monthly Progress Report, SID 62-300-4, p. 84.

During the Month

NAA evaluated the possibility of integrating the fuel cell and environmental control system heat rejection into one system. The integrated system proved to be unsatisfactory, being 300 pounds heavier and considerably more complex than the two separate systems. A preliminary design of separate fuel cell radiators, possibly located on the service module, was started by NAA.

Apollo Monthly Progress Report, SID 62-300-4, p. 82.

During the Month

NAA studies on the prototype crew couch included one on the use of the center couch for supporting a crewman at the astro sextant during lunar approach and another on the displacement of outboard couches for access to equipment areas.

Apollo Monthly Progress Report, SID 62-300-4, p. 65.

During the Month

Two NAA analyses showed that the urine management system would prevent a rise in the command module humidity load and atmospheric contamination and that freeze-up of the line used for daily evacuation of urine to the vacuum of space could be prevented by proper orificing of the line.

Apollo Monthly Progress Report, SID 62-300-4, pp. 10-11

June 7

Wernher von Braun, Director, Marshall Space Flight Center, recommended to the NASA Office of Manned Space Flight that the lunar orbit rendezvous mode be adopted for the lunar landing mission. He also recommended the development of an unmanned, fully automatic, one-way Saturn C-5 logistics vehicle in support of the lunar expedition; the acceleration of the Saturn C-1B program; the development of high-energy propulsion systems as a backup for the service module and possibly the lunar excursion module; and further development of the F-1 and J-2 engines to increase thrust or specific impulse.

"Concluding Remarks by Dr. Wernher von Braun about Mode Selection for the Lunar Landing Program Given to Dr. Joseph F. Shea, Deputy Director (Systems), Office of Manned Space Flight, June 7, 1962,"

undated.

June 10-11

NAA was directed by the Apollo Spacecraft Project Office at the monthly design review meeting to design an earth landing system for a passive touchdown mode to include the command module cant angle limited to about five degrees and favoring offset center of gravity, no roll orientation control, no deployable heatshield, and depressurization of the reaction control system propellant prior to impact. At the same meeting, NAA was requested to use a single "kicker" rocket and a passive thrust-vector-control system for the spacecraft launch escape system.

Apollo Spacecraft Project Office, MSC, Weekly Activity Report, June 8-14, 1962.

June 16

NASA announced that the Apollo service module propulsion system would be tested at a new facility at White Sands Missile Range, N. Mex.

Oakley, *Historical Summary, S&ID Apollo Program*, p. 7.

June 16-22

Results of a preliminary investigation by NAA showed that a 100 percent oxygen atmosphere for the command module would save about 30 pounds in weight and reduce control complexity.

NASA-Resident Apollo Spacecraft Project Office, NAA, Weekly Activity Report for Week Ending June 22, 1962, p. 3.

June 18

As the result of considerable joint engineering effort and discussion by NAA and MIT Instrumentation Laboratory, the location of the onboard space sextant in the command module was changed from the main instrument panel to the wall of the lower equipment bay. The instrument would penetrate the hull on the hot side during reentry and the navigator would have to leave his couch to make navigation sightings and to align the inertial measurement unit.

David G. Hoag, personal notes, June 18, 1962.

June 22

MSC Director Robert R. Gilruth reported to the Manned Space Flight Management Council that the

selection of the ablative material for the Apollo spacecraft heatshield would be made by September 1. The leading contender for the forebody ablative material was an epoxy resin with silica fibers for improving char strength and phenolic microballoons for reducing density.

In addition, Gilruth noted that a reevaluation of the Saturn C-1 and C-1B launch capabilities appeared to indicate that neither vehicle would be able to test the complete Apollo spacecraft configuration, including the lunar excursion module. Complete spacecraft qualification would require the use of the Saturn C-5.

MSF Management Council Minutes, June 22, 1962, Agenda Item 2.

June 22

Joseph F. Shea, NASA Deputy Director of Manned Space Flight (Systems), presented to the Manned Space Flight Management Council the results of the study on lunar mission mode selection. The study included work by personnel in Shea's office, MSC, and Marshall Space Flight Center. The criteria used in evaluating the direct ascent technique, earth orbit rendezvous connecting and fueling modes, and lunar orbit rendezvous were: the mission itself, weight margins, guidance accuracy, communications and tracking requirements, reliability (abort problems), development complexity, schedules, costs, flexibility, growth potential, and military implications.

MSF Management Council Minutes, June 22, 1962, Agenda Item 12.

June 22

After an extended discussion, the Manned Space Flight Management Council unanimously decided:

- Lunar orbit rendezvous, using the Saturn C-5 launch vehicle, should be the mission mode for lunar exploration.
- The development of a lunar logistics vehicle, using the Saturn C-1B or the C-5 launch vehicle, should be started and a six-month study of this development should begin immediately.
- Time was too short and the expense too great to develop a parallel backup mode.
- Study of the Nova vehicle should continue with the expectation that its development would follow the C-5 by two or three years.
- The C-1B launch vehicle should be started immediately, looking toward the first two-stage flight in mid- 1965.
- Development of a lunar excursion module should begin at once.

These decisions were to be presented to NASA Associate Administrator Robert C. Seamans, Jr., NASA Deputy Administrator Hugh L. Dryden, and NASA Administrator James E. Webb for approval.

MSF Management Council Minutes, June 22, 1962, Agenda Item 12.

June 30

A thermal coverall for use in extravehicular space suit design was completed in-house and would be shipped to Vought Astronautics for use in the MSC evaluation contract.

MSC, Weekly Activity Report for the Office of the Director, Manned Space Flight, June 24-30, 1962.

During the Month

Five NASA scientists, dressed in pressure suits, completed an exploratory study at Rocketdyne Division of the feasibility of repairing, replacing, maintaining, and adjusting components of the J-2 rocket while in space. The scientific team also investigated the design of special maintenance tools and the effectiveness of different pressure suits in performing maintenance work in space.

Rocketdyne *Skywriter*, July 13, 1962.

Summer-Fall

NASA and MIT agreed that the Instrumentation Laboratory would use the microcircuit for the prototype Apollo onboard computer. The Fairchild Controls Corporation microcircuit was the only one available in the United States.

Interview with Ralph Ragan, Instrumentation Laboratory, MIT, April 27, 1966.

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PART 3 (D)

Lunar Orbit Rendezvous: Mode and Module

July 1962 through September 1962

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July 1-7

The delta V (rate of incremental change in velocity) requirements for the lunar landing mission were established and coordinated with NAA by the Apollo Spacecraft Project Office.

Apollo Spacecraft Project Office, MSC, Weekly Activity Report, July 1-7, 1962.

July 2

NASA awarded three contracts totaling an estimated \$289 million to NAA's Rocketdyne Division for the further development and production of the F-1 and J-2 rocket engines.

Wall Street Journal, July 3, 1962.

July 6

The document entitled "Charter of the MSFC-STG Space Vehicle Board," adopted on October 3, 1961, was revised to read "Spacecraft Launch Vehicle Coordination Charter for the Apollo Program MSFC-MSFC." The reasons for the revision were: to include the recently formed Management Council, to include the Electrical Systems Integration Panel and Instrumentation and Communications Panel responsibilities, and to establish Integration Offices within MSC and Marshall Space Flight Center

(MSFC) to manage the Panels.

MSF Management Council Minutes, June 25, 1963, Agenda Item 6.

July 6

Employment at NAA's Space and Information Systems Division reached 14,119, an increase of 7,000 in seven months.

Oakley, *Historical Summary, S&ID Apollo Program*, p. 7.

July 10

The first Apollo spacecraft mockup inspection was held at NAA's Space and Information Systems Division. In attendance were Robert R. Gilruth, Director, MSC; Charles W. Frick, Apollo Program Manager, MSC; and Astronaut Virgil I. Grissom.

Oakley, *Historical Summary, S&ID Apollo Program*, p. 7.

July 10-11

At the monthly Apollo spacecraft design review meeting with NAA, MSC officials directed NAA to design the spacecraft atmospheric system for 5 psia pure oxygen. From an engineering standpoint, the single-gas atmosphere offered advantages in minimizing weight and leakage, in system simplicity and reliability, and in the extravehicular suit interface. From the standpoint of physiological considerations, the mixed-gas atmosphere (3.5 psia oxygen, 3.5 psia nitrogen) had the advantages of offering protection against dysbarism and atelectasis, whereas the single-gas atmosphere afforded greater decompression protection. The atmosphere validation program demonstrated the known fire hazard of a pure oxygen atmosphere. Two fires occurred, one at the Air Force School of Aerospace Medicine, Brooks Air Force Base, Tex., on September 10 and the other at the U.S. Naval Air Engineering Center, Philadelphia, Penna., on November 17. The answer to this problem appeared to be one of diligent effort on the part of spacecraft designers to be aware of the fire hazard and to exercise strict control of potential ignition sources and material selection. The official authorization was issued to NAA by NASA on August 28.

Apollo Spacecraft Project Office, MSC, Weekly Activity Report, July 8-14, 1962; *Apollo Quarterly Status Report No. 1*, p. 13 ; Edward L. Michel, George B. Smith, Jr., and Richard S. Johnston, *Gaseous Environment Considerations and Evaluation Programs Leading to Spacecraft Atmosphere Selection*, NASA Technical Note TN D-2506 (1965), pp. 1-6; letter, C. D. Sword, MSC, to NAA, Space and Information Systems Division, "Contract Change Authorization No. 1," August 28, 1962.

July 10-11

Charles W. Frick, MSC Apollo Project Office Manager, assigned MIT Instrumentation Laboratory to report on a simulated lunar landing trainer using guidance and navigation equipment and other displays as necessary or proposed.

Ralph Ragan, notes, 4th Apollo Design Review Meeting, NAA, S&ID, Downey, Calif., July 10 and 11, 1962.

July 11

NASA officials announced at a Washington, D.C., press conference that the lunar orbit rendezvous (LOR) technique had been selected as the primary method of accomplishing the lunar landing mission. The launch vehicle would be the Saturn C-5, with the smaller two-stage Saturn C-1B (S-IVB as second stage) used in early earth orbital spacecraft qualification flights. Requests for industrial proposals would be issued immediately on the lunar excursion module. The reasons for the decision on lunar orbit rendezvous were explained:

- A higher probability of mission success with essentially equal mission safety was provided by this technique.
- The method promised mission success some months earlier than other modes.
- LOR costs would be ten to 15 percent less than other techniques.
- LOR would require the least amount of technical development beyond existing commitments while advancing significantly the national technology.

In addition, it was announced that:

- Studies would continue on the feasibility of using the Saturn C-5 to launch a two-man spacecraft in a direct ascent approach to the moon or in an earth orbit rendezvous mode.
- An in-depth study would be made on a lunar logistics vehicle.
- Investigations would continue on the development of the Nova launch vehicle.

NASA, "Lunar Orbit Rendezvous: News Conference on Apollo Plans at NASA Headquarters on July 11, 1962," pp. 1, 3, 4.

July 16

Beech Aircraft Corporation was selected by NASA to build the spherical pressure vessels that would be used to store in the supercritical state the hydrogen-oxygen reactants for the spacecraft fuel cell power supply.

Apollo Quarterly Status Report No. 1, p. 23; Oakley, *Historical Summary, S&ID Apollo Program*, p. 6.

July 17

Joseph F. Shea, NASA Deputy Director of Manned Space Flight (Systems) , told an American Rocket Society meeting in Cleveland, Ohio, that the first American astronauts to land on the moon would come down in an area within ten degrees on either side of the lunar equator and between longitudes 270 and 260 degrees. Shea said that the actual site would be chosen for its apparent scientific potential and that the Ranger and Surveyor programs would provide badly needed information on the lunar surface. Maps on the scale of two fifths of a mile to the inch would be required, based on photographs which would show lunar features down to five or six feet in size. The smallest objects on the lunar surface yet identified by telescope were about the size of a football field.

MSC Space News Roundup, August 22, 1962, p. 8.

July 17

In an address to the American Rocket Society lunar missions meeting in Cleveland, Ohio, James A. Van Allen, Chairman of the Department of Physics and Astronomy, State University of Iowa, said that protons of the inner radiation belt could be a serious hazard for extended manned space flight and that nuclear detonations might be able to clean out these inner belt protons, perhaps for a prolonged period, making possible manned orbits about 300 miles above the earth.

New York Times, July 18, 1962.

July 20

NASA Administrator James E. Webb announced that the Mission Control Center for future manned space flights would be located at MSC. The Center would be operational in time for Gemini rendezvous flights in 1964 and later Apollo lunar missions. The overriding factor in the choice of MSC was the existing location of the Apollo Spacecraft Project Office, the astronauts, and Flight Operations Division at Houston.

New York Times, July 22, 1962; NASA News Release, 62-172, July 20, 1962; memorandum, Robert C. Seamans, Jr., to Administrator, "Location of Mission Control Center," July 10, 1962.

July 21

NASA announced plans for an advanced Saturn launch complex to be built on 80,000 acres northwest of Cape Canaveral. The new facility, Launch Complex 39, would include a building large enough for the vertical assembly of a complete Saturn launch vehicle and Apollo spacecraft.

Washington Sunday Star, July 22, 1962.

July 25

MSC invited 11 firms to submit research and development proposals for the lunar excursion module (LEM) for the manned lunar landing mission. The firms were Lockheed Aircraft Corporation, The Boeing Airplane Company, Northrop Corporation, Ling-Temco-Vought, Inc., Grumman Aircraft Engineering Corporation, Douglas Aircraft Company, General Dynamics Corporation, Republic Aviation Corporation, Martin- Marietta Company, North American Aviation, Inc., and McDonnell Aircraft Corporation.

The Statement of Work distributed to the prospective bidders described the contractor's responsibilities:

- Detail design and manufacture of the LEM and related test articles, mockups, and other hardware with the exception of certain government- furnished equipment [navigation and guidance system (excepting the rendezvous radar and radar altimeter), flight research and development instrumentation system, scientific instrumentation system, and certain components of the crew equipment system (space suits, portable life support systems, and personal radiation dosimeters.)]
- Integration of government-furnished equipment into the LEM; development of specifications for equipment performance, interfaces, and design environment; and maintenance of interface control documentation in a state of validity and concurrence.
- Detailed trajectory analysis from lunar orbit separation until lunar orbit rendezvous directly related to the contractor's area of responsibility.
- Specification of the mission environment on the lunar surface and assessment of the effects of the spacecraft adapter environment on the LEM.
- Detail design of the LEM-mounted equipment for repositioning and mating the LEM to the command module CM.
- Design of the LEM-mounted equipment within the overall specification of the Principal Contractor NAA.
- Determination of the desirability of checkout or operation of the LEM during the translunar period of the flight.
- Identification of crew tasks related to the LEM before and during separation, whether actually performed in the LEM or CM.
- Design and manufacture of the ground support equipment directly associated with the hardware for which the contractor was responsible and ensurance of compatibility of all ground support equipment involved with the LEM.
- Design and manufacture of certain LEM training equipment for flight or ground personnel as required by NASA.
- Prelaunch preparation and checkout of the LEM, working with the other contractors in the same manner as during systems testing.
- Coordination of all LEM activities with the overall spacecraft prelaunch requirements.
- Planning and implementation of a reliability and quality assurance program.
- Provision of adequate logistic support for the equipment furnished by the contractor.

The mockups to be delivered by the contractor would include but not be limited to:

- Complete LEM
- Cabin interior arrangement
- Cabin exterior equipment
- Docking system
- Environmental control system
- Crew support system
- Antenna radiation pattern
- Handling and transportation
- Module interface

Before the first translunar midcourse correction, the LEM would be transferred from its stowed position in the spacecraft adapter to a docked configuration with the command and service modules (CSM). At a later point in the mission, the two-man LEM crew would enter the LEM from the CSM by means of a hatch without being exposed to the environment of space. Another hatch would allow access to the LEM during countdown and egress into space while docked with the CSM.

The LEM systems were to operate at their normal design performance level for a mission of two days without resupply. Equipment normally operated in the pressurized LEM cabin environment would be designed to function for a minimum of two days in vacuum without failure. The LEM pressurization system would be capable of six complete cabin repressurizations and a continuous leak rate as high as 0.2 pound per hour. Provision would be made for a total of six recharges of the portable life support system which had a normal operating time without resupply of four hours. Under usual conditions in the LEM cabin, the crew would wear unpressurized space suits. Either crewman would be able, alone, to return the LEM to the CSM and successfully perform the rendezvous and docking maneuver. Of the overall crew safety goal of 0.999, the goal apportioned to the LEM was 0.995.

The LEM would be capable of independently performing the separation from the CSM, lunar descent, landing, ascent, rendezvous, and docking with the CSM. It would allow for crew exploration in the vicinity of lunar touchdown but would not be required to have lunar surface mobility.

Lunar landing would be attempted from a lunar orbit of 100 nautical miles. After separation, the LEM would transfer from the circular orbit to an equal-period elliptical orbit which would not intersect the lunar surface. The hovering, final touchdown maneuvers, and landing would be performed by the LEM from the elliptical orbit.

Normally there would not be a requirement to reposition the LEM attitude before lunar launch. To rendezvous and dock with the CSM, the LEM would transfer from an elliptical to a circular orbit after lunar launch.

The LEM would not be recoverable.

Included in the Statement of Work was a description of the major LEM systems:

Guidance and control system

The navigation and guidance system would provide steering and thrust control signals for the stabilization and control system, reaction control system, and the lunar excursion propulsion system. Its basic components were:

- Inertial measurement unit
- Optical measurement unit
- Range-drift measurement unit (reticle)
- Computer Power and servo assembly
- Control and display unit
- Displays and controls
- Cabling and junction box
- Chart book and star catalog
- Rendezvous radar and radar altimeter

The stabilization and control system would meet the attitude stabilization and maneuver control requirements and would include:

- Attitude reference
- Rate sensors
- Control electronics assembly
- Manual controls
- Displays
- Power supplies

Lunar excursion propulsion system

The system would use storable hypergolic bipropellants and a pressurized propellant feed system.

Variable thrust would be required from a propulsion system to be designed.

Propellants

The fuel would be monomethylhydrazine or a mixture of 50 percent hydrazine and 50 percent unsymmetrical dimethylhydrazine. Nitrogen tetroxide with nitrous oxide, added to depress the freezing point if necessary, would be used as oxidizer.

Reaction control system

The system comprised two independent, interconnectable, pulse-modulated subsystems, each capable of meeting the total torque and impulse requirements and providing two-directional control about all axes. The same propellant combination would be used as for the LEM propulsion system.

Lunar touchdown system

Attached to the LEM by hard points which would accommodate variations of landing gear geometrics, the system would have load distribution capabilities compatible with anticipated landing gear loads and would include meteoroid protection and radiation protection inherent in its structure. Normally, the system would be deployed from within the spacecraft but could be operated manually by the crew in spacesuits outside the spacecraft.

Crew systems

The flight Crew would consist of the Commander and Systems Engineer. The crew equipment system would include an adjustable seat for each crewman, restraint system for each seat, food and water, first aid equipment, space suits, portable life support systems for each crewman, and personal radiation dosimeters.

Environmental control system

The following conditions would be provided:

- Total cabin pressure: Oxygen, 5 +/- 0.2 psia
- Relative humidity : 40 to 70 percent
- Carbon dioxide partial pressure (maximum): 7.6 mm Hg
- Temperature: 75 degrees ±5 degrees F

Electrical power system

Selection of the source was still to be made and would depend largely on the time contingency allowed for various mission events, especially during rendezvous maneuvers.

Instrumentation system

The operational instrumentation system would consist of a clock, tape recorder system, display and control system, sensors, calibration system, cameras, and telescope.

The flight research and development instrumentation system would be made up of telemetry systems (including transmitters), clock and tape recorder system, sensors and signal conditioning, calibration system, power supply, radar transponder, and antennas.

The scientific instrumentation system would comprise a lunar atmosphere analyzer, gravitometer, magnetometer, radiation spectrometer, specimen return container, rock and soil analysis equipment, seismographic equipment, and soil temperature instrument.

NASA, *Project Apollo Lunar Excursion Module Development Statement of Work* (MSC, July 24, 1962), pp. 2-5, A-89 to A-108; *Astronautical and Aeronautical Events of 1962*, p. 130.

July 25

Wesley F. Messing was designated as Acting Resident MSC Manager at White Sands Missile Range, N. Mex., to coordinate MSC test programs at that site.

MSC Announcement No. 67, Establishment of Resident MSC Manager at White Sands Missile Range, July 25, 1962.

July 29-August 4

As a result of an MSC in-house technical review, NAA was directed to investigate the adaptation of the Gemini-type heatshield to the Apollo spacecraft.

Apollo Spacecraft Project Office, MSC, Weekly Activity Report.

July 30

The Office of Systems under NASA's Office of Manned Space Flight summarized its conclusions on the selection of a lunar mission mode based on NASA and industry studies conducted in 1961 and 1962:

- There were no significant technical problems which would preclude the acceptance of any of the modes, if sufficient time and money were available. [The modes considered were the C-5 direct ascent, C-5 earth orbit rendezvous (EOR), C-5 lunar orbit rendezvous (LOR), Nova direct ascent, and solid-fuel Nova direct ascent.]
- The C-5 direct ascent technique was characterized by high development risk and the least flexibility for further development.
- The C-5 EOR mode had the lowest probability of mission success and the greatest development complexity.
- The Nova direct ascent method would require the development of larger launch vehicles than the C-5. However, it would be the least complex from an operational and subsystem standpoint and had greater crew safety and initial mission capabilities than did LOR.
- The solid-fuel Nova direct flight mode would necessitate a launch vehicle development parallel to the C-5. Such a development could not be financed under current budget allotments.
- Only the LOR and EOR modes would make full use of the development of the C-5 launch vehicle and the command and service modules. Based on technical considerations, the LOR

mode was distinctly preferable.

- The Directors of MSC and Marshall Space Flight Center had both expressed strong preference for the LOR mode.

On the basis of these conclusions, the LOR mode was recommended as most suitable for the manned lunar landing mission. [The studies summarized in this document were used by the Manned Space Flight Management Council in their mission mode decision on June 22.]

Office of Systems, Office of Manned Space Flight, "Manned Lunar Landing Program Comparison," July 30, 1962, pp. 145-146.

July 31

The Manned Space Flight Management Council decided that the Apollo spacecraft design criteria should be worked out under the guidance of the Office of Manned Space Flight (OMSF) Office of Systems. These criteria should be included in the systems specifications to be developed. A monthly exchange of information on spacecraft weight status should take place among the Centers and OMSF. Eldon W. Hall of the Office of Space Systems would be responsible for control of the detailed system weights.

MSF Management Council Minutes, July 31, 1962, Agenda Item 16.

During the Month

The Hamilton Standard Division of United Aircraft Corporation was selected by NASA as the prime contractor for the Apollo space suit assembly. Hamilton's principal subcontractor was International Latex Corporation, which would fabricate the pressure garment. The contract was signed on October 5.

Apollo Quarterly Status Report No. 1, p. 29.

During the Month

The control layout of the command module aft compartment was released by NAA. This revised drawing incorporated the new umbilical locations in the lower heatshield, relocated the pitch-and-yaw engines symmetrically, eliminated the ground support equipment tower umbilical, and showed the resulting repositioning of tanks and equipment.

NAA, *Apollo Monthly Progress Report*, SID 62-300-5, July 31, 1962, p. 96.

During the Month

NAA completed control layouts for all three command module windows, including heatshield windows

and sightlines. Structural penalties were investigated, window-panes sized, and a weight-comparison chart prepared.

Apollo Monthly Progress Report, SID 62-300-5, p. 98.

During the Month

NAA's evaluation of the emergency blow-out hatch study showed that the linear-shaped explosive charge should be installed on the outside of the command module, with a backup structure and an epoxy-foam-filled annulus on the inside of the module to trap fragmentation and gases. Detail drawings of the crew hatch were prepared for fabrication of actual test sections.

Apollo Monthly Progress Report, SID 62-300-5, pp. 97-98.

During the Month

After the determination of the basic design of the spacecraft sequencer schematic, the effect of the deployment of the forward heatshield before tower jettison was studied by NAA. The sequence of events of both the launch escape system and earth landing system would be affected, making necessary the selection of different sequences for normal flights and abort conditions. A schematic was prepared to provide for these sequencing alternatives.

Apollo Monthly Progress Report, SID 62-300-5, p. 123.

During the Month

NAA completed the analysis and design of the Fibreglass heatshield. It duplicated the stiffness of the aluminum heatshield and would be used on all boilerplate spacecraft.

Apollo Monthly Progress Report, SID 62-300-5, p. 93.

During the Month

Final design of the command module forward heatshield release mechanism was completed by NAA.

Apollo Monthly Progress Report, SID 62-300-5, p. 79.

During the Month

Air recirculation system components of the command module were rearranged to accommodate a disconnect fitting and lines for the center crewman's suit. To relieve an obstruction, the cabin pressure

regulator was relocated and a design study drawing was completed.

Apollo Monthly Progress Report, SID 62-300-5, p. 73.

During the Month

A study was made by NAA to determine optimum location and configuration of the spacecraft transponder equipment. The study showed that, if a single deep space instrumentation facility transponder and power amplifier were carried in the command module instead of two complete systems in the service module, spacecraft weight would be reduced, the system would be simplified, and command and service module interface problems would be minimized. Spares in excess of normal would be provided to ensure reliability.

Apollo Monthly Progress Report, SID 62-300-5, p. 84.

During the Month

A modified method of cooling crew and equipment before launch and during boost was tentatively selected by NAA. Chilled, ground-support-equipment-supplied water-glycol would be pumped through the spacecraft coolant system until 30 seconds before launch, when these lines would be disconnected. After umbilical separation the glycol, as it evaporated at the water boiler, would be chilled by Freon stored in the water tanks.

Apollo Monthly Progress Report, SID 62-300-5, p. 75.

During the Month

NAA selected the lunar landing radar and completed the block diagram for the spacecraft rendezvous radar. Preliminary design was in progress on both types of radar.

Apollo Monthly Progress Report, SID 62-300-5, p. 57.

During the Month

A 70-mm pulse camera was selected by NAA for mission photodocumentation. The camera was to be carried in the upper parachute compartment. Because of the lack of space and the need for a constant power supply for a 35-watt heating element, NAA was considering placing the camera behind the main display panel. The advantages of this arrangement were that the camera would require less power, be available for changing magazines, and could be removed for use outside the spacecraft.

One 16-mm camera was also planned for the spacecraft. This camera would be positioned level with the

commander's head and directed at the main display panel. It could be secured to the telescope for recording motion events in real time such as rendezvous, docking, launch and recovery of a lunar excursion module, and earth landing; it could be hand-held for extravehicular activity.

Apollo Monthly Progress Report, SID 62-300-5, p. 81.

During the Month

NAA investigated several docking methods. These included extendable probes to draw the modules together; shock-strut arms on the lunar excursion module with ball locators to position the modules until the spring latch caught, fastening them together; and inflatable Mylar and polyethylene plastic tubing. Also considered was a system in which a crewman, secured by a lanyard, would transfer into the open lunar excursion module. Another crewman in the open command module airlock would then reel in the lanyard to bring the modules together.

Apollo Monthly Progress Report, SID 62-300-5, p. 99.

During the Month

Command module (CM) flotation studies were made by NAA, in which the heatshield was assumed to be upright with no flooding having occurred between the CM inner and outer walls. The spacecraft was found to have two stable attitudes: the desired upright position and an unacceptable on-the-side position 128 degrees from the vertical. Further studies were scheduled to determine how much lower the CM center of gravity would have to be to eliminate the unacceptable stable condition and to measure the overall flotation stability when the CM heatshield was extended.

Apollo Monthly Progress Report, SID 62-300-5, p. 27.

August 1

A recent Russian article discussed various methods which the Soviet Union had been studying for sending a man to the moon during the decade. The earth orbital rendezvous method was reported the most reliable, but consideration also had been given to the direct ascent method, using the "Mastodon" rocket.

Astronautical and Aeronautical Events of 1962, p. 1 36.

August 1

At MSC, J. Thomas Markley was appointed Project Officer for the Apollo spacecraft command and service modules contract, and William F. Rector was named Project Officer for the lunar excursion module contract.

MSC *Space News Roundup*, August 22, 1962, p. 1.

August 2

NASA's Office of Manned Space Flight issued Requests for Proposals for a study of the lunar "bus" and studies for payloads which could be handled by the C-1B and C-5 launch vehicles. Contract awards were expected by September 1 and completion of the studies by December 1.

MSF Management Council Minutes, July 31, 1962, Agenda Item 7.

August 2

The heatshield for Apollo command module boilerplate model 1 was completed five days ahead of schedule.

Oakley, *Historical Summary, S&ID Apollo Program*, p. 8.

August 6

The MIT Instrumentation Laboratory ordered a Honeywell 1800 electronic computer from the Minneapolis- Honeywell Regulator Company's Electronic Data Processing Division for work on the Apollo spacecraft navigation system. After installation in 1963, the computer would aid in circuitry design of the Apollo spacecraft computer and would also simulate full operation of a spaceborne computer during ground tests.

Astronautical and Aeronautical Events of 1962, p. 141.

August 7

The first completed boilerplate model of the Apollo command module, BP- 25, was subjected to a one-fourth-scale impact test in the Pacific Ocean near the entrance to Los Angeles Harbor. Three additional tests were conducted on August 9.

Oakley, *Historical Summary, S&ID Apollo Program*, p. 8; MSC, Weekly Activity Report for the Office of the Director, Manned Space Flight, August 5-11, 1962.

August 8

NASA awarded a \$141.1 million contract to the Douglas Aircraft Company for design, development, fabrication, and testing of the S-IVB stage, the third stage of the Saturn C-5 launch vehicle. The contract

called for 11 S-IVB units, including three for ground tests, two for inert flight, and six for powered flight.

Astronautical and Aeronautical Events of 1962, p. 144.

August 8

Representatives of the MSC Gemini Project Office and Facilities Division inspected the proposed hangar and office facilities to be refurbished at El Centro Naval Air Facility, Calif., for joint use in the Apollo and Gemini drop-test programs.

MSC, *Project Gemini Quarterly Status Report No. 2 for Period Ending August 31, 1962*, p. 14.

August 8

At a bidders' conference held at NASA Headquarters, proposals were requested from Centers and industry for two lunar logistic studies: a spacecraft "bus" concept that could be adapted for use first on the Saturn C-1B and later on the Saturn C-5 launch vehicles and a variety of payloads which could be soft-landed near manned Apollo missions. The latter study would determine how a crew's stay on the moon might be extended, how human capability for scientific investigation of the moon might be increased, and how man's mobility on the moon might be facilitated.

Astronautical and Aeronautical Events of 1962, p. 144.

August 10

MSC requested the reprogramming of \$100,000 of Fiscal Year 1963 funds for advance design on construction facilities. The funds would be transferred from Launch Operations Center to MSC for use on the Little Joe II program at White Sands Missile Range, N. Mex., and would cover Army Corps of Engineers design work on the launch facility.

MSC, Weekly Activity Report for the Office of the Director, Manned Space Flight, August 5-11, 1962.

August 10

NASA selected the Aerojet-General Algol solid-propellant motor to power the Little Joe II booster, which would be used to flight-test the command and service modules of the Apollo spacecraft.

Astronautical and Aeronautical Events of 1962, p. 146.

August 11

A NASA program schedule for the Apollo spacecraft command and service modules through calendar year 1965 was established for financial planning purposes and distributed to the NASA Office of Manned Space Flight, Marshall Space Flight Center, and MSC. The key dates were: complete service module drawing release, May 1, 1963; complete command module drawing release, June 15, 1963; manufacture complete on the first spacecraft, February 1, 1964; first manned orbital flight, May 15, 1965. This tentative schedule depended on budget appropriations.

MSC, Weekly Activity Report for the Office of the Director, Manned Space Flight, August 5-11, 1962, pp. 4, 5.

August 11

Of the 11 companies invited to bid on the lunar excursion module on July 25, eight planned to respond. NAA had notified MSC that it would not bid on the contract. No information had been received from the McDonnell Aircraft Corporation and it was questionable whether the Northrop Corporation would respond.

MSC, Weekly Activity Report for the Office of the Director, Manned Space Flight, August 5-11, 1962, p. 4.

August 11-12

The Soviet Union launched Vostok III into orbit at 11:30 a.m. Moscow time, the spacecraft piloted by Andrian G. Nikolayev. At 11:02 a.m. Moscow time the next day, the Soviet Union launched the Vostok IV spacecraft into orbit with Pavel R. Popovich as pilot. Within about an hour, Cosmonaut Popovich, traveling in nearly the same orbit as Vostok III, made radio contact with Cosmonaut Nikolayev. Nikolayev reported shortly thereafter that he had sighted Vostok IV. In their official report, Nikolayev and Popovich said their spacecraft had been within a little over three miles of each other at their closest approach. This was the first launching of two manned spacecraft within a 24-hour period. Popovich and Nikolayev landed safely in Kazakhstan, U.S.S.R., on August 15,

New York Times, August 14 and 22, 1962.

August 13

Ten Air Force pilots emerged from a simulated space cabin in which they had spent the previous month participating in a psychological test to determine how long a team of astronauts could work efficiently on a prolonged mission in space. Project Director Earl Alluisi said the experiment had "far exceeded our expectations" and that the men could have stayed in the cabin for 40 days with no difficulty.

New York Herald Tribune, August 14, 1962.

August 13-14

NAA suggested that the pitch, roll, and yaw rates required for the Apollo guidance and navigation system would permit reduction in the reaction control thrust.

MSC-NAA Apollo Spacecraft Design Review No. 5, August 13-14, 1962, Downey, Calif., Item 5-6.

August 14

The NAA spacecraft Statement of Work was revised to include the requirements for the lunar excursion module (LEM) as well as other modifications. The LEM requirements were identical with those given in the LEM Development Statement of Work of July 24.

The command module (CM) would now be required to provide the crew with a one-day habitable environment and a survival environment for one week after touching down on land or water. In case of a landing at sea, the CM should be able to recover from any attitude and float upright with egress hatches free of water.

The service propulsion system would now provide all major velocity increments required for translunar midcourse velocity corrections, for placing the spacecraft into a lunar orbit, for rendezvous of the command and service modules CSM with the LEM on a backup mode, for transfer of the CSM from lunar orbit into the transearth trajectory, and for transearth midcourse velocity corrections for lunar missions.

Three FIST-type drogue parachutes would replace the original two called for in the earth landing system.

The CM camera system was revised to require one for monitoring the crew, displays, and spacecraft interior; the other for lunar photography and stellar studies. The latter camera could be used in conjunction with the telescope or independently at the crew's discretion.

A new communication concept was described in which all voice, telemetry, television, and ranging information for near-earth and lunar distances would be transmitted over a unified frequency system.

All references to the lunar landing module and space laboratory module were dropped. Among other deletions from the previous Statement of Work were:

- Parawing and other earth landing systems instead of parachutes
- The "skip" reentry technique
- HF beacon as recovery aid
- Radar altimeter from CSM communication system
- Crew recreational equipment
- Engineering and Development Test Plan

NASA, *Project Apollo Spacecraft Development Statement of Work* (MSC, December 18, 1961, Revised August 14, 1962), Part 3, Technical Approach, pp. 3, 7, 12, 61, 84, and 88.

Mid-August

The first Apollo boilerplate command module, BP-25, was delivered to MSC for water recovery and handling tests. Flotation, water stability, and towing tests were conducted with good results. J. Thomas Markley of MSC described all spacecraft structural tests thus far as "successful."

Apollo Quarterly Status Report No. 1, p. 41; *Astronautical and Aeronautical Events of 1962*, p. 167; Apollo Spacecraft Project Office, Weekly Activity Report, Period Ending August 18, 1962.

August 16

The second stage (S-IV) of the Saturn C-1 launch vehicle was successfully static-fired for the first time in a ten-second test at the Sacramento, Calif., facility by the Douglas Aircraft Company.

Astronautical and Aeronautical Events of 1962, p. 156.

August 17

Carl Sagan, University of California astronomer, warned scientists at a lunar exploration conference, Blacksburg, Va., of the need for sterilization of lunar spacecraft and decontamination of Apollo crewmen, pointing out that Lunik II and Ranger IV probably had deposited terrestrial microorganisms on the moon. Even more serious, he said, was the possibility that lunar microorganisms might be brought to earth where they could multiply explosively.

Washington Post, August 18, 1962.

August 22

Responsibility for the design and manufacture of the reaction controls for the Apollo command module was shifted from The Marquardt Corporation to the Rocketdyne Division of NAA, with NASA concurrence.

Oakley, *Historical Summary, S&ID Apollo Program*, p. 7.

August 22

The length of the Apollo service module was increased from 11 feet 8 inches to 12 feet 11 inches to

provide space for additional fuel.

Oakley, *Historical Summary, S&ID Apollo Program*, p. 7.

During the Month

Robert R. Gilruth, Director of MSC, presented details of the Apollo spacecraft at the Institute of the Aerospace Sciences meeting in Seattle, Wash. During launch and reentry, the three-man crew would be seated in adjacent couches; during other phases of flight, the center couch would be stowed to permit more freedom of movement. The Apollo command module cabin would have 365 cubic feet of volume, with 22 cubic feet of free area available to the crew: "The small end of the command module may contain an airlock; when the lunar excursion module is not attached, the airlock would permit a pressure-suited crewman to exit to free space without decompressing the cabin. Crew ingress and egress while on earth will be through a hatch in the side of the command module."

Astronautical and Aeronautical Events of 1962, p. 167.

During the Month

The first tests incorporating data acquisition in the Apollo test program were conducted at El Centro, Calif. They consisted of monitoring data returned by telemetry during a parachute dummy-load test.

Oakley. *Historical Summary, S&ID Apollo Program*, p. 7.

During the Month

The revised NAA Summary Definitions and Objectives Document was released. This revision incorporated the lunar orbit rendezvous concept, without lunar excursion module integration, and a revised master phasing schedule, reflecting the deletion of the second-stage service module. The NAA Apollo Mission Requirements and Apollo Requirements Specifications were also similarly re-oriented and released.

NAA, *Apollo Monthly Progress Report*, SID 62-300-6, August 31, 1962, p. 24.

During the Month

The establishment of a basic command module (CM) airlock and docking design criteria were discussed by NAA and NASA representatives. While NASA preferred a closed-hatch, one-man airlock system, NAA had based its design on an open-hatch, two-man airlock operation.

Another closed-hatch configuration under consideration would entirely eliminate the CM airlock.

Astronauts transferring to and from the lunar excursion module would be in a pressurized environment constantly.

Apollo Monthly Progress Report, SID 62-300-6, p. 97.

During the Month

The launch escape thrust-vector-control system was replaced by a passive system using a "kicker" rocket as directed by NASA at the June 10-11 design review meeting. The rocket would be mounted at the top of the launch escape system tower and fired tangentially to impart the necessary pitchover motion during the initial phase of abort. The main motor thrust was revised downward from 180,000 to 155,000 pounds and aligned 2.8 degrees off the center line. A downrange abort direction was selected; during abort the spacecraft and astronauts would rotate in a heels over head movement.

Apollo Monthly Progress Report, SID 62-300-6, p. 4.

During the Month

A preliminary NAA report was completed on a literature search concerning fire hazards in 100 percent oxygen and oxygen-enriched atmospheres. This report showed that limited testing would be warranted.

Apollo Monthly Progress Report, SID 62-300-6, p. 12.

During the Month

A final decision was made by NAA to redesign the command module fuel cell radiator and associated tubing to accommodate a 30-psi maximum pressure drop. Pratt & Whitney Aircraft Division agreed to redesign their pump for this level.

Apollo Monthly Progress Report, SID 62-300-6, p. 109.

During the Month

Layouts of a command module (CM) telescope installation in the unpressurized upper parachute compartment were completed by NAA. The concept was for the telescope to extend ten inches from the left side of the spacecraft. The light path would enter the upper bulkhead through the main display panel to an eyepiece presentation on the commander's side of the spacecraft. A static seal (one-half-inch-thick window) would be used to prevent leakage in the pressurized compartment. The installation was suitable for use in the lunar orbit rendezvous mission and would allow one man in the CM to accomplish docking with full visual control.

Apollo Monthly Progress Report, SID 62-300-5, pp. 81, 83; *Apollo Monthly Progress Report*, SID 62-300-6, pp. 72-73.

During the Month

NAA established design criteria for materials and processes used in food reconstitution bags. An order was placed for polypropylene material with a contoured mouthpiece. This material would be machined and then heat-fused to a thermoplastic bag.

Apollo Monthly Progress Report, SID 62-300-6, p. 56.

During the Month

Preliminary studies were made by NAA to determine radiation instrument location, feasibility of shadow-shielding, and methods of determining direction of incidence of radiation. Preliminary requirements were established for the number and location of detectors and for information display.

Apollo Monthly Program Report, SID 62-300-6, p. 72.

During the Month

An NAA study indicated that the effects of crew motions on spacecraft attitude control would be negligible.

Apollo Monthly Progress Report, SID 62-300-6, p. 53.

During the Month

The command module waste management system analysis, including a new selection valve, revised tubing lengths, odor removal filter, and three check valves, was completed by NAA for a 5 psia pressure. There was only a small change in the flow rates through the separate branches as a result of the change to 5 psia.

Apollo Monthly Progress Report, SID 62-300-6, p. 12.

During the Month

NAA completed attitude orientation studies, including one on the control of a tumbling command module (CM) following high-altitude abort above 125,000 feet. The studies indicated that the CM stabilization and control system would be adequate during the reentry phase with the CM in either of the two possible trim configurations.

Apollo Monthly Progress Report, SID 62-300-6, p. 5.

During the Month

NAA finished structural requirements for a lunar excursion module adapter mating the 154-inch diameter service module to the 260-inch diameter S-IVB stage.

Apollo Monthly Progress Report, SID 62-300-6, p. 107.

September 4

An interim Apollo flight operation plan for Fiscal Year 1963, dated August 28, calling for funding of \$489.9 million, was transmitted to NASA Headquarters from MSC. System requirements were under study to determine the feasibility of cost reduction to avoid schedule slippage.

MSC, Weekly Activity Report for the Office of the Director, Manned Space Flight, September 2-8, 1962, p. 4.

September 4

Nine industry proposals for the lunar excursion module were received from The Boeing Company, Douglas Aircraft Company, General Dynamics Corporation, Grumman Aircraft Engineering Corporation, Ling-Temco-Vought, Inc., Lockheed Aircraft Corporation, Martin-Marietta Corporation, Northrop Corporation, and Republic Aviation Corporation. NASA evaluation began the next day. Industry presentations would be held on September 13 and 14 at Ellington Air Force Base, Tex. One-day visits to company sites by evaluation teams would be made September 17-19. After evaluation of the proposals, NASA planned to award the contract within six to eight weeks.

Apollo Spacecraft Project Office, MSC, Weekly Activity Report, September 2-8, 1962; *Wall Street Journal*, September 6, 1962.

September 5

Two three-month studies of an unmanned logistic system to aid astronauts on a lunar landing mission would be negotiated with three companies, NASA announced. Under a \$150,000 contract, Space Technology Laboratories, Inc., would look into the feasibility of developing a general-purpose spacecraft into which varieties of payloads could be fitted. Under two \$75,000 contracts, Northrop Space laboratories and Grumman Aircraft Engineering Corporation would study the possible cargoes that such a spacecraft might carry. NASA Centers simultaneously would study lunar logistic: trajectories, launch vehicle adaptation, lunar landing touchdown dynamics, scheduling, and use of roving vehicles on the lunar surface.

Wall Street Journal, September 6, 1962; *Astronautical and Aeronautical Events of 1962*, pp. 173-174.

September 5

Apollo Spacecraft Project Office requested NAA to perform a study of command module-lunar excursion module (CM-LEM) docking and crew transfer operations and recommend a preferred mode, establish docking design criteria, and define the CM-LEM interface. Both translunar and lunar orbital docking maneuvers were to be considered. The docking concept finally selected would satisfy the requirements of minimum weight, design and functional simplicity, maximum docking reliability, minimum docking time, and maximum visibility.

The mission constraints to be used for this study were :

- The first docking maneuver would take place as soon after S-IVB burnout as possible and hard docking would be within 30 minutes after burnout.
- The docking methods to be investigated would include but not be limited to free fly-around, tethered fly-around, and mechanical repositioning.
- The S-IVB would be stabilized for four hours after injection.
- There would be no CM airlock. Extravehicular access techniques through the LEM would be evaluated to determine the usefulness of a LEM airlock.
- A crewman would not be stationed in the tunnel during docking unless it could be shown that his field of vision, maneuverability, and communication capability would substantially contribute to the ease and reliability of the docking maneuver.
- An open-hatch, unpressurized CM docking approach would not be considered.
- The relative merit of using the CM environmental control system to provide initial pressurization of the LEM instead of the LEM environmental control system would be investigated.

Apollo Spacecraft Project Office, MSC, Weekly Activity Report, September 2-8, 1962; letter, C. D. Sword, MSC, to NAA, "Contract Change Authorization No. 4," September 22, 1962.

September 6

NASA deleted five Apollo mockups, three boilerplate spacecraft, and several ground support equipment items from the NAA contract because of funding limitations.

Oakley, *Historical Summary, S&ID Apollo Program*, p. 7.

September 7

Apollo command module boilerplate model BP-1 was accepted by NASA and delivered to the NAA Engineering Development Laboratory for land and water impact tests. On September 25, BP-1 was drop-

tested with good results. Earth-impact attenuation and crew shock absorption data were obtained.

Oakley, *Historical Summary, S&ID Apollo Program*, p. 7; *Apollo Quarterly Status Report No. 1*, p. 41.

September 10

Apollo command module boilerplate model BP-3, showing the arrangement of the cabin interior, was shipped to MSC.

Oakley, *Historical Summary, S&ID Apollo Program*, p. 7

September 10

Fire broke out in a simulated space cabin at the Air Force School of Aerospace Medicine, Brooks Air Force Base, Tex., on the 13th day of a 14-day experiment to determine the effects of breathing pure oxygen in a long-duration space flight. One of the two Air Force officers was seriously injured. The cause of the fire was not immediately determined. The experiment was part of a NASA program to validate the use of a 5 psia pure oxygen atmosphere for the Gemini and Apollo spacecraft.

Washington Evening Star, September 10, 1962; Michel *et al.*, *Gaseous Environment Considerations and Evaluation Programs Leading to Spacecraft Atmosphere Selection*, pp. 5-6.

Early September

MSC reported that it had received a completed wooden mockup of the interior arrangement of the Apollo command module (CM). An identical mockup was retained at NAA for design control. Seven additional CM and service module (SM) mockups were planned: a partial SM and partial adapter interface, CM for exterior cabin equipment, complete SM, spacecraft for handling and transportation (two), crew support system, and complete CSM's. A mockup of the navigation and guidance equipment had been completed. A wooden mockup of the lunar excursion module exterior configuration was fabricated by NAA as part of an early study of spacecraft compatibility requirements.

Apollo Quarterly Status Report No. 1, p. 41.

September 11

J. Thomas Markley, command and service module Project Officer at MSC, announced details of the space facility to be established by NASA at White Sands Missile Range (WSMR). To be used in testing the Apollo spacecraft's propulsion and abort systems, the WSMR site facilities would include two static-test-firing stands, a control center blockhouse, various storage and other utility buildings, and an administrative services area.

MSC Fact Sheet No. 97, Apollo at White Sands, September 11, 1962.

September 12

President John F. Kennedy spoke at Rice University, Houston, Tex., where he said:

"Man, in his quest for knowledge and progress, is determined and cannot be deterred. The exploration of space will go ahead, whether we join in it or not, and it is one of the great adventures of all time, and no nation which expects to be the leader of other nations can expect to stay behind in this race for space. . . .

"We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win, and the others, too.

"It is for these reasons that I regard the decision last year to shift our efforts in space from low to high gear as among the most important decisions that will be made during my incumbency in the office of the Presidency. . . ."

Senate Staff Report, *Documents on International Aspects of the Exploration and Use of Outer Space, 1954-1962*, pp. 328-330.

September 17

NASA's nine new astronauts were named in Houston, Tex., by Robert R. Gilruth, MSC Director. Chosen from 253 applicants, the former test pilots who would join the original seven Mercury astronauts in training for Projects Gemini and Apollo were: Neil A. Armstrong, NASA civilian test pilot; Maj. Frank Borman, Air Force; Lt. Charles Conrad, Jr., Navy; Lt.Cdr. James A. Lovell, Jr., Navy; Capt. James A. McDivitt, Air Force; Elliot M. See, Jr., civilian test pilot for the General Electric Company; Capt. Thomas P. Stafford, Air Force; Capt. Edward H. White II, Air Force; and Lt. Cdr. John W. Young, Navy.

Washington *Daily News*, September 18, 1962.

September 21

NASA contracted with the Armour Research Foundation for an investigation of conditions likely to be found on the lunar surface. Research would concentrate first on evaluating the effects of landing velocity, size of the landing area, and shape of the landing object with regard to properties of the lunar soils. Earlier studies by Armour had indicated that the lunar surface might be composed of very strong material. Armour reported its findings during the first week of November.

Astronautical and Aeronautical Events of 1962, p. 196.

September 23-October 6

Deletion of non-critical equipment and improvement of existing systems reduced the weight of the command and service modules by 1,239 pounds, with a target reduction of 1,500 pounds.

Among the items deleted from the command module (CM) were exercise and recreation equipment, personal parachutes and parachute containers located in the couches, individual survival kits, solar radiation garments, and eight-ball displays. A telescope, cameras and magazines considered scientific equipment, and a television monitor were deleted from the CM instrumentation system.

Apollo Spacecraft Project Office, MSC, Activity Report for the Period September 23-October 6, 1962.

September 24

General Dynamics/Convair recommended and obtained NASA's concurrence that the first Little Joe II launch vehicle be used for qualification, employing a dummy payload.

Little Joe II Test Launch Vehicle, NASA Project Apollo: Final Report, Vol. I, p. 1-4.

September 26

NASA announced that it had completed preliminary plans for the development of the \$500-million Mississippi Test Facility. The first phase of a three-phase construction program would begin in 1962 and would include four test stands for static-firing the Saturn C-5 S-IC and S-II stages; about 20 support and service buildings would be built in the first phase. A water transportation system had been selected, calling for improvement of about 15 miles of river channel and construction of about 15 miles of canals at the facility. Sverdrup and Parcel Company of St. Louis, Mo., was preparing design criteria; the Army Corps of Engineers was acquiring land for NASA in cooperation with the Lands Division of the Justice Department. The 13,500-acre facility in southwestern Mississippi was 35 miles from NASA Michoud Operations, where Saturn stages were fabricated.

Astronautical and Aeronautical Events of 1962, pp. 200-201.

During the Month

MSC reported that the reliability goal for design purposes in the spacecraft Statement of Work for the Apollo mission was 0.9. The probability that the crew would not be subjected to conditions in excess of the stated limits was 0.9, and the probability that the crew would not be subjected to emergency limits was 0.999. The initial Work Statement apportionment for the lunar excursion module was 0.984 for

mission success and 0.9995 for crew safety. Other major system elements would require reapportionment to reflect the lunar orbit mission.

Apollo Quarterly Status Report No. 1, p. 37.

During the Month

Release of the structural design of the Apollo command module was 65 percent complete; 100 percent release was scheduled for January 1 963.

Apollo Quarterly Status Report No. 1, p. 11.

During the Month

The lunar excursion module was defined as consisting of 12 principal systems: guidance and navigation, stabilization and control, propulsion, reaction control, lunar touchdown, structure including landing and docking systems, crew, environmental control, electrical power, communications, instrumentation, and experimental instrumentation. A consideration of prime importance to practically all systems was the possibility of using components from Project Mercury or those under development for Project Gemini.

Apollo Quarterly Status Report No. 1, p. 26.

During the Month

MSC reported that renovation of available buildings at the El Centro Joint Service Parachute Facility was required to support the Apollo earth recovery tests. The Air Force's commitment of a C-133A aircraft to support the qualification tests had been obtained.

Apollo Quarterly Status Report No. 1, p. 52.

During the Month

MSC reported that Arnold Engineering Development Center facilities at Tullahoma, Tenn., were being scheduled for use in the development of the Apollo reaction control and propulsion systems. The use of the Mark I altitude chamber for environmental tests of the command and service modules was also planned.

Apollo Quarterly Status Report No. 1, p. 52.

During the Month

MIT's Lincoln Laboratory began a study program to define Apollo data processing requirements and to examine the problems associated with the unified telecommunications system. The system would permit the use of the lunar mission transponder during near-earth operations and eliminate the general transmitters required by the current spacecraft concept, thus reducing weight, complexity, and cost of the spacecraft system.

Apollo Quarterly Status Report No. 1, p. 47.

During the Month

MSC reported that Apollo training requirements planning was 40 percent complete. The preparation of specific materials would begin during the first quarter of 1964. The crew training equipment included earth launch and reentry, orbital and rendezvous, and navigation and trajectory control part-task trainers, which were special-purpose simulators. An early delivery would allow extensive practice for the crew in those mission functions where crew activity was time-critical and required development of particular skills. The mission simulators had complete mission capability, providing visual as well as instrument environments. Mission simulators would be located at MSC and at Cape Canaveral.

Apollo Quarterly Status Report No. 1, p. 45.

During the Month

The Apollo wind tunnel program was in its eighth month. To date, 2,800 hours of time had been used in 30 government and private facilities.

Apollo Quarterly Status Report No. 1, p. 35.

During the Month

The external natural environment of the Apollo spacecraft as defined in the December 18, 1961, Statement of Work had been used in the early Apollo design work. The micrometeoroid, solar proton radiation, and lunar surface characteristics were found to be most critical to the spacecraft design.

Apollo Quarterly Status Report No. 1, p. 32.

During the Month

The freeze-dried food that would be used in the Gemini program would also be provided for the Apollo program. Forty-two pounds of food would be necessary for a 14-day lunar landing mission. Potable water would be supplied by the fuel cells and processed by the environmental control system. A one-day water supply of six pounds per man would be provided at launch as an emergency ration if needed before the fuel cells were fully operative.

Apollo Quarterly Status Report No. 1, p. 13.

During the Month

The Apollo spacecraft weights had been apportioned within an assumed 90,000pound limit. This weight was termed a "design allowable." A lower target weight for each module had been assigned. Achievement of the target weight would allow for increased fuel loading and therefore greater operational flexibility and mission reliability. The design allowable for the command module was 9,500 pounds; the target weight was 8,500 pounds. The service module design allowable was 11,500 pounds; the target weight was 11,000 pounds. The S-IVB adapter design allowable and target weight was 3,200 pounds. The amount of service module useful propellant was 40,300 pounds design allowable; the target weight was 37,120 pounds. The lunar excursion module design allowable was 25,500 pounds; the target weight was 24,500 pounds.

Apollo Quarterly Status Report No. 1, p. 31.

During the Month

MSC reported that the lunar excursion module guidance system was expected to use as many components as possible identical to those in the command and service modules. Studies at the MIT Instrumentation Laboratory indicated that the changes required would simplify the computer and continue the use of the same inertial measurement unit and scanning telescope.

Apollo Quarterly Status Report No. 1, p. 27.

During the Month

MSC reported that the three liquid-hydrogen-liquid-oxygen fuel cells would supply the main and emergency power through the Apollo mission except for the earth reentry phase. Two of the fuel cells would carry normal electrical loads and one would supply emergency power. Performance predictions had been met and exceeded in single-cell tests. Complete module tests would begin during the next quarter. The liquid-hydrogen liquid-oxygen reactants for the fuel cell power supply were stored in the supercritical state in spherical pressure vessels. A recent decision had been made to provide heat input to the storage vessels with electrical heaters rather than the water-glycol loop. Three zinc-silver oxide batteries would supply power for all the electrical loads during reentry and during the brief periods of peak loads. One of the batteries was reserved exclusively for the postlanding phase. Eagle Picher Company, Joplin, Mo., had been selected in August as subcontractor for the batteries.

Apollo Quarterly Status Report No. 1, p. 23.

During the Month

MSC reported that meteoroid tests and ballistic ranges had been established at the Ames Research Center, Langley Research Center, and NAA. These facilities could achieve only about one half of the expected velocity of 75,000 feet per second for the critical-sized meteoroid. A measured improvement in the capability to predict penetration would come from a test program being negotiated by NAA with General Motors Corporation, whose facility was capable of achieving particle velocities of 75,000 feet per second.

Apollo Quarterly Status Report No. 1, p. 32.

During the Month

MSC outlined a tentative Apollo flight plan:

Pad abort:

Two tests to simulate an abort on the pad. The purpose of these tests was to qualify the launch escape system and its associated sequencing.

Suborbital (Little Joe II test launch vehicle):

Three suborbital tests with the objective of development and qualification of the launch escape system and qualification of the command module structure. Test conditions would include maximum dynamic pressure for the launch escape system and module structure testing and high atmospheric altitudes for launch escape system testing. The latter test requirement was being reviewed.

Saturn C-1:

Current Apollo requirements for the Saturn developmental flights were to determine launch exit environment on SA-6 with SA-8 as backup. Requirements on launch vehicles SA-7, SA-9, and SA-10 were to flight- test components of or the complete emergency detection system.

Saturn C-1B:

Four launch vehicle development flights prior to the manned flight. Flight test objectives for the unmanned flights were one launch environment flight with a spare and two launch vehicle emergency detection system flights.

Saturn C-5:

Six unmanned Saturn C-5 launch vehicle development flights. Flight test objectives were two launch vehicle emergency detection system flights, one spacecraft launch environment flight, and three reentry qualification flights. Preliminary objectives of manned flights were completion of the lunar excursion module qualification, lunar reconnaissance, and lunar exploration. Although the first C-5 manned flight was scheduled as the seventh C-5, a spacecraft suitable for manned flight would be available for use on the sixth C-5 to take advantage of possible earlier development success.

Apollo Quarterly Status Report No. 1, p. 48.

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PART 3 (E)

Lunar Orbit Rendezvous: Mode and Module

October 1962 through 7 November 1962

[1962 October](#)

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1962

October 1

The pad abort boilerplate command module, BP-6, to qualify the launch escape system, was scheduled for delivery to White Sands Missile Range by mid-April 1963. A pad abort test of BP-6 was scheduled for May 15, 1963.

Apollo Quarterly Status Report No. 1, p. 42.

October 3

The *Sigma 7* spacecraft with Astronaut Walter M. Schirra, Jr., as pilot was launched into orbit by a Mercury-Atlas vehicle from Atlantic Missile Range. In the most successful American manned space flight to date, Schirra traveled nearly six orbits, returning to earth at a predetermined point in the Pacific Ocean 9 hours, 13 minutes after liftoff. Within 40 minutes after landing, he and his spacecraft were safely aboard the aircraft carrier U.S.S. *Kearsarge*.

Grimwood, *Project Mercury: A Chronology*, pp. 174-175; *Astronautical and Aeronautical Events of 1962*, pp. 208-209.

October 4

Rocketdyne Division successfully completed the first full-duration (250-seconds) static firing of the J-2 engine.

Rocketdyne *Skywriter*, October 12, 1962.

October 5

NASA signed a \$1.55-million contract with Hamilton Standard Division of United Aircraft Corporation and International Latex Corporation for the development of a space suit for the Apollo crewmen. As the prime contractor, Hamilton Standard would have management responsibility for the overall program and would develop a life-support, backpack system to be worn by crewmen during lunar expeditions. International Latex Corporation as subcontractor would fabricate the suit, with Republic Aviation Corporation furnishing human factors information and environmental testing. The suit would allow a crewman greater mobility than previous space suits, enabling him to walk, climb, and bend with relative ease.

Astronautical and Aeronautical Events of 1962, p. 211; MSC, *Project Apollo Quarterly Status Report No. 2 for Period Ending December 31, 1962*, p. 22.

October 10

The Minneapolis-Honeywell Regulator Company letter subcontract for the Apollo stabilization and control system was suspended by NAA and amended in accordance with the current design concepts,

Apollo Quarterly Status Report No. 2, p. 16.

October 15

The analysis of scientific measurements made by the *Ranger III* lunar probe showed that gamma-ray intensity in interplanetary space was ten times greater than expected, NASA reported. Measurements were taken by gamma-ray spectrometers on *Ranger III* after it was launched on January 26. NASA scientists, however, did not believe that gamma-ray intensity was "great enough to require any changes in the design of radiation shielding for manned spacecraft."

New York Times, October 16, 1962.

October 15

NASA announced that five additional Ranger spacecraft would be added to the lunar exploration program, raising the total to 14 to be launched through 1964.

New York Times, October 15, 1962.

October 16

NASA announced the selection of the International Business Machines Corporation to provide a ground-based computer system for Projects Gemini and Apollo. The computer complex would be part of the mission control center at MSC.

Astronautical and Aeronautical Events of 1962, p. 216.

October 18

The *Ranger V* lunar probe was launched from Atlantic Missile Range by an Atlas-Agena B launch vehicle. The Agena B stage attained parking orbit and 25 minutes later reignited to send *Ranger V* toward the moon. The spacecraft's solar cells did not provide power, making reception of the flight-path correction signal impossible and rendering its television cameras useless. *Ranger V* was to have relayed television pictures of the lunar surface and rough-landed an instrumented capsule containing a seismometer. The spacecraft was tracked for 8 hours, 44 minutes, before its small reserve battery went dead.

On October 29, Homer E. Newell, NASA Director of the Office of Space Sciences, established a Board of Inquiry to review the entire Ranger program. The Board, headed by Albert J. Kelley of NASA Headquarters, submitted its report on December 4 and found that, while the Ranger design concept was basically sound, improvements could be made to increase flight reliability.

Washington Post, October 19 and 22, 1962; U.S. Congress, House, Subcommittee on Space Sciences and Advanced Research and Technology of the Committee on Science and Astronautics, *1964 NASA Authorization*, Hearings on H.R. 5466, 88th Congress, 1st Session (1963), pp. 1597-1598.

October 22

The Lunar and Planetary Laboratory of the University of Arizona, directed by Gerard P. Kuiper, reported that its analysis of lunar photographs taken by *Lunik III* differed from that announced by Soviet scientists. The most extensive feature of the moon's far side, photographed in 1959, had been named "The Soviet Mountains"; this feature was identified by the Arizona laboratory as an elongated area of bright patches and rays, possibly flat. Another feature, named the "Joliot-Curie Crater" by Soviet scientists, was re-identified by the Arizona laboratory as Mare Novum (New Sea), first identified by German astronomer Julius Franz near the turn of the century.

New York Times, October 22, 1962.

October 23

At the request of NASA, about 300 pieces of Gemini ground support equipment were examined by NAA engineers. It appeared that about 190 items would be usable on the Apollo program.

Oakley, *Historical Summary, S&ID Apollo Program*, p. 7.

October 24

The Office of Systems under NASA's Office of Manned Space Flight completed a manned lunar landing mode comparison embodying the most recent studies by contractors and NASA Centers. The report was the outgrowth of the decision announced by NASA on July 11 to continue studies on lunar landing modes while basing planning and procurement primarily on the lunar orbit rendezvous (LOR) technique. The results of the comparison between the LOR technique, a two-man C-5 direct flight, and a two-man earth orbit rendezvous EOR mode were:

- The C-5 direct flight mode required cryogenic fuels and was marginal, even with a two-man spacecraft.
- Both the LOR and EOR modes were feasible.
- The reliability differences between LOR and EOR could not be demonstrated conclusively by analysis at this time. LOR appeared to have a higher probability of mission success at less risk to the astronauts.
- Designing the lunar excursion module specifically for the lunar landing and performing the mission with a single C-5 launch vehicle were important advantages of the LOR mode, offsetting the problems connected with LOR rendezvous.
- Human factors considerations were not significant in the mode selections; the addition of rendezvous to the requirement for lunar landing and reentry did not add appreciably to crew stress or fatigue or to the overall hazards of the mission.
- Both LOR and EOR provided the basis for projected national space requirements before the development of Nova-class launch vehicles. The C-5 launch vehicle capability met estimated payload requirements. LOR provided experience in personnel transfer between spacecraft as contrasted with fuel transfer in EOR.
- The lunar landing mission could be accomplished at least one year and probably 18 months sooner by using LOR rather than EOR.
- The LOR mode was 10 to 15 percent less expensive than EOR.
- The LOR mode provided the cleanest management structure within the NASA organization.

In conclusion, the LOR mode offered the best opportunity of meeting the goal of an American manned lunar landing within the decade of the sixties.

Office of Systems, Office of Manned Space Flight, "Manned Lunar Landing Comparison," October 24, 1962, pp. 1, 5-6.

October 25

Republic Aviation Corporation selected the Radio Corporation of America to design and build the data

acquisition and communications subsystem for Project Fire.

Astronautical and Aeronautical Events of 1962, p. 222.

October 26

Flight missions of the Apollo spacecraft were to be numerically identified in the future according to the following scheme :

Pad aborts: PA-1, PA-2, etc.

Missions using Little Joe II launch vehicles: A-001, A-002, etc. Missions using Saturn C-1 launch vehicles: A-101, A-102, etc. Missions using Saturn C-1B launch vehicles: A-201, A-202, etc. Missions using Saturn C-5 launch vehicles: A-501, A-502, etc.

The 'A' denoted Apollo, the first digit stood for launch vehicle type or series, and the last two digits designated the order of Apollo spacecraft flights within a vehicle series.

Memorandum, Charles W. Frick, Manager, Apollo Spacecraft Project Office, to Distribution, "Designations for Apollo Missions," October 26, 1962.

October 30

NASA announced the realignment of functions under Associate Administrator Robert C. Seamans, Jr. D. Brainerd Holmes assumed new duties as a Deputy Associate Administrator while retaining his responsibilities as Director of the Office of Manned Space Flight. NASA field installations engaged principally in manned space flight projects (Marshall Space Flight Center Manned Spacecraft Center, and Launch Operations Center) would report to Holmes; installations engaged principally in other projects (Ames, Langley, Lewis, and Flight Research Centers, Goddard Space Flight Center, Jet Propulsion Laboratory, and Wallops Station) would report to Thomas F. Dixon, Deputy Associate Administrator for the past year. Previously most field center directors had reported directly to Seamans on institutional matters beyond program and contractual administration.

Rosholt, *An Administrative History of NASA, 1958-1963*, pp. 256-257; *Washington Evening Star*, October 31, 1962.

October 30

MSC Director Robert R. Gilruth reported to the Manned Space Flight Management Council that the Apollo drogue parachutes would be tested in the Langley Research Center wind tunnels.

MSF Management Council Minutes, October 30, 1962, Agenda Item 1.

October 30

NASA announced the signing of a contract with the Space and Information Systems Division of NAA for the development and production of the second stage (S-II) of the Saturn C-5 launch vehicle. The \$319.9-million contract, under the direction of Marshall Space Flight Center, covered the production of nine live flight stages, one inert flight stage, and several ground-test units for the advanced Saturn launch vehicle. NAA had been selected on September 11, 1961, to develop the S-II. *Wall Street Journal*, October 31, 1962.

October 31

NAA completed the firm-cost proposal for the definitive Apollo program and submitted it to NASA. MSC had reviewed the contract package and negotiated a program plan position with NAA.

Oakley, *Historical Summary, S&ID Apollo Program*, p. 7; *Apollo Quarterly Status Report No. 2*, pp. 5, 6.

October 31

NASA announced that the Douglas Aircraft Company had been awarded a \$2.25million contract to modify the S-IVB stage for use in the Saturn C- 1B program.

NASA News Release, 62-232, October 31, 1962.

During the Month

Proposed designs for view port covers on the crew-hatch window, docking ports, and earth landing windows were prepared by NAA. Design planning called for these port covers to be removed solely in the space environment. [Crew members would not use such windows during launch and reentry phases.] NAA,

Apollo Monthly Progress Report, SID 62-300-7, October 31, 1962, p. 71.

During the Month

Elimination of the requirement for personal parachutes nullified consideration of a command module (CM) blowout emergency escape hatch. A set of quick-acting latches for the inward-opening crew hatch would be needed, however, to provide a means of egress following a forced landing. The latches would be operable from outside as well as inside the pressure vessel. Outside hardware for securing the ablative

panel over the crew door would be required as well as a method of releasing the panel from inside the CM.

Apollo Monthly Progress Report, SID 62-300-7, p. 70.

During the Month

An NAA study on the shift of the command module center of gravity during reentry proposed moving the crew and couches about ten inches toward the aft equipment bay and then repositioning them for landing impact.

A review of body angles used for the current couch geometry disclosed that the thigh-to-torso angle could be closed sufficiently for a brief period during reentry to shorten the overall couch length by the required travel along the Z-Z axis. [See diagrams]. The more acute angle was desirable for high g conditions. This change in the couch adjustment range, as well as a revision in the lower leg angle to gain structure clearance, would necessitate considerable couch redesign.

Apollo Monthly Progress Report, SID 62-300-7, p. 68.

During the Month

Incandescent lamps would be used for floodlighting the command module because they weighed less than fluorescent lamps and took up less space while increasing reliability and reducing system complexity. A 28-volt lamp was most desirable because of its compatibility with the spacecraft 28-volt dc power system. Laboratory tests with a 28-volt incandescent lamp showed that heat dissipation would not be a problem in the vacuum environment but that a filament or shock mount would have to be developed to withstand vibration. An incandescent quartz lamp was studied because of its small size and high concentration of light.

Apollo Monthly Progress Report, SID 62-300-7, p. 89.

During the Month

The feasibility of using the Gemini fuel cell for the lunar excursion module was studied by NAA. However, because of modifications to meet Apollo control and auxiliary requirements, the much lighter Gemini system would ultimately weigh about as much as the Apollo fuel cell. In addition, the Gemini fuel cell schedule would slip if the system had to be adapted to the Apollo mission.

Apollo Monthly Progress Report, SID 62-300-7, pp. 91-92.

During the Month

The valves of the command module (CM) environmental control system were modified to meet the 5.0 psia oxygen operating requirements. All oxygen partial pressure controls were deleted from the system and the relief pressure setting of 7 +/- 0.2 psia was changed to 6 +/- 0.2 psia. The CM now could be repressurized from 0 to 5.0 psia in one hour.

Apollo Monthly Progress Report, SID 62-300-7, p. 48.

During the Month

The revised NAA recommendation for a personal communications system consisted of a duplex capability with a simplex backup. Simultaneous transmission of voice and biomedical data with a break-in capability would be possible. Two changes in spacecraft VHF equipment would be needed: a dual-channel in place of a single-channel receiver, and a diplexer for use during duplex operation.

Apollo Monthly Progress Report, SID 62-300-7, p. 57.

During the Month

NAA completed a preliminary design for the deployment of the spacecraft deep space instrumentation facility antenna to the Y axis [see diagrams]. The antenna would be shifted into the deploy position by actuation of a spring-loaded swing-out arm.

Apollo Monthly Progress Report, SID 62-300-7, p. 82.

During the Month

An NAA digital computer program for calculating command module heatshield and couch system loads and landing stability was successful. Results showed that a five-degree negative-pitch attitude was preferable for land landings.

Apollo Monthly Progress Report, SID 62-300-7, p. 14.

During the Month

NAA completed a study of reentry temperatures. Without additional cooling, space suit inlet temperatures were expected to increase from 50 degrees F at 100,000 feet to 90 degrees F at spacecraft parachute deployment. The average heat of the command module inner wall was predicted not to exceed 75 degrees F at parachute deployment and 95 degrees F on landing, but then to rise to nearly 150 degrees F.

Apollo Monthly Progress Report, SID 62-300-7, p. 26.

During the Month

A new launch escape tower configuration with an internal structure that would clear the launch escape motor exhaust plume at 30,000 feet was designed and analyzed by NAA. Exhaust impingement was avoided by slanting the diagonal members in the upper bay toward the interior of the tower and attaching them to a ring.

Apollo Monthly Progress Report, SID 62-300- 7, p. 26.

During the Month

The technique tentatively selected by NAA for separating the command and service modules from lower stages during an abort consisted of firing four 2000-pound-thrust posigrade rockets mounted on the service module adapter. With this technique, no retrorockets would be needed on the S-IV or S-IVB stages. Normal separation from the S-IVB would be accomplished with the service module reaction control system.

Apollo Monthly Progress Report, SID 62-300-7, p. 17.

November 2

NAA completed the release of the layout and preliminary design of command module crew accessories and survival equipment.

NAA, *Apollo Monthly Progress Report, SID 62-300-8, November 1962, p. 34.*

First Week

The Armour Research Foundation reported to NASA that the surface of the moon might not be covered with layers of dust. The first Armour studies showed that dust particles become harder and denser in a higher vacuum environment such as that of the moon, but the studies had not proved that particles eventually become bonded together in a rocket substance as the vacuum increases.

Astronautical and Aeronautical Events of 1962, p. 234.

November 3

Four "hot spots" on the moon were reported to have been discovered by Bruce C. Murray and Robert L. Wildey of California Institute of Technology, using a new telescope with a heat-sensitive, gold-plated mirror to detect infrared radiation. The two space scientists speculated that hot spots could indicate large areas of bare rock exposed on the lunar surface. The spots were discovered during a survey of the moon

which also revealed that the lunar surface became colder at night than previously believed, -270 degrees F compared to -243 degrees F recorded by earlier heat measuring devices. Murray said the new evidence could mean that there were prominences of heat-retaining rock protruding through a thick dust layer on the lunar surface.

Washington Post, November 4, 1962.

November 5

William L. Gill, Chief of Crew Systems Division's Radiation Branch, MSC, said that the walls of the Apollo spacecraft would provide most of the radiation shielding required for the crew. Astronauts would have special shielding devices only for their eyes.

Astronautical and Aeronautical Events of 1962, p. 233.

November 7

NASA announced that the Grumman Aircraft Engineering Corporation had been selected to build the lunar excursion module of the three-man Apollo spacecraft under the direction of MSC. The contract, still to be negotiated, was expected to be worth about \$350 million, with estimates as high as \$1 billion by the time the project would be completed. NASA Administrator James E. Webb, in announcing the selection, remarked: "We are affirming our tentative decision of last July" [in favor of the lunar orbit rendezvous approach]. D. Brainerd Holmes, NASA Director of the Office of Manned Space Flight, noted that more than one million man-hours of some 700 outstanding scientists, engineers, and researchers had gone into studies of the Apollo mission during the past year. "The results of these studies," he said, "added up to the conclusion that lunar orbit rendezvous is the preferable mode to take." With this award, the last major part of the Apollo program had been placed under contract.

New York Times, November 8, 1962; TWX, NASA Headquarters to MSC; Marshall Space Flight Center; Launch Operations Center; Ames, Langley, Lewis, and Flight Research Centers; Goddard Space Flight Center; Jet Propulsion Laboratory; Wallops Station; and Western Operations Office, November 7, 1962.

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Appendix 1

Glossary of Abbreviations

DOD - Department of Defense

MIT - Massachusetts Institute of Technology

MSC - Manned Spacecraft Center

NAA - North American Aviation, Inc.

NACA - National Advisory Committee for Aeronautics

NASA - National Aeronautics and Space Administration

STG - Space Task Group

U.S. - United States of America

U.S.S.R. - Union of Soviet Socialist Republics

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APPENDIX 2

COMMITTEES

Special Committee on Space Technology (Stever Committee)

Date of organization: January 12, 1958

Date of first meeting: February 13, 1958

Recommendations submitted to NASA: October 28, 1958

- H. Guyford Stever, Chairman
- Norman C. Appold
- Abraham Hyatt
- Wernher von Braun
- Hugh L. Dryden
- Robert R. Gilruth
- H. Julian Allen
- Abe Silverstein
- H. W. Bode
- Milton U. Clauser
- Dale R. Corson
- James R. Dempsey
- Samuel K. Hoffman
- W. Randolph Lovelace II
- William H. Pickering
- Louis N. Ridenour
- James A. Van Allen
- Carl B. Palmer, Secretary

Working Group on Space Research Objectives

- James A. Van Allen, Chairman
- Dale R. Corson

- Norman C. Appold
- Robert Cornag
- Robert P. Haviland
- John R. Pierce
- Lyman Spitzer, Jr.
- Ernest O. Pearson, Jr., Secretary

Working Group on Vehicular Program

- Wernher von Braun, Chairman
- Samuel K. Hoffman
- Norman C. Appold
- Abraham Hyatt
- Louis N. Ridenour
- Abe Silverstein
- Krafft A. Ehricke
- M. W. Hunter
- C. C. Ross
- Homer J. Stewart
- George S. Trimble, Jr.
- William H. Woodward, Secretary

Working Group on Reentry

- Milton U. Clauser, Chairman
- H. Julian Allen
- Mac C. Adams
- Alfred J. Eggers, Jr.
- Maxime A. Faget
- Alexander H. Flax
- Lester Lees
- Harlowe J. Longfelder
- J. C. McDonald
- S. A. Schaaf
- John P. Stapp
- R. Fabian Gornason, Secretary
- Harvey H. Brown, Secretary

Working Group on Range, Launch, and Tracking Facilities

- James R. Dempsey, Chairman
- Robert R. Gilruth

- Paul T. Cooper
- L. G. deBey
- Carl E. Duckett
- Robert F. Freitag
- J. Allen Hynek
- John T. Mengel
- Grayson Merrill
- Carl B. Palmer, Secretary

Working Group on Instrumentation

- William H. Pickering, Chairman
- Louis N. Ridenour
- H. W. Bode
- Robert W. Buchheim
- Harry J. Goett
- Albert C. Hall
- Eberhardt Rechtin
- William T. Russell
- Robert C. Seamans, Jr.
- Bernard Maggin, Secretary

Working Group on Space Surveillance

- H. W. Bode, Chairman
- William H. Pickering
- Wilbur B. Davenport, Jr.
- W. B. Hebenstreit
- Richard D. Leghorn
- K. G. Macleish
- William B. McLean
- Alan H. Shapley
- Fred L. Whipple
- Carl B. Palmer, Secretary

Working Group on Human Factors and Training

- W. Randolph Lovelace II, Chairman
- A. Scott Crossfield
- Hubert M. Drake
- Don D. Flickinger
- Edward B. Giller

- James D. Hardy
 - Wright Haskell Langham
 - Ulrich C. Luft
 - Boyd C. Myers II, Secretary
-

Working Group on Lunar Exploration

Date of formation: February 5, 1959

First meeting attended by representatives of NASA, Jet Propulsion Laboratory, California Institute of Technology, and the University of California (names of representatives are currently unavailable).

DOD-NASA Saturn Ad Hoc Committee

Date of formation: March 17, 1959

Research Steering Committee on Manned Space Flight (Goett Committee)

Date of formation: April 1-8, 1959

Date of first meeting: May 25-26, 1959

Date of last meeting: December 8-9, 1959

- Harry J. Goett, Chairman
 - Alfred J. Eggers, Jr.
 - Bruce T. Lundin
 - Laurence K. Loftin, Jr.
 - De E. Beeler
 - Harris M. Schurmeier
 - Maxime A. Faget
 - George M. Low
 - Milton B. Ames, Jr. part time
-

Booster Evaluation Committee

Date of organization: April 15, 1959

Dates of first meetings: September 16-18, 1959

- Herbert F. York and Hugh L. Dryden, Co-chairmen
 - Abe Silverstein
 - Richard E. Horner
 - Joseph V. Charyk
 - And a representative of the United States Army
-

New Projects Panel of the Space Task Group

Date of organization: Early July, 1959

Date of first meeting: July 12, 1959

- H. Kurt Strass, Chairman
 - Alan B. Kehlet
 - William S. Augerson
 - Jack Funk
 - Caldwell C. Johnson
 - Harry H. Ricker, Jr.
 - Robert G. Chilton
 - Stanley C. White
-

Saturn Vehicle Team (Silverstein Committee)

Date of formation: November 27, 1959

Recommendations submitted to NASA: December 15, 1959

Abe Silverstein, Chairman

(Names of committee members are unavailable.)

Space Exploration Program Council

Date of organization: January 1960

Date of first meeting: February 10-11, 1960

Date of fifth meeting: January 5-6, 1961

- Harry J. Goett
- Wernher von Braun
- William H. Pickering
- Ira H. Abbott
- Abe Silverstein
- Don R. Ostrander
- Albert F. Siefert
- Richard E. Horner, Chairman
- Robert L. King, Secretary (succeeded by John I. Cumberland)

Other officials, including T. Keith Glennan, Hugh L. Dryden, Abraham Hyatt, Robert C. Seamans. Jr., Aaron Rosenthal, and Donald H. Heaton, attended from time to time.

Advanced Vehicle Team (of Space Task Group)

Date of formation: May 25, 1960

- Robert O. Piland, Head
 - H. Kurt Strass
 - Robert G. Chilton
 - Jack Funk
 - Alan B. Kehlet
 - R. Bryan Erb
 - Owen E. Maynard
 - Richard B. Ferguson
 - Alfred B. Eickmeier
-

Integration of the Saturn and Saturn Application Programs Study Group

Date of formation: September 2, 1960

- Lloyd Wood
 - Richard B. Canright
 - Alfred M. Nelson
 - John L. Sloop
 - Oran W. Nicks
 - Fred D. Kochendorfer
 - George M. Low
-

Evaluation Board

(to consider industry proposals for Apollo spacecraft feasibility studies)

Date of appointment: October 4, 1960

Recommendations submitted to Robert R. Gilruth, Director, STG: October 24, 1960

- Charles J. Donlan, Chairman
 - Maxime A. Faget
 - Robert O. Piland
 - John H. Disher
 - Alvin Seiff
 - John V. Becker
 - H. H. Koelle
 - Harry J. Goett, ex officio
 - Robert R. Gilruth, ex officio
-

Working Group on the Manned Lunar Landing Program

Date of organization: October 17, 1960

- George M. Low
- Eldon W. Hall
- Oran W. Nicks

- John H. Disher
-

Apollo Technical Liaison Groups

Date of organization: November 22, 1960

First meetings of the groups: January 6, 11, and 12, 1961

Joint meeting of the groups: April 10, 1961

Second meetings of the groups: April 10-14, 1961

Group for Configurations and Aerodynamics

- Alan B. Kehlet, Chairman, STG
- Hubert M. Drake, Flight Research Center (FRC)
- Edward L. Linsley, Marshall Space Flight Center (MSFC)
- Eugene S. Love, Langley Research Center (LaRC)
- Edwin Pounder, Jet Propulsion Laboratory (JPL)
- Clarence A. Syvertson, Ames Research Center (ARC)
- William W. Petynia, Secretary, STG

Group for Guidance and Control

- Richard R. Carley, Chairman, STG
- James D. Acord, JPL
- John M. Eggleston, LaRC
- Edmund J. Habib, Goddard Space Flight Center (GSFC)
- Euclid C. Holleman, FRC
- Helmut A. Kuehnel, STG
- G. Allen Smith, ARC
- Wilbur G. Thornton, MSFC
- James P. Nolan, Jr., Secretary, STG

Group on Heating

- Kenneth C. Weston, Chairman, STG
- Harvey A. Connell, MSFC
- Thomas V. Cooney, FRC

- Werner K. Dahm, MSFC
- Glen Goodwin, ARC
- John W. Lucas, JPL
- Robert L. Trimpi, LaRC
- Leo T. Chauvin, Secretary, STG

Group on Human Factors

- Richard S. Johnston, Chairman, STG
- David Adamson, LaRC
- Bruce A. Aikenhead, STG
- C. Patrick Laughlin, STG
- Robert F. Seldon, Lewis Research Center (LRC)
- Harald A. Smedel, ARC
- G. Dale Smith, NASA Hq.
- Milton O. Thompson, FRC
- Lee N. McMillion, Secretary, STG

Group for Instrumentation and Communications

- Ralph S. Sawyer, Chairman, STG
- Dennis E. Fielder, STG
- Heinz W. Kampmeier, MSFC
- Eberhardt Rehtin, JPL
- Kenneth C. Sanderson, FRC
- Wilford E. Sivertson, LaRC
- Robert E. Tozier, LRC
- Friedrich O. Vonbun, GSFC
- J. Thomas Markley, Secretary, STG

Group for Mechanical Systems

- Richard B. Ferguson, Chairman, STG
- Peter J. Armitage, STG
- Herman F. Beduerftig, MSFC
- Robert R. Godman, LRC
- Joseph M. Hallissy, Jr., LaRC
- Perry V. Row, FRC
- John B. Lee, Secretary, STG

Group for Onboard Propulsion

- Maxime A. Faget, Chairman, STG
- Henry Burlage, Jr., NASA Hq.
- William Cohen, NASA Hq.
- Norman E. DeMar, FRC
- Duane F. Dipprey, JPL
- David M. Hammock, MSFC
- Edmund R. Jonash, LRC
- Alexander A. McCool, MSFC
- Joseph G. Thibodaux, Jr., LaRC
- Robert H. Rollins, Secretary, STG

Group on Structures and Materials

- Robert O. Piland, Chairman, STG
- Roger A. Anderson, LaRC
- William J. Carley, JPL
- Jack B. Esgar, LRC
- Erich E. Goerner, MSFC
- Charles A. Hermach, ARC
- Robert E. Vale, STG
- Herbert G. Patterson, Secretary, STG

Group on Trajectory Analysis

- Jack Funk, Chairman, STG
- Donald R. Bellman, FRC
- Victor C. Clarke, Jr., JPL
- James F. Dalby, STG
- Seymour C. Himmel, LRC
- Rudolph F. Hoelker, MSFC
- William H. Michael, Jr., LaRC
- Stanley F. Schmidt, ARC
- Kenneth R. Squires, GSFC
- Donald C. Cheatham, Secretary, STG

Manned Lunar Landing Task Group

(Low Committee)

Date of organization: January 5-6, 1961

Date of first meeting: January 9, 1961

Date of second meeting: January 16, 1961

Report submitted to Robert C. Seamans, Jr., NASA Associate Administrator: February 7, 1961

- George M. Low, Chairman
 - Eldon W. Hall
 - A. M. Mayo
 - Ernest O. Pearson, Jr.
 - Oran W. Nicks
 - Maxime A. Faget
 - H. H. Koelle
-

Ad Hoc Committee on Space

(Wiesner Committee)

Report submitted to President-elect John F. Kennedy: January 10, 1961

- Jerome B. Wiesner, Chairman
 - Kenneth BeLieu
 - Trevor Gardner
 - Donald F. Hornig
 - Edwin H. Land
 - Max Lehrer
 - Edward H. Purcell
 - Bruno B. Rossi
 - Harry J. Watters
-

Ad Hoc Task Group for a Manned Lunar Landing Study

(Fleming Committee)

Date of formation: May 2, 1961

Report submitted to Robert C. Seamans, Jr., NASA Associate Administrator: June 16, 1961

- William A. Fleming, Chairman
- Addison M. Rothrock, Deputy Chairman
- Albert J. Kelley
- Berg Paraghamian
- Walter W. Haase

Spacecraft

- John H. Disher
- Merle G. Waugh
- Kenneth S. Kleinknecht
- Alan B. Kehlet

Launch Vehicles

- Eldon W. Hall
- Melvyn Savage
- H. H. Koelle
- Norman Rafel
- Alfred M. Nelson

Facilities

- Samuel Snyder
- Secret L. Berry
- Robert D. Briskman

Life Sciences

- James P. Nolan, Jr.
- A. H. Schwichtenberg

Advanced Technology

- Ernest O. Pearson, Jr.

Space Sciences

- William Shipley

- Robert Fellows
-

Lundin Committee

Date of formation: May 25, 1961

Study completed and submitted to Robert C. Seamans, Jr., NASA Associate Administrator: June 10, 1961

- Bruce T. Lundin, Chairman
 - Walter J. Downhower
 - Alfred J. Eggers, Jr.
 - George W. S. Johnson
 - Laurence K. Loftin, Jr.
 - Harry O. Ruppe
 - William J. D. Escher, Secretary
 - Ralph W. May, Jr., Secretary
-

Ad Hoc Task Group for Study of Manned Lunar Landing by Rendezvous Techniques

(Heaton Committee)

Date of organization: June 1961

Report submitted to Robert C. Seamans, Jr., NASA Associate Administrator: August 1961

- Donald H. Heaton, Chairman
- Richard B. Canright
- L. E. Baird
- Norman Rafel
- Joseph E. McGolrick

Launch Vehicle Performance and Logistics

- Wilson B. Schramm
- L. H. Glassman

- John L. Hammersmith
- R. Voss

Guidance and Control

- Paul J. DeFries
- Robert D. Briskman
- William H. Phillips
- J. Yolles

Orbital Launch Operations

- John C. Houbolt
- Hubert M. Drake
- H. H. Koelle
- James P. Nolan, Jr.
- Warren J. North
- Harry O. Ruppe

Advanced Technology

- William H. Woodward
-

Manned Lunar Landing Coordination Group

Date of first meeting: July 6, 1961

- Robert C. Seamans, Jr.
 - Ira H. Abbott
 - Don R. Ostrander
 - Charles H. Roadman
 - William A. Fleming
 - DeMarquis D. Wyatt (part time)
 - George M. Low (attended first meeting in place of Silverstein)
 - Abe Silverstein
-

DOD-NASA Large Launch Vehicle Planning Group

(Golovin Committee)

Date of organization: July 20, 1961

- Nicholas E. Golovin, Director
 - Lawrence L. Kavanau
 - Warren Amster
 - Edward J. Barlow
 - Aleck C. Bond
 - David L. Carter
 - Matthew R. Collins, Jr.
 - Otto J. Glasser
 - Eldon W. Hall
 - Harvey Hall
 - Milton W. Rosen (served until August 18, 1961)
 - Wilson B. Schramm
 - Levering Smith
 - Lewis J. Stecher, Jr. (appointed August 29, 1961)
 - Kurt R. Stehling
 - H. J. Weigand
 - Francis L. Williams
 - William W. Wolman
-

Source Evaluation Board

(for evaluation of contractors' proposals for the Apollo spacecraft)

Date of appointment: July 28, 1961

Report submitted to James E. Webb,

NASA Administrator: November 24, 1961

- Walter C. Williams, Chairman
- Robert O. Piland
- Wesley L. Hjernevik
- Maxime A. Faget
- James A. Chamberlin
- Charles W. Mathews

- Dave W. Lang
- Oswald H. Lange

Nonvoting members: George M. Low, James T. Koppenhaver, Brooks C. Preacher

Technical Subcommittee

Date of appointment: August 7, 1961

Evaluation of proposals began: October 9, 1961

Report submitted to Source Evaluation Board: November 1, 1961

- Robert O. Piland, Chairman, STG
- Robert G. Chilton, STG
- Caldwell C. Johnson, STG
- Kenneth S. Kleinknecht, STG
- Christopher C. Kraft, Jr., STG
- Andre J. Meyer, Jr., STG
- Stanley C. White, STG
- Alvin Seifi, ARC
- John V. Becker, LaRC
- William A. Mrazek, MSFC

Technical Subpanels

Report submitted to Technical Subcommittee: October 25, 1961

Systems Integration

- Caldwell C. Johnson, Chairman, STG
- William M. Bland, STG
- John D. Hodge, STG
- Alan B. Kehlet, STG
- Owen E. Maynard, STG
- Alan B. Shepard, Jr., STG
- Hubert M. Drake, FRC
- Stanley R. Reinartz, MSFC
- John J. Williams, STG

Propulsion

- David M. Hammock, Chairman, STG
- Arthur M. Busch, STG
- Robert H. Rollins, STG
- Robert R. Brashears, JPL
- Joseph G. Thibodaux, Jr., LaRC
- Edmund R. Jonash, LRC
- John W. Conlon, STG

Flight Mechanics

- Robert G. Chilton, Chairman, STG

Aerodynamics

- Alan B. Kehlet, Group Leader, STG
- Clarence A. Syvertson, ARC
- Edward L. Linsley, MSFC
- Eugene S. Love, LaRC
- Bruce G. Jackson, STG
- Warren J. North, NASA Hq.

Trajectory Analysis

- Jack Funk, Group Leader, STG
- John P. Mayer, STG
- Luigi Cicolani, ARC
- Kenneth R. Squires, GSFC
- Tecwyn Roberts, STG

Guidance and Control

- Robert G. Chilton, Group Leader, STG
- Morris V. Jenkins, STG
- Richard R. Carley, STG
- John M. Eggleston, LaRC
- Euclid C. Holleman, FRC
- Thomas V. Chambers, STG
- Welby T. Risler, STG

Structures, Materials, and Heating

- Robert E. Vale, Chairman, STG

- Kenneth C. Weston, STG
- Glen Goodwin, ARC
- Roger A. Anderson, LaRC
- Harry L. Runyan, Jr., LaRC
- Richard H. Kemp, LRC
- George J. Vetko, MSFC

Human Factors

- Richard S. Johnston, Chairman, STG

Crew Considerations

- Richard S. Johnston, Group Leader, STG
- C. Patrick Laughlin, STG
- Gerard J. Pesman, STG
- Walter M. Schirra, Jr., STG
- Harald A. Smedal, ARC
- Lee N. McMillion, STG

Training and Crew Participation

- Robert B. Voas, Group Leader, STG
- Virgil I. Grissom, STG
- Harold I. Johnson, STG
- Richard F. Day, FRC
- Milton O. Thompson, FRC

Radiation

- David Adamson, Group Leader, LaRC
- Francis W. Casey, Jr., STG
- C. Patrick Laughlin, STG
- William L. Gill, STG

Instrumentation and Communications

- Ralph S. Sawyer, Chairman, STG

Instrumentation

- Alfred B. Eickmeier, Group Leader, STG

- Jacob C. Moser, STG
- Kenneth C. Sanderson, FRC
- Harvey Golden, MSFC
- Marion R. Franklin, Jr., STG
- John A. Dodgen, LaRC

Communications

- Ralph S. Sawyer, Group Leader, STG
- Dennis E. Fielder, STG
- Richard Z. Toukdarian, JPL
- Robert E. Tozier, LRC
- William R. Stelges, STG

Onboard Systems

- Richard B. Ferguson, Chairman, STG

Auxiliary Power Supplies

- Richard B. Ferguson, Group Leader, STG
- Preston T. Maxwell, STG
- Robert N. Parker, STG
- Joseph M. Hallissy, Jr., LaRC
- Thomas Williams, STG

Environmental Control Systems

- Richard B. Ferguson, Group Leader, STG
- James R. Hiers, STG
- Frank H. Samonski, Jr., STG
- Walter M. Schirra, Jr., STG
- Edward L. Hays, STG
- James F. Saunders, STG

Landing and Recovery Systems

- John W. Kiker, Group Leader, STG
- Peter J. Armitage, STG
- M. Scott Carpenter, STG
- James K. Hinson, STG
- Rodney G. Rose, STG

- Samuel T. Beddingfield, STG

Mechanical Systems

- Richard F. Smith, STG
- John Janokaitis, STG
- Perry V. Row, FRC
- Herman F. Beduerftig, MSFC
- Walter J. Kapryan, STG

Ground Operational Support Systems and Operations

- Christopher C. Kraft, Jr., Chairman, STG

Ground Operational Support Systems

- Robert D. Harrington, Group Leader, STG
- Howard C. Kyle, STG
- John W. Small, Jr., STG
- Friedrich O. Vonbun, GSFC
- Gerald W. Brewer, STG
- Robert B. Voas, STG

Operations

- Christopher C. Krait, Jr., STG
- Sigurd A. Sjoberg, STG
- B. Porter Brown, STG
- L. Gordon Cooper, STG
- Philip R. Maloney, STG
- Robert F. Thompson, STG
- Paul C. Donnelly, STG
- Emil P. Bertram, MSFC

Technical Development Plan

- Kenneth S. Kleinknecht, Chairman, STG
- Alan B. Kehlet, STG
- Donald C. Cheatham, STG
- Donald K. Slayton, STG
- H. Kurt Strass, STG
- John H. Disher, NASA Hq.

Reliability

- F. John Bailey, STG
- John C. French, STG
- Edward H. Olling, STG
- Harold D. Toy, STG
- K. Fred Okano, NASA Hq.

Manufacturing

- Joseph V. Piland, Chairman, STG
- Jack Kinzler, STG
- William J. Nesbitt, STG
- T. Schaus, Air Force Systems Command
- Clyde Thiele, LaRC
- Norman Levine, MSFC
- Frank M. Crichton, STG
- Archibald E. Morse, Jr., STG

Business Subcommittee

Date of organization: August 16, 1961

Evaluation of proposals began: October 9, 1961

Report submitted to the Source Evaluation Board: November 3, 1961

- Glenn F. Bailey, Chairman, STG
- Phillip H. Whitbeck, STG
- John D. Young, NASA Hq.
- Douglas E. Hendrickson, STG
- George F. MacDougall, Jr., STG
- John M. Curran, NASA Hq.
- Wilbur H. Gray, STG
- John H. Glenn, Jr., STG
- Thomas F. Baker, STG

Business Assessment Panels

Organization and Management

- Thomas W. Briggs, Chairman, STG
- J. B. Trenholm, Jr., Air Force Systems Command
- Henry P. Yschek, STG
- Pinkney McGathy, STG
- Allen L. Granfield, STG
- James A. Bennett, STG
- Bryant L. Johnson, STG
- Nickolas Jevas, STG
- J. Thomas Markley, STG
- Dugald O. Black, STG
- Walter W. Haase, NASA Hq.
- Ralph E. Cushman, NASA Hq.
- Earl E. McGinty, NASA Hq.
- Don Hardin, MSFC
- Peter F. Korycinski, LaRC

Logistics

- Lawrence Jacobson, Chairman, NASA Hq.
- Paul H. Kloetzer, STG
- Richard F. Baillie, STG
- Walter D. Wolhart, STG
- A. Martin Eiband, STG

Subcontract Administration

- Harry L. Watkins, STG
- Wayne W. Corbett, STG
- John B. Lee, STG
- James S. Evans, Western Operations Office
- Eldon W. Kaser, ARC

Cost

- Charles J. Finegan, Chairman, NASA Hq.
- A. E. Hyatt, STG
- J. Howard Allison, STG
- Lester A. Stewart, STG
- James H. Sumpter, Jr., Army Audit Agency
- Irving J. Sandler, AF Auditor General's Office
- Adaron B. Jordan, AF Systems Command

MSFC-MSC-LOC Coordination Panels

(originally designated MSFC-MSC Coordination Panels);

Date of establishment: October 3, 1961

Date of first meeting: November 8, 1961

Panels reported to:

Space Vehicle Review Board (MSFC-MSC-LOC Space Vehicle Review Board), which consisted of the Directors of the three Centers (Wernher von Braun, Robert R. Gilruth, and Kurt H. Debus); division directors and other key technical personnel; NASA Headquarters representatives; observers; specialists; panel representatives invited to attend by the Directors of MSFC, MSC, and LOC.

Electrical Systems Integration Panel

MSC

- Milton G. Kingsley, Co-chairman
- Lyndon Robinson
- R. C. Irvin, Co-secretary
- Robert E. Munford
- W. E. Williams

LOC

- Daniel D. Collins

MSFC

- Hans J. Fichtner, Co-chairman
- Richard G. Smith
- Robert M. Aden
- David B. Gardiner, Jr.,
- Co-secretary James Vann

Instrumentation and Communication Panel

MSC

- Alfred B. Eickmeier, Co-chairman
- Clyde Whittaker, Co-secretary
- Robert F. Thompson
- James L. Strickland
- Howard C. Kyle
- Gordon Woosley
- William R. Stelges

LOC

- Daniel D. Collins

MSFC

- Otto A. Hoberg, Co-chairman
- Harvey Golden, Co-secretary
- Heinz W. Kampmeier
- Herman F. Kurtz
- James Vann

Mechanical Integration Panel

MSC

- Lyle M. Jenkins, Co-chairman
- Robert P. Smith, Co-secretary
- Percy Hurt
- Robert E. Vale
- Samuel T. Beddingfield

LOC

- Andrew J. Pickett
- Robert Moore

MSFC

- Hans R. Palaoro, Co-chairman
- Robert O. Barraza, Co-secretary
- Jack H. Furman
- Tom Isbell

- Earl M. Butler
- Wallace Kistler
- Desmond Beck
- Fred G. Edwards

Flight Mechanics, Dynamics, Guidance, and Control Panel

MSC

- Calvin H. Perrine, Jr., Co-chairman
- Robert J. Ward, Co-secretary
- Robert G. Chilton
- Aaron Cohen
- John P. Mayer

LOC

- A. H. Knothe

MSFC

- R. F. Hoelker, Co-chairman
- Lewis L. McNair, Co-secretary
- Thomas G. Reed
- Hans H. Hosenthien
- F. Brooks Moore
- John W. Massey

Launch Operations Panel

MSC

- John J. Williams
- Melvin Dell
- Philip R. Maloney
- Paul C. Donnelly

LOC

- Rocco A. Petrone, Chairman
- Emil P. Bertram, Secretary
- Robert E. Gorman

MSFC

- Robert E. Moser
- Joachim P. Kuettner

Mission Control Operations Panel

MSC

- John D. Hodge, Co-chairman
- Dennis E. Fielder, Co-secretary
- Howard C. Kyle
- Tecwyn Roberts
- Gordon Woosley
- Eugene F. Kranz

LOC

- Rudolf H. Bruns
- Emil P. Bertram
- Walter W. Kavanaugh

MSFC

- Fridjof A. Speer, Co-chairman
- Ernest B. Nathan, Co-secretary
- James T. Felder
- Wallace Kistler
- E. W. King
- Ludie G. Richard
- Grady Williams

Crew Safety Panel

MSC

- Alfred Mardel, Co-chairman
- Art White, Co-secretary
- Donald K. Slayton
- Sigurd A. Sjoberg
- Warren J. North

- C. K. Anderson

LOC

- Emil P. Bertram

MSFC

- Joachim P. Kuettner, Co-chairman
 - E. W. King, Co-secretary
 - James Powell
 - Friedrich W. Brandner
 - Jerry L. Mack
 - George Butler, Jr.
 - Wallace Kistler
 - Robert M. Hunt
 - James P. Lindberg, Jr.
 - Frank Bryan
-

MSFC-MSc Advanced Program Coordination Board

Date of first meeting: October 20, 1961

Attended first meeting:

MSc

- Robert R. Gilruth
- Walter C. Williams
- Aleck C. Bond
- Maxime A. Faget
- Kenneth S. Kleinknecht
- J. Thomas Markley
- Charles W. Mathews
- Robert O. Piland
- G. Merritt Preston
- Paul E. Purser
- James A. Chamberlin
- Alan B. Shepard, Jr.

MSFC

- Wernher von Braun
 - Paul J. DeFries
 - Fred E. Digesu
 - Ernst D. Geissler
 - Joachim P. Kuettner
 - Charles A. Lundquist
 - Jerry C. McCall
 - William A. Mrazek
 - J. Unger
 - H. H. Koelle
-

Rosen Working Group

Date of organization: November 6, 1961

Recommendations submitted to D. Brainerd Holmes, Director, Office of Manned Space Flight:

November 20, 1961

- Milton W. Rosen, Chairman
 - Richard B. Canright
 - Eldon W. Hall
 - Elliott Mitchell
 - Norman Rafel
 - Melvyn Savage
 - Adelbert O. Tischler
 - William A. Mrazek
 - Hans H. Maus
 - James B. Bramlet
 - John H. Disher
 - David M. Hammock
-

Manned Space Flight Management Council

Date of formation and first meeting: December 21, 1961

- D. Brainerd Holmes
- Robert R. Gilruth
- Walter C. Williams
- Wernher von Braun
- Eberhard F. M. Rees
- George M. Low
- Milton W. Rosen
- Charles H. Roadman
- William E. Lilly
- Joseph F. Shea

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APPENDIX 3

MAJOR SPACECRAFT CONTRACTORS

August 9, 1961, through November 7, 1962

Principal Contractor - Spacecraft

Company	System	Potential Value of Contract (in millions)
=====	=====	=====
North American Aviation, Inc., Space and Information Systems Division	Command and service modules	\$900

Subcontractors

Aerojet-General Corp.	Service module propulsion motor	\$ 28.423
Avco Corp.	Ablative heatshield	\$ 22.462
Beech Aircraft Corp.	Supercritical gas storage system	\$ 4
Collins Radio Co.	Communications and data	\$ 96.996
Garrett Corp., AiResearch Mfg. Co.	Environmental control system	\$ 44.735
Lockheed Propulsion Co.	Launch escape and	\$ 9.702

	pitch control motors	
Marquardt Corp.	Reaction control motors (service module)	\$ 19.593
Minneapolis-Honeywell Regulator Co.	Stabilization and flight control	\$104.064
Northrop Corp., Ventura Division	Earth landing system	\$ 10.486
Thiokol Chemical Corp., Hunter-Bristol Division	Escape system jettison motors	\$ 2.629
United Aircraft Corp., Hamilton Standard Division	Space suit	\$ 1.550
United Aircraft Corp., Pratt & Whitney Aircraft Division	Fuel cell	\$ 43.531

Guidance and Navigation

Massachusetts Institute of Technology, Instrumentation Laboratory	Management of guidance and navigation development	\$ 71
General Motors Corp., AC Spark Plug Division	Inertial platform and associated ground support equipment	\$ 44.545
Kollsman Instrument Co.	Optical subsystems	\$ 10
Raytheon Co.	Onboard guidance computer	\$ 15
Sperry Rand Corp., Sperry Gyroscope Division	Accelerometers	\$ 0.747

Lunar Excursion Module

Grumman Aircraft
Engineering Corp.

Lunar excursion module

Undeter-
mined

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Appendix 9

Apollo Experiments

Part I: Lunar Surface Experiments

The lunar surface experiments were of two kinds:

1. The Apollo Lunar Surface Experiments Package (ALSEP) systems, which were left on the lunar surface by the astronauts and which continued sending telemetry data until turned off Sept. 30, 1977, and
2. experiments conducted on the lunar surface by the astronauts and returned to earth in the command module.

The dates and lunar coordinates are given in the following listing. The ALSEP-related experiments are listed next, by experiment number, with Apollo mission numbers.

Apollo 12:

The Apollo 12 ALSEP was deployed on November 19, 1969, at latitude 3 degrees 11' S, longitude 23 degrees 23' W in Oceanus Procellarum.

Apollo 13:

Because of service module problems, a lunar landing was not accomplished during the Apollo 13 mission.

Apollo 14:

The ALSEP was deployed on February 5, 1971, at latitude 3 degrees 40' S, longitude 17 degrees 27' W in the Fra Mauro formation.

Apollo 15:

The ALSEP was deployed July 31, 1971, at latitude 26 degrees 06' N, longitude 3 degrees 39' E in the Hadley-Apennine region.

Apollo 16:

The ALSEP was deployed April 21, 1972, at latitude 8 degrees 59' 34" S, longitude 15 degrees 30' 47" E in the Descartes Highlands.

Apollo 17:

The ALSEP was deployed on December 12, 1972, at latitude 20 degrees 09' 55" N, longitude 30 degrees 45' 57" E in the Taurus-Littrow region.

Apollo ALSEP Experiments

Number & Experiment	Apollo Mission (12,14,15,16)				
S 031 Passive Seismic	12	14	15	16	
S 033 Active Seismic	14	16			
S 034 Lunar Surface Magnetometer	12	15	16		
S 035 Solar-wind Spectrometer	12	15			
S036 Suprathermal Ion Detector	12	14	15		
S 037 Heat flow	15	(1)	17		
S 038 Charged Particle	14				
S 058 Cold Cathode Gage	12	14	15		
S 059 Lunar Geology	12	14	15	16	17
S 078 Laser Ranging Retroreflector	12	14	15		
S 152 Cosmic Ray Detector	16				
S 198 Portable Magnetometer	14	16			
S 199 Traverse Gravimeter	17				
S 200 Soil Mechanics	12	14	15	16	17
S 201 Far UV Camera/Spectrograph	16				
S 202 lunar Ejecta and Meteorites	17				
S 203 Lunar Seismic Profiling	17				
S 204 Surface Electrical Properties	17				
S 205 Lunar Atmospheric Composition	17				
S 207 Lunar Surface Gravimeter	17				
S 229 Neutron Probe	12	14	15	16	17
M 515 Dust Detector	12	14	15		

Part II: Lunar Orbital Experiments

Most of the lunar orbital experiments were added to the Apollo program during missions *15*, *16*, and *17*. The objectives of these experiments were to determine and understand regional variations in the chemical composition of the lunar surface, to study the gravitational field of the moon, to determine the induced and permanent magnetic fields of the moon, and to make a detailed study of the morphology and albedo of the lunar surface. These experiments and the missions during which they were performed

are listed in the following table.

Apollo Orbital Experiments

Number & Experiment	Apollo Mission (12,14,15,16,17)				
	15	16			
S 160 Gamma-Ray Spectrometer	15	16			
S 161 S-Ray Fluorescence	15	16			
S 162 Alpha-Particle Spectrometer	15	16			
S 164 S-Bank Transponder (subsattellite)	15	16			
S 164 S-Band Transponder (CSM/LM)	12	14	15	16	17
S 165 Mass Spectrometer	15	16			
S 169 Far UV Spectrometer	17				
S 170 Bistatic Radar	14	15	16		
S 171 Infrared Scanning Radiometer	17				
S 173 Particle Shadow/Boundary Layer (subsattellite)	15	16			
S 174 Magnetometer (subsattellite)	15	16			
S 175 Laser Altimeter	15	16	17		
S 209 Lunar Sounder	17				

Part III: Apollo Experiment Principal Investigators

The principal investigators for the lunar surface and lunar orbital experiments are listed by experiment numbers. The lunar surface group is listed first.

Lunar Surface Experiment Investigators

S 031 Passive Seismic

G. V. Latham, Marine Biomedical Institute, Galveston, Texas

S 033 Active Seismic

Robert L. Kovach, Stanford University

S 203 Lunar Seismic Profiling

Robert L. Kovach, Stanford University

S 034 Lunar Surface Magnetometer

Palmer Dyal, Ames Research Center;

Charles P. Sonett, Lunar and Planetary Laboratory, University of Arizona

- S 035 Solar-wind Spectrometer
Conway W. Snyder, Jet Propulsion Laboratory
- S 036 Suprathermal Ion Detector
John W. Freeman, Rice University
- S 037 Heat Flow
Marcus E. Langseth, Columbia University
- S 038 Charged-Particle Lunar Environment Experiment
D. L. Reasoner, Rice University
- S 058 Cold Cathode Gage
Francis S. Johnson, University of Texas at Dallas
- S 059 Lunar Geology
Gordon A. Swann, Center of Astrogeology, U.S. Geological Survey.;
- William R. Muehlberger, University of Texas
- S 078 Laser Ranging Retroreflector
James E. Faller, Wesleyan University
- S 152 Cosmic Ray Detector
R. L. Fleischer, General Electric Research and Development Laboratory, Schenectady, N.Y.;
- Buford Price, University of California at Berkeley.;
- Robert M. Walker, Washington University St. Louis, Mo.
- S 198 Lunar Portable Magnetometer
Palmer Dyal, Ames Research Center
- S 199 Traverse Gravimeter
Manik Talwani, Columbia University
- S 200 Soil Mechanics
J. Mitchell, University of California at Berkeley
- S 201 Far UV Camera/Spectrograph
G. R. Carruthers, E. O. Hurlburt Center for Space Research, Naval Research Laboratory,
Washington, D.C.;
- Thornton Page, Johnson Space Center
- S 202 Lunar Ejecta and Meteorites
Otto E. Berg, Goddard Space Flight Center
- S 204 Surface Electrical Properties
M. Gene Simmons, Massachusetts Institute of Technology.;
- David W. Strangway, University of Toronto
- S 205 Lunar Atmospheric Composition
J. R. Hoffman, University of Texas at Dallas
- S 207 Lunar Surface Gravimeter

Joseph Weber, University of Maryland

S 229 Lunar Neutron Probe

D. S. Burnett, California Institute of Technology

M 515 Dust Thermal Radiation Engineering Measurement

James R. Bates, Johnson Space Center

Lunar Orbital Experiment Investigators

S 160 Gamma-Ray Spectrometer

James R. Arnold, University of California at San Diego

S 161 X-Ray Fluorescence

Isidore Adler, University of Maryland

S 162 Alpha-Particle Spectrometer

Paul Gorenstein, Smithsonian Astrophysical Observatory, Cambridge, Mass.

S 164 S-Band Transponder

William L. Sjogren, Jet Propulsion Laboratory

S 165 Lunar Orbital Mass Spectrometer

J. H. Hoffman, University of Texas at Dallas

S 169 Ultraviolet Spectrometer

William E. Fastie, Johns Hopkins University

S 170 Bistatic Radar

H. Taylor Howard, Stanford University

S 171 Infrared Scanning Radiometer

Frank J. Low, University of Arizona.;

W. W. Mendell, Johnson Space Center

S 173 Subsatellite Particles and Shadows

Kinsey A. Anderson University of California at Berkeley

S 174 Particles and Fields Subsatellite Magnetometer

P. J. Coleman, University of California at Los Angeles.

S 175 Laser Altimeter

William M. Kaula, University of California at Los Angeles.;

William L. Sjogren, Jet Propulsion Laboratory

S 209 Lunar Sounder

Roger J. Phillips, Jet Propulsion Laboratory.;

Stanley Ward, University of Utah.;

Walter E. Brown, Jr., Jet Propulsion Laboratory

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APPENDIX 4

Flight Summary

August 17, 1958, through November 7, 1962

*The launches described in this table include only those related to the exploration of the moon: unmanned lunar probes, unmanned tests of spacecraft designed for later manned missions, and manned spacecraft flights. The table is not intended as a comprehensive summary of all American and Soviet space flights.

AMR - Atlantic Missile Range.

S - successful.

P - Partially successful.

U - Unsuccessful.

Unknown - Launch vehicle malfunctions did not give the payload a chance to exercise its main experiments.

Date	Name	General Mission	Launch Vehicle	Performance
			(site)	Veh Payload
====	=====	=====	=====	===
=====				=====

1958

Aug 17	Pioneer	Scientific lunar probe	Thor-Able (AMR)	U	Unknown	U
--------	---------	------------------------	-----------------	---	---------	---

Oct 11	Pioneer I	Scientific lunar probe	Thor-Able (AMR)	U	Unknown	U
Nov 8	Pioneer II	Scientific lunar probe	Thor-Able (AMR)	U	Unknown	U
Dec 6	Pioneer III	Scientific lunar probe	Juno II (AMR)	U	P	P

1959

Jan 2	Lunik I	Scientific lunar probe	Unknown (U.S.S.R.)	P	P	P
Mar 3	Pioneer IV	Scientific lunar probe	Juno II (AMR)	P	P	P
Sep 12	Lunik II	Scientific lunar lander	Unknown (U.S.S.R.)	S	S	S
Oct 4	Lunik III	Lunar photography	Unknown	S	S	S
Nov 26	Pioneer	Scientific lunar probe	Atlas-Able (AMR)	U	Unknown	U

1960

May 9	Mercury abort test	Capsule escape rocket test, unmanned	Launch escape rocket (Wallops Is.)	S	S	S
May 15	Korabl Sputnik I	Unmanned orbital spacecraft flight	Unknown (U.S.S.R.)	P	S	P
Jul 29	Mercury-Atlas 1 (MA-1)	Unmanned suborbital spacecraft	Atlas (AMR)	U	Unknown	U

		flight				
Aug 19	Korabl Sputnik II	Unmanned orbital spacecraft flight	Unknown (U.S.S.R.)	S	S	S
Sep 25	Pioneer	Lunar orbiter	Atlas-Able (AMR)	U	Unknown	U
Nov 8	Little Joe 5 (LJ-5)	Unmanned max q Mercury spacecraft abort test	Little Joe (Wallops Is.)	U	Unknown	U
Nov 21	Mercury- Redstone 1 (MR-1)	Unmanned suborbital spacecraft flight	Redstone (AMR)	U	Unknown	U
Dec 1	Korabl Sputnik III	Unmanned orbital spacecraft flight	Unknown (U.S.S.R.)	P	S	P
Dec 15	Pioneer	Scientific lunar probe	Atlas-Able (AMR)	U	Unknown	U
Dec 19	Mercury- Redstone 1A (MR-1A)	Unmanned suborbital spacecraft flight	Redstone (AMR)	S	S	S

1961

Jan 31	Mercury- Redstone 2 (MR-2)	Unmanned suborbital spacecraft flight	Redstone (AMR)	S	S	S
Feb 21	Mercury- Atlas 2 (MA-2)	Unmanned suborbital spacecraft	Atlas (AMR)	S	S	S

		flight				
Mar 9	Korabl Sputnik IV	Unmanned orbital spacecraft flight	Unknown (U.S.S.R.)	S	S	S
Mar 18	Little Joe 5A (LJ-5A)	Unmanned max q Mercury spacecraft abort test	Little Joe (Wallops Is.)	P	P	P
Mar 25	Korabl Sputnik V	Unmanned orbital spacecraft flight	Unknown (U.S.S.R.)	S	S	S
Apr 12	Vostok I	Manned orbital spacecraft flight	Unknown (U.S.S.R.)	S	S	S
Apr 25	Mercury- Atlas 3 (MA-3)	Unmanned orbital spacecraft flight	Atlas (AMR)	U	Unknown	U
Apr 28	Little Joe 5B (LJ-5B)	Unmanned max q Mercury spacecraft abort test	Little Joe (Wallops Is.)	P	S	S
May 5	Freedom 7 (MR-3)	Suborbital manned spacecraft flight	Redstone (AMR)	S	S	S
Jul 21	Liberty Bell 7 (MR-4)	Suborbital manned spacecraft flight	Redstone (AMR)	S	S	S
Aug 6	Vostok II	Manned orbital spacecraft	Unknown (U.S.S.R.)	S	S	S

		flight				
Aug 23	Ranger I	Scientific lunar probe	Atlas-Agena B (AMR)	U	Unknown	U
Sep 13	Mercury-Atlas 4 (MA-4)	Unmanned orbital spacecraft flight	Atlas (AMR)	S	S	S
Oct 27	Saturn (SA-1)	Launch vehicle development test	Saturn C-1 (AMR)	S		S
Nov 18	Ranger II	Scientific lunar probe	Atlas-Agena B (AMR)	U	Unknown	U
Nov 29	Mercury-Atlas 5 (MA-5)	Unmanned orbital spacecraft flight	Atlas (AMR)	S	S	S

1962

Jan 26	Ranger III	Scientific lunar lander	Atlas-Agena B (AMR)	U	Unknown	U
Feb 20	Friendship 7 (MA-6)	Manned orbital spacecraft flight	Atlas (AMR)	S	S	S
Apr 23	Ranger IV	Scientific lunar lander	Atlas-Agena B (AMR)	U	Unknown	U
Apr 25	Saturn (SA-2)	Launch vehicle development test	Saturn C-1 (AMR)	S	S	S
May 24	Aurora 7 (MA-7)	Manned orbital spacecraft flight	Atlas (AMR)	S	S	S
Aug 11	Vostok III-	Manned orbital	Unknown	S	S	S

-12 Vostok IV spacecraft (U.S.S.R.)
flights

Oct 3 Sigma 7 Manned orbital Atlas S S S
(MA-8) spacecraft (AMR)
flight

Oct 18 Ranger V Scientific Atlas-Agena B S S S
lunar lander (AMR)

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Flight Summary

August 17, 1958, through November 7, 1962

*The launches described in this table include only those related to the exploration of the moon: unmanned lunar probes, unmanned tests of spacecraft designed for later manned missions, and manned spacecraft flights. The table is not intended as a comprehensive summary of all American and Soviet space flights.

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S - successful.

P - Partially successful.

U - Unsuccessful.

Unknown - Launch vehicle malfunctions did not give the payload a chance to exercise its main experiments.

Date	Name	General Mission	Launch Vehicle (site)	Veh	Performance Payload	Mission Results
1958						
Aug 17	Pioneer	Scientific lunar probe	Thor-Able (AMR)	U	Unknown	U
Oct 11	Pioneer I	Scientific lunar probe	Thor-Able (AMR)	U	Unknown	U
Nov 8	Pioneer II	Scientific lunar probe	Thor-Able (AMR)	U	Unknown	U
Dec 6	Pioneer III	Scientific lunar probe	Juno II (AMR)	U	P	P
1959						

Jan 2	Lunik I	Scientific lunar probe	Unkown (U.S. S.R.)	P	P	P
Mar 3	Pioneer IV	Scientific lunar probe	Juno II (AMR)	P	P	P
Sep 12	Lunik	Scientific lunar lander	Unkown	S	S	S
Oct 4	Lunik III	Lunar photography	Unknown	S	S	S
Nov 26	Pioneer	Scientific lunar probe	Atlas-Able (AMR)	U	Unknown	U
1960						
May 9	Mercury abort test	Capsule escape rocket test, unmanned	Launch escape rocket (Wallops Is.)	S	S	S
May 15	Korabl Sputnik I	Unmanned orbital spacecraft flight	Unknown(U.S. S.R.)	P	S	P
Jul 29	Mercury-Atlas 1 (MA-1)	Unmanned suborbital spacecraft flight	Atlas (AMR)	U	Unknown	U
Aug 19	Korabl Sputnik II	Unmanned orbital spacecraft flight	Unknown (U. S.S.R.)	S	S	S
Sep 25	Pioneer	Lunar orbiter	Atlas-Able (AMR)	U	Unknown	U
Nov 8	Little Joe 5 (LJ-5)	Unmanned max q Mercury spacecraft abort test	Little Joe (Wallops Is.)	U	Unknown	U
Nov 21	Mercury-Redstone 1 (MR-1)	Unmanned suborbital spacecraft flight	Redstone (AMR)	U	Unknown	U
Dec 1	Korabl Sputnik III	unmanned orbital spacecraft flight	Unknown	P	S	P
Dec 15	Pioneer	Scientific lunar probe	Atlas-Able (AMR)	U	Unknown	U
Dec 19	Mercury-Redstone 1A (MR-1A)	Unmanned suborbital spacecraft flight	Redstone	S	S	S
1961						

Jan 31	Mercury-Redstone 2 (MR-2)	Unmanned suborbital spacecraft flight	Redstone (AMR)	S	S	S
Feb 21	Mercury-Atlas 2 (MA-2)	Unmanned suborbital spacecraft flight	Atlas (AMR)	S	S	S
Mar 9	Korabl Sputnik IV	Unmanned orbital spacecraft flight	Unknown (U.S.S.R.)	S	S	S
Mar 18	Little Joe 5A (LJ-5A)	Unmanned max q Mercury spacecraft abort test	Little Joe (Wallops Is.)	P	P	P
Mar 25	Korabl Sputnik V	Unmanned orbital spacecraft flight	Unknown (U.S.S.R.)	S	S	S
Apr 12	Vostok I	Manned orbital spacecraft flight	Unknown (U.S.S.R.)	S	S	S
Apr 25	Mercury-Atlas 3 (MA-3)	Unmanned orbital spacecraft flight	Atlas (AMR)	U	Unknown	U
Apr 28	Little Joe 5B (LJ-5B)	Unmanned max q Mercury spacecraft abort test	Little Joe (Wallops Is.)	P	S	S
May 5	Freedom 7 (MR-3)	Suborbital manned spacecraft flight	Redstone (AMR)	S	S	S
Jul 21	Liberty Bell 7 (MR-4)	Suborbital manned spacecraft flight	Redstone (AMR)	S	S	S
Aug 6	Vostok II	Manned orbital spacecraft flight	Unknown (U.S.S.R.)	S	S	S
Aug 23	Ranger I	Scientific lunar probe	Atlas-Agena B (AMR)	U	Unknown	U
Sep 13	Mercury-Atlas 4 (MA-4)	Unmanned orbital spacecraft flight	Atlas (AMR)	S	S	S
Oct 27	Saturn (SA-1)	Launch vehicle development test	Saturn C-1 (AMR)	S		S
Nov 18	Ranger II	Scientific lunar probe	Atlas-Agena B (AMR)	U	Unknown	U

Nov 29	Mercury-Atlas 5 (MA-5)	Unmanned orbital spacecraft flight	Atlas (AMR)	S	S	S
1962						
Jan 26	Ranger III	Scientific lunar lander	Atlas-Agena B (AMR)	U	Unknown	U
Feb 20	Friendship 7 (MA-6)	Manned orbital spacecraft flight	Atlas (AMR)	S	S	S
Apr 23	Ranger IV	Scientific lunar lander	Atlas-Agena B (AMR)	U	Unknown	U
Apr 25	Saturn (SA-2)	Launch vehicle development test	Saturn C-1 (AMR)	S	S	S
May 24	Aurora 7 (MA-7)	Manned orbital spacecraft flight	Atlas (AMR)	S	S	S
Aug 11-12	Vostok III-Vostok IV	Manned orbital spacecraft flights	Unknown (U.S.S.R.)	S	S	S
Oct 3	Sigma 7 (MA_8)	Manned orbital spacecraft flight	Atlas (AMR)	S	S	S
Oct 18	Ranger V	Scientific lunar lander	Atlas-Agena B (AMR)	S	S	S

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APPENDIX 5

Funding

Fiscal Year =====	Funding =====
1960 \$523,575,000	NASA: Advanced technical development studies: \$100,000
1961 \$964,000,000	NASA: Advanced technical development studies: \$1,000,000
1962 \$1,109,630,000 (Original budget \$29,500,000 request)	NASA: Apollo:
1962 \$1,417,821,000 (Revised budget \$72,100,000 request, March 17, 1961)	NASA: Apollo:
1962 \$1,235,300,000 (Bureau-of-the- \$29,500,000 Budget-approved request)	NASA: Apollo:

1962
 \$1,361,900,000
 (H.R. 6874,
 \$72,100,000
 May 24, 1961)

NASA:

Apollo:

1962
 \$1,671,750,000
 (Final budget
 \$160,000,000
 appropriation)

NASA:

Apollo:

Apollo funding
 \$63,900,000
 breakdown (1962)
 \$16,550,000
 \$27,550,000
 \$52,000,000

Orbital flight tests:
 Biomedical flight tests:
 High-speed reentry tests:
 Spacecraft development:

1963 (Original
 \$3,787,276,000
 budget request
 \$617,164,000
 inc. Fiscal Year
 1962 supplemental)

NASA:

Apollo:

1963 (Final budget
 \$3,674,115,000
 appropriation
 \$617,164,000
 with Fiscal Year
 1962 supplemental)

NASA:

Apollo:

Apollo funding
 \$345,000,000
 breakdown (1963)
 \$123,100,000
 \$32,400,000

Command and service modules:
 Lunar excursion module:
 Guidance and navigation system:
 Instrumentation and scientific equipment:

\$11,500,000

Operational support:

\$2,500,000

Supporting development:

\$3,000,000

Little Joe II development:

\$8,800,000

Saturn C-1 launch vehicles (10):

\$90,864,000

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APPENDIX 5

Funding

Fiscal Year	Funding	
1960	NASA:	\$523,575,000
	Advanced technical development studies:	\$100,000
1961	NASA:	\$964,000,000
	Advanced technical development studies:	\$1,000,000
1962	NASA:	\$1,109,630,000
(Original budget request)	Apollo:	\$29,500,000
1962	NASA:	\$1,417,821,000
(Revised budget request, March 17, 1961)	Apollo:	\$72,100,000
1962	NASA:	\$1,235,300,000
(Bureau-of-the-Budget-approved request)	Apollo:	\$29,500,000
1962	NASA:	\$1,361,900,000
(H.R. 6874, MAY 24, 1961)	Apollo:	\$72,100,000
1962	NASA:	\$1,671,750,000
(Final budget appropriation)	Apollo:	\$160,000,000
Apollo funding breakdown (1962)	Orbital flight tests:	\$63,900,000
	Biomedical flight tests:	\$16,550,000
	High-speed reentry tests:	\$27,550,000
	Spacecraft development:	\$52,000,000
1963 (Original budget request inc. Fiscal Year 1962 supplemental)	NASA:	\$3,787,276,000
	Apollo:	\$617,164,000
1963 (Final budget appropriation with Fiscal Year 1962 supplemental)	NASA:	\$3,674,115,000
	Apollo:	\$617,164,000

Apollo funding breakdown (1963)	Command and service modules:	\$345,000,000
	Lunar excursion module:	\$123,100,000
	Guidance and navigation system:	\$32,400,000
	Instrumentation and scientific equipment:	\$11,500,000
	Operational support:	\$2,500,000
	Supporting development	\$3,000,000
	Little Joe II development:	\$8,800,000
	Saturn C-1 launch vehicles (10):	\$90,864,000

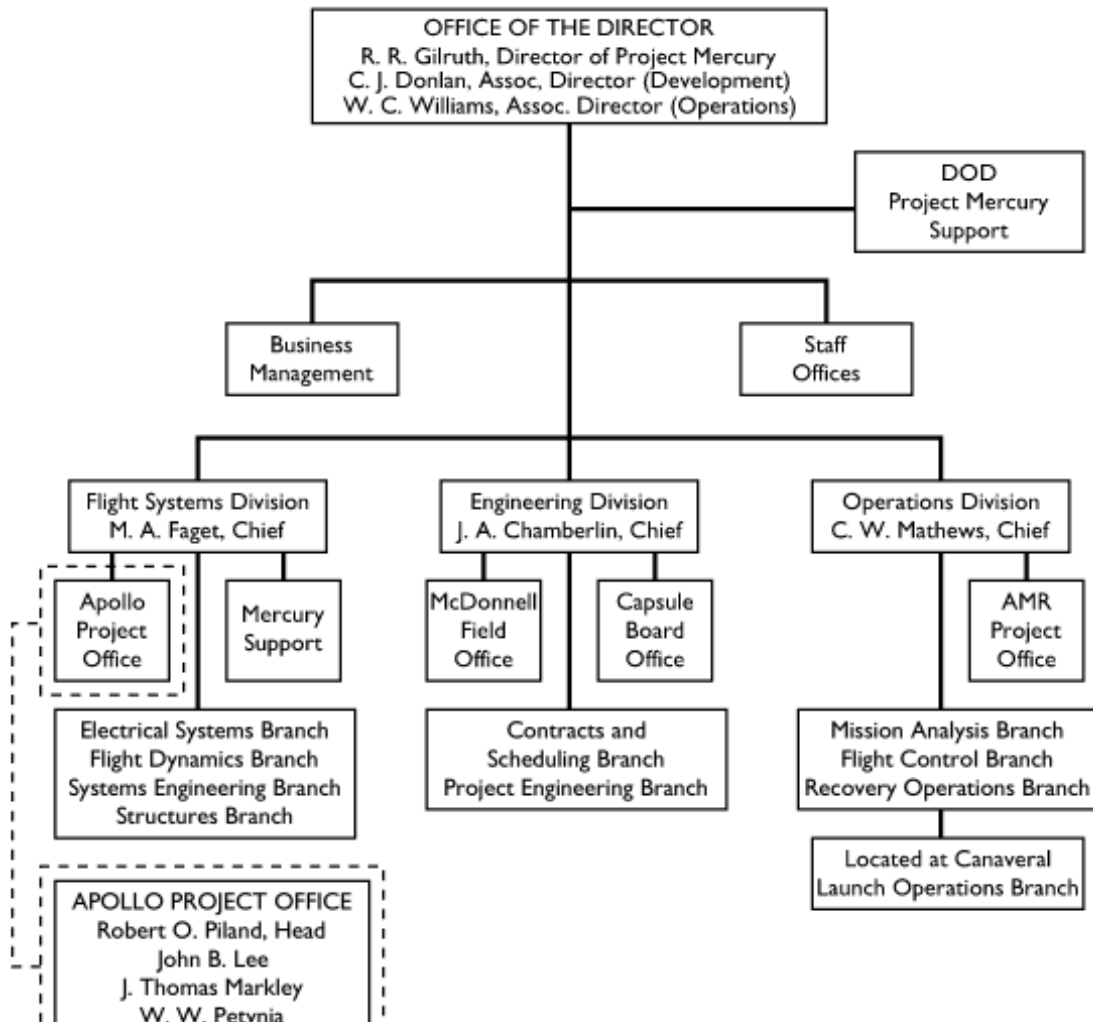
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APPENDIX 6

Organization Charts

Space Task Group

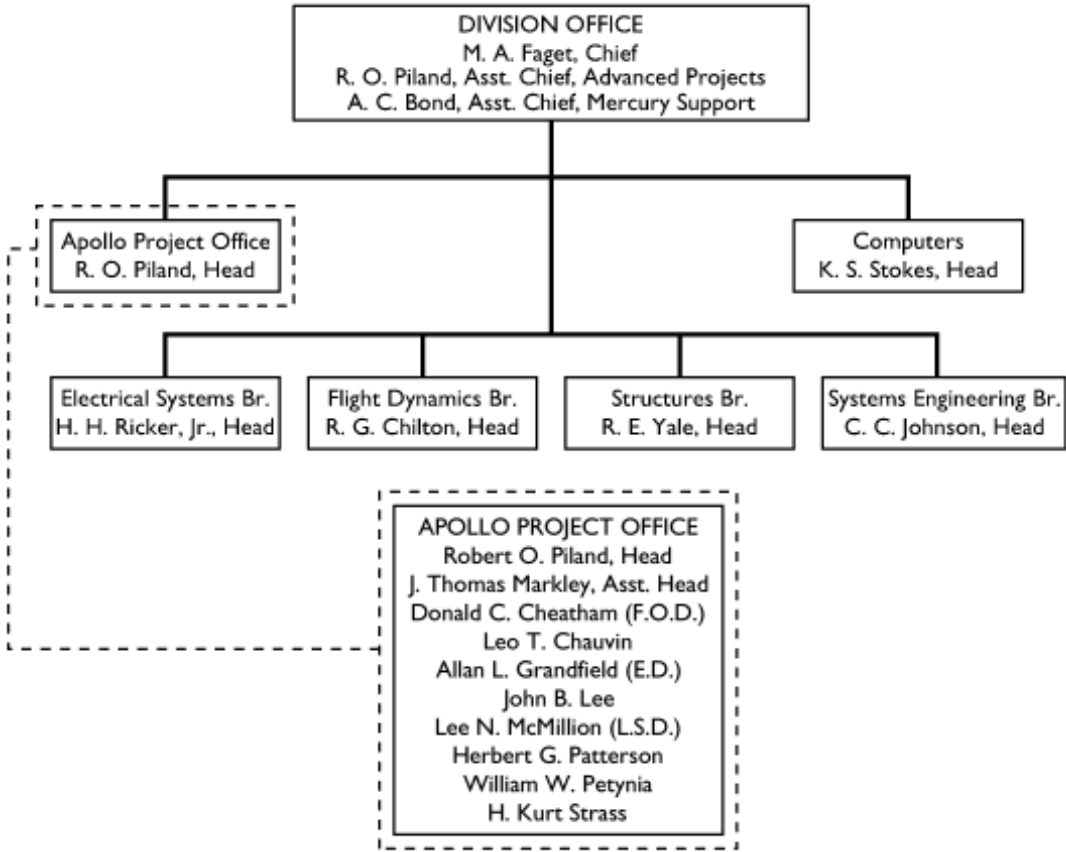
September 26, 1960



H. Kurt Strass

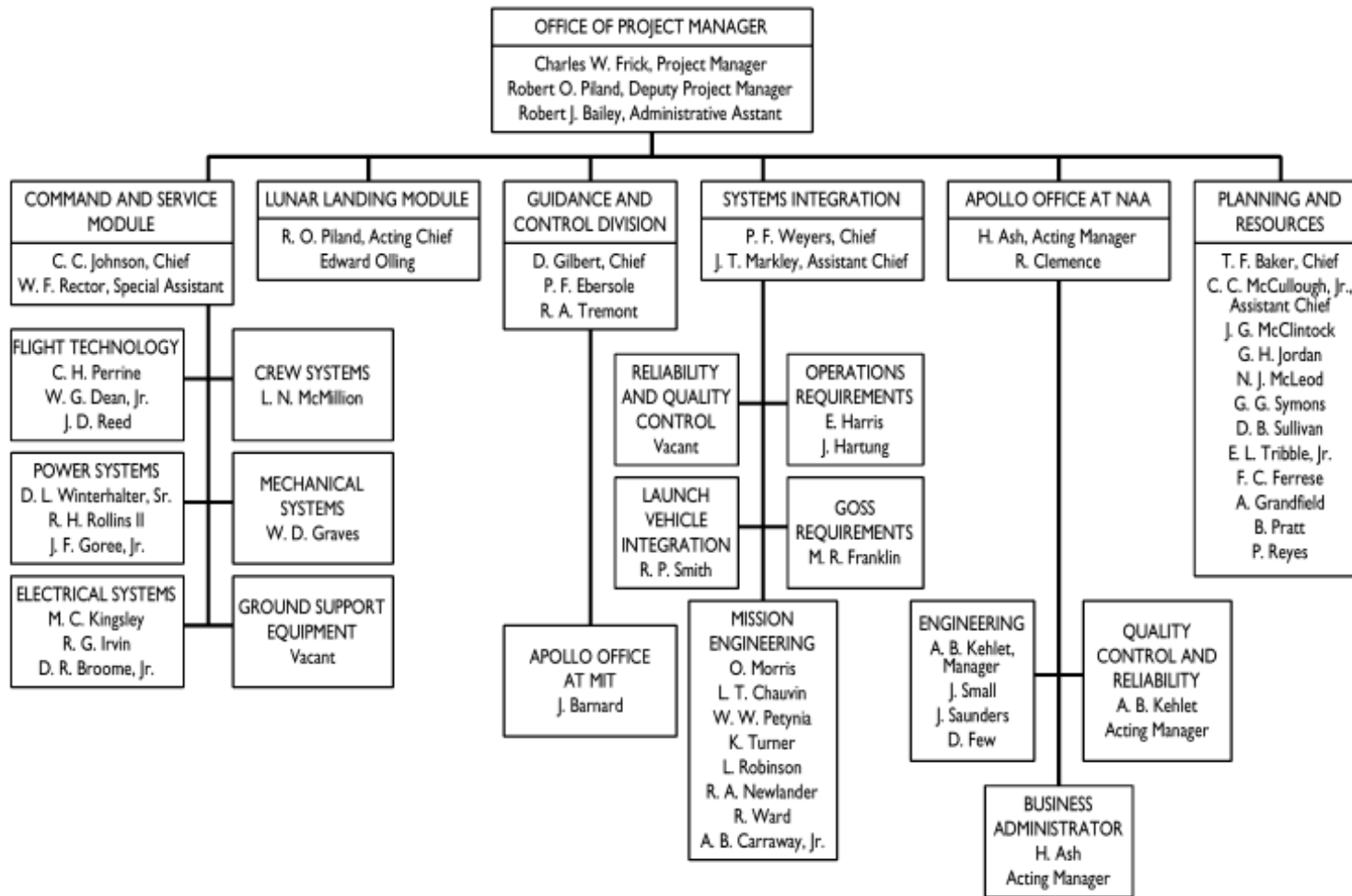
Flight Systems Division

May 23, 1961



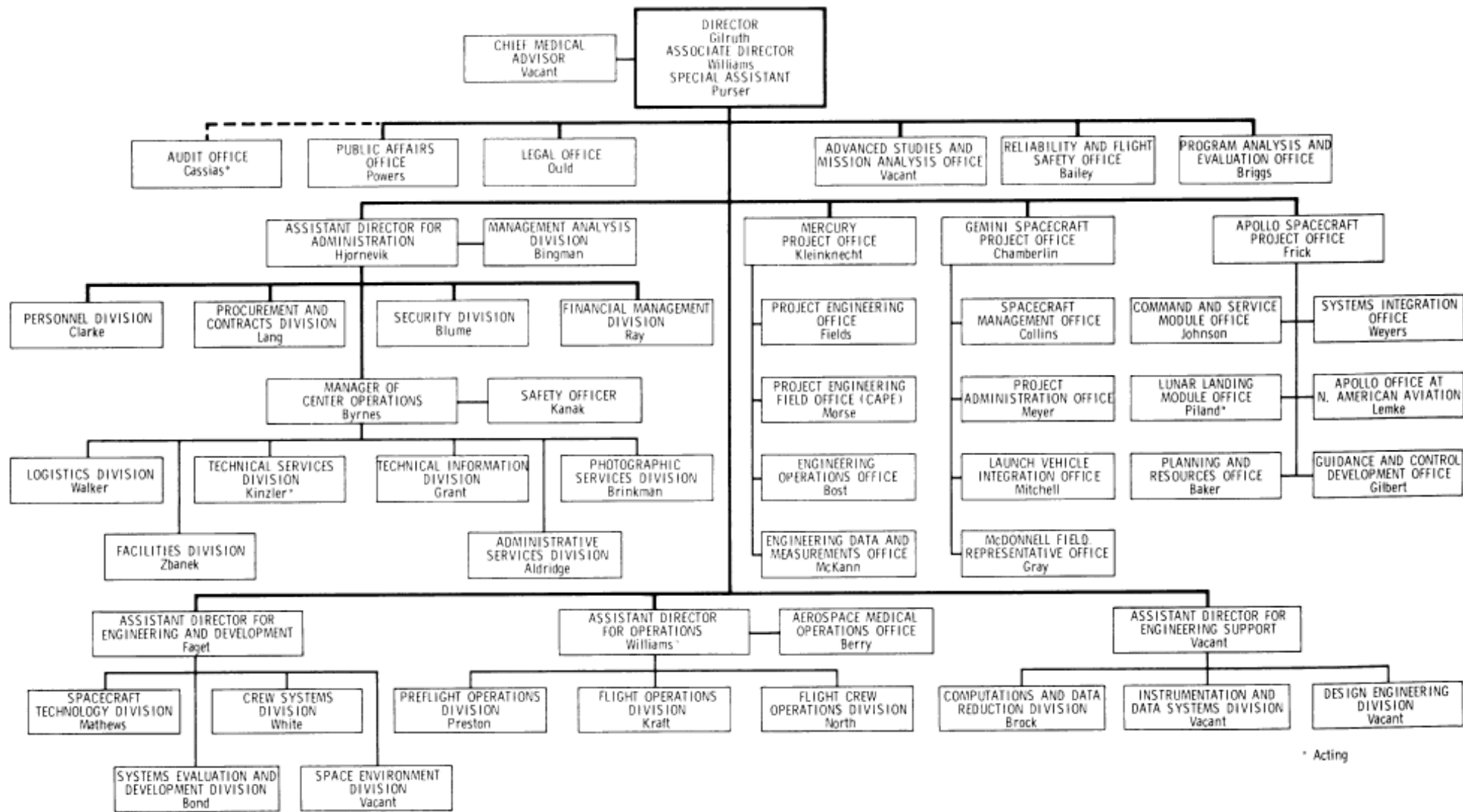
Apollo Spacecraft Project Office

March 6, 1962



Manned Spacecraft Center

September 1962



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APPENDIX 7

Apollo Launch Vehicle Family

Little Joe II

Configuration:

Single stage test vehicle powered by Algol solid-propellant motors. Recruit rocket motors were used as booster motors, to supplement liftoff thrust.

Mission:

The Little Joe II test launch vehicle, under construction during the period of this volume, was to be used to man-rate the launch escape system for the command module.

Saturn C-1 (renamed Saturn I)

Configuration:

S-1 booster (eight H-1 engines, clustered, producing 1.5 million pounds of thrust); S-IV second stage (four engines using liquid-hydrogen and liquid-oxygen propellants and producing 80,000 pounds of thrust); and S-V third stage (two engines of the type used in the S-IV stage, producing 40,000 pounds of thrust). The LR-119 engine (17,500 pounds of thrust), an uprated version of the LR-115 engine (15,000 pounds of thrust), was selected to be used in the S-IV and S-V stages. On March 29, 1961, NASA approved a change to six LR-115 engines on the S-IV stage. On June 1, 1961, NASA announced that the S-V had been dropped from the configuration.

Mission:

Two successful launches of the Saturn C-1 took place during the period covered by this volume. Later launches would test boilerplate Apollo command and service modules under flight conditions.

Saturn C-1B (renamed Saturn IB or Uprated Saturn I)

Configuration:

S-IB booster (eight uprated H-1 engines, clustered, producing 1.6 million pounds of thrust); and S-IVB second stage (one J-2 engine, producing 200,000 pounds of thrust).

Mission:

On July 11, 1962, NASA announced that the Saturn C-1B would be used to launch unmanned

and manned Apollo spacecraft into earth orbit.

Saturn C-2

Four-stage configuration:

S-I booster (same as booster stage of the Saturn C-1); S-II second stage (not defined); S-IV third stage (same as Saturn C-1 second stage); and S-V fourth stage (same as Saturn C-1 third Stage).

Three-stage configuration:

S-I booster (same as booster stage of the Saturn C-1); S-II second stage (not defined); and S-IV third stage (same as Saturn C-1 second stage).

History:

Plans for the Saturn C-2 were canceled in June 1961 in favor of the proposed Saturn C-3.

Saturn C-3

Configuration:

Booster stage (two F-1 engines, producing 3 million pounds of thrust); second stage (four J-2 engines, producing 800,000 pounds of thrust); and S-IV third stage (same as Saturn C-1 second stage).

History:

Plans for the Saturn C-3 were canceled in favor of a more powerful launch vehicle.

Saturn C-4

Configuration:

Booster stage (four F-1 engines, clustered, producing 6 million pounds of thrust); second stage (four J-2 engines, producing 800,000 pounds of thrust).

History:

The Saturn C-4 was briefly considered in planning for the advanced Saturn launch vehicle but was rejected in favor of the Saturn C-5.

Saturn C-5 (renamed Saturn V)

Configuration:

S-IC booster (five F-1 engines, clustered, producing 7.5 million pounds of thrust); S-II second stage (five J-2 engines, producing 1 million pounds of thrust); and the S-IVB third stage (one J-2 engine, producing 200,000 pounds of thrust).

Mission:

The Saturn C-5 was selected by NASA in December 1961 as the launch vehicle to be used in accomplishing the lunar landing mission.

Saturn C-8

Configuration:

First stage (eight F-1 engines, clustered, producing 12 million pounds of thrust); second stage (eight J-2 engines, producing 1.6 million pounds of thrust); and third stage (one J-2 engine, producing 200,000 pounds of thrust).

History:

The Saturn C-8 was briefly considered for the direct ascent lunar landing mission during the selection of the lunar landing mode. It was rejected in favor of the Saturn C-5 which would be used in the lunar orbit rendezvous mission.

Nova

Configuration:

Several configurations were proposed during the period of this volume. All were based on the use of the F-1 engine in the first stage. One typical configuration was: first stage (eight F-1 engines, clustered, producing 12 million pounds of thrust); second stage (four liquid-hydrogen M-1 engines, producing 4.8 million pounds of thrust); third stage (one J-2 engine, producing 200,000 pounds of thrust). Nuclear upper stages were also proposed.

Mission:

The Nova was intended for use in a direct ascent lunar landing mission.

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The Authors

Ivan D. Ertel has been the Assistant Historian of the Manned Spacecraft Center since September 1964. Born in Marion, New York (1914) he received his B.B.A. degree from Georgia State College, Atlanta, Georgia (1958). He was news editor of Atlanta's Suburban Reporter, East Point, Georgia, and the Decatur-DeKalb News, Decatur, Georgia (1954-1957). Before coming to NASA in 1961 he was Press Officer at Headquarters, Third Army. Ertel established the MSC official news organ, Space News Roundup, and authored brochures and fact sheets about each Mercury and Gemini manned flight. He is married and has three daughters.

Mary Louise Morse has been a Research Associate with the Department of History of the University of Houston since the fall of 1966. Born in Beverly, Massachusetts, she received her B.S. in Education from Salem State College, Salem, Massachusetts (1947), and her M.A. in History from Columbia University (1950). She was a senior editor with the MIT Press, Cambridge, Massachusetts, before moving to Houston.

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Foreword

This, the second volume of the Apollo Spacecraft Chronology, takes up the story where the first left off, in November 1962. The first volume dealt with the birth of the Apollo Program and traced its early development. The second concerns its teenage period, up to September 30, 1964.

By late 1962 the broad conceptual design of the Apollo spacecraft and the Apollo lunar landing mission was complete. The Administrator formally advised the President of the United States on December 10 that NASA had selected lunar orbit rendezvous over direct ascent and earth orbit rendezvous as the mode for landing on the moon. All major spacecraft contractors had been selected; detailed system design and early developmental testing were under way.

On October 20, 1962, soon after Wally Schirra's six-orbit mission in *Sigma 7*, the first formal overall status review of the Apollo spacecraft and flight mission effort was given to Administrator James E. Webb. The writer of this foreword, who was then the Assistant Director for Apollo Spacecraft Development, recalls George Low, then Director of Manned Spacecraft and Flight Missions under D. Brainerd Holmes, discussing the planning schedule for completion of the Mercury Project in 1963, initiation of Gemini flights in 1964, and the start of Apollo earth orbital flights in 1965. Major design features of the spacecraft and subsystems were discussed and so were facilities, training, flight mission plans, and resources. At the conclusion of the review, Mr. Webb, Dr. Dryden, and Dr. Seamans commented favorably on the overview provided and on the accomplishments and hard planning that had been completed. The chronology of events during the subsequent two years, as summarized herein, provides an interesting comparison with the plans as discussed that day; we came very close to what was planned for 1963 and 1964.

During 1963 formal contract negotiations with the previously selected major spacecraft contractors were completed. In addition most of the contractors for major facilities and support activities on the ground were selected. The latter group included Radio Corporation of America to furnish the spacecraft vacuum test chamber at Houston, Bell Aerosystems for the lunar landing training vehicle, Philco Corporation as prime contractor for the Mission Control Center, Link Division of General Precision, Inc., for the lunar mission simulators, and International Business Machines for the Real Time Computer Complex at Houston's Mission Control Center.

Also in 1963 the Office of Manned Space Flight was reorganized under its new leader, George E. Mueller, to strengthen its systems engineering and integration role in overall management of the Apollo-Saturn Program. In December Dr. Mueller brought in General Sam Phillips as Deputy Director of the Apollo Program. Soon thereafter Phillips was named Apollo Program Director. A comparable reorganization took place at the Manned Spacecraft Center in Houston as the tempo of spacecraft module design and development increased. At the same time, the prime contractors were selecting and completing negotiations with their subcontractors and suppliers for the thousands of subsystems and

components involved. The government-industry team for carrying out the Apollo spacecraft and flight mission related tasks was essentially complete by late 1963. Concurrently, similar activities were proceeding for the Saturn launch vehicles at the Marshall Space Flight Center and for launch site preparation at the Kennedy Space Center, as it was named by President Johnson on November 28, 1963.

Meanwhile, a series of basic program decisions were made; these enabled the spacecraft and lunar landing mission design teams to proceed into detail design. Among these decisions were the following:

- Nominal earth landing would be on the water. This was a change from the original plan which provided for earth landing in either Australia or the southwestern United States. The change was made primarily to take advantage of the softer impact conditions afforded by water landing, although the operational flexibility afforded by ocean landing was an additional favorable factor.
- CSM to LM transposition and docking would be by the free flying mode. This meant that, after injection into translunar trajectory, the crew would detach the CSM from its launch position and would rotate the spacecraft 180 degrees and manually maneuver it into a docked position with the LM.
- The crew would operate the LM from standing position.
- The spacecraft guidance computer would use micrologic design.
- The Lunar Module would have a four-legged, deployable landing gear. This was a change from the original Grumman configuration which had five legs.
- The Lunar Module would be capable of supporting the effective operation of two men on the lunar surface for up to 24 hours, plus 24 hours in flight.

At the same time, rapid progress was made on the development of the spacecraft, on the Saturn launch vehicles, and on the facilities to support them. Typical events in 1963 included:

- The service propulsion prototype engine successfully completed initial firings.
- The first of a number of parachute malfunctions occurred during development drop tests.
- The impact test facility for development and verification of the Command Module landing system at the North American plant in Downey, California, was completed.
- Flight of Saturn SA-4 verified the capability of the Saturn first stage to operate satisfactorily after a simulated in-flight failure of one engine.
- The Little Joe II launch complex at White Sands was completed and the first Little Joe II test article was launched successfully.
- The LM-1 lunar module mockup was completed.
- Prototype fuel cells were delivered by Pratt & Whitney to North American.
- The first pad abort test was successfully completed at White Sands.
- The J-2 engine successfully completed its initial long duration firing.

The Mercury Program ended with Gordon Cooper's 34-hour earth orbit mission on May 15-16, 1963, the unmanned Lunar Orbiter Project was approved, and scientific guidelines for the Apollo mission were promulgated. A new group of 14 astronauts, including Buzz Aldrin and Mike Collins, who were

destined to join Neil Armstrong in the first lunar landing mission, was selected in October 1963.

Dr. Mueller, in the fall of 1963, introduced something that was to have a mighty effect on "landing before this decade is out." It was called "all-up testing." Under the "all-up" concept, launch vehicle and spacecraft development flights were combined, with all elements active and as close to lunar configuration as possible, beginning with the very first flight. This plan replaced the more conventional approach of making initial launch vehicle tests with dummy upper stages and dummy spacecraft.

Because the Saturn I flight program was of an interim non-lunar configuration, it was curtailed and four manned earth orbital flights with the Saturn launch vehicle were canceled. The Saturn IB development for manned flight was accelerated and all Saturn IB flights, beginning with SA-201, would carry operational spacecraft. Similarly, the Saturn V development flights, beginning with 501, would be in "all-up" configuration and vehicle 501 would be used to obtain reentry data on the Apollo spacecraft. The first manned flight on both the Saturn IB and V would follow two successful unmanned flights, so that the first manned flights could be as early as vehicles 203 and 503 for the IB and V, respectively. This would exploit early successful flight operation of the new launch vehicles by reducing the total number of flights required to qualify the lunar flight configuration for manned operations. The first manned flight on a Saturn V did of course take place on vehicle 503 in December 1968 - the successful Apollo 8 mission.

Another Mueller innovation was the Apollo Executives Group, which first met in the fall of 1963. It brought together senior officials of the major Apollo-Saturn contractors, such as the Presidents of North American, Boeing, and Grumman, with senior NASA Manned Space Flight executives (Mueller, von Braun, Gilruth, and Debus). These periodic meetings proved to be an excellent mechanism for opening lines of communication at the top, for assuring timely top management attention to the most important problems as they arose, and for assuring a coordinated team effort on the many faceted Apollo-Saturn activities. A similar group of Gemini Executives was also set up; there was considerable cross-communication between the two since several of the same organizations were involved in both programs.

During 1964 ground and flight development activity accelerated further and the first of many flight components, the launch escape rockets built by the Lockheed Propulsion Company, successfully completed qualification testing.

In early 1964, the Block II CSM lunar-orbit-rendezvous configuration guidelines were forwarded by NASA to North American, and the Block II mockup was formally reviewed in September of that year. The Block I configuration had been configured before the LOR mode was chosen; as a consequence, it did not have the docking and crew-transfer provisions which, among other changes, were incorporated in the Block II.

The first Gemini mission, a successful unmanned test flight, was launched on April 8. *Ranger VII* provided the first close-up pictures of the moon in July. Project FIRE provided flight data at Apollo reentry speeds, and Saturn I flights SA-5, SA-6, and SA-7 were successfully completed during 1964. SA-

7, the seventh straight Saturn I success, provided a functional verification of the Apollo Launch Escape System jettison. The unbroken string of Saturn launch successes presented a far different picture from earlier days when a 50% launch success record was considered exceptional.

In summary, the two years covered by this volume of the Chronology saw the essential completion of the putting together of the Apollo government-industry team, substantial maturing of the design, verification of many essential design features by test, streamlining of the flight program through adoption of the all-up concept, and the acquisition of first data about the lunar surface from the Ranger Program.

As this volume comes to a close, there were still four years to go before the first manned Apollo mission, and nearly five years to the first lunar landing. Many difficulties lay ahead, but the course had been marked and giant strides had been taken along that course.

John H. Disher

Deputy Director, Skylab Program

Former Director, Test Division

Apollo Program Office

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The Key Events

1962

November 16: Saturn-Apollo 3 (SA-3) launch marks first full-weight liftoff of Saturn C-1 rocket.

December 4: Contract for Vertical Assembly Building at Cape Canaveral let to a consortium of four New York architectural engineering firms.

During December: Manned Spacecraft Center (MSC) prepared the preliminary lunar landing mission design.

1963

January 2: Contract let to Radio Corporation of America for two large vacuum chambers at MSC for space environmental testing.

January 18: Contract let to Bell Aerosystems Company for two lunar landing research vehicles by Flight Research Center.

January 28: Philco Corporation selected as prime contractor for the Mission Control Center (MCC) at MSC.

February 8: Definitive contract let to Raytheon Company for command module (CM) onboard digital computer.

February 13: MSC reorganized Apollo Spacecraft Project Office.

February 18: Definitive contract let to General Dynamics/Convair for the Little Joe II test vehicle.

February 20: NASA reorganized the Office of Manned Space Flight.

March 11: Definitive contract formalized between NASA and Grumman Aircraft Engineering Corporation for the Lunar Excursion Module.

March 13: First long-duration static test of Saturn SA-5 first stage.

March 28: Saturn SA-4 launched in successful test of engine-out capability.

April 10: Contract let to Link Division, General Precision, Inc., for lunar mission simulators.

May 3: First of series of qualification drop tests for the earth landing system conducted at El Centro, Calif.

May 15-16: Last flight of Mercury: Cooper in Faith 7.

June 14-19: Vostok V and VI tandem flights.

During June: Most CM subsystem designs frozen.

July 12: Definitive contract let to International Business Machines for the realtime computer complex at MSC's MCC.

August 5: First static firing test of Saturn S-IV stage for SA-5 conducted by Douglas Aircraft Company in Sacramento, Calif.

August 14: Definitive contract with North American Aviation, Inc., for command and service modules signed on a cost-plus-fixed-fee basis for \$938.4 million.

August 28: First Little Joe II launched at White Sands Missile Range, N. Mex.

August 30: Lunar Orbiter program officially approved.

September 16-18: Grumman Aircraft Engineering Corporation (GAEC) held inspection and review of first lunar excursion module (LEM) ascent stage mockup M-1.

October 8: Joseph F. Shea named manager of Apollo Spacecraft Project Office at Manned Spacecraft Center (MSC).

October 18: Third "class" of astronauts introduced.

October 24: George E. Mueller, the new NASA Associate Administrator for Manned Space Flight, held first meeting of NASA-Industry Apollo Executives.

November 1: Major reorganization of NASA Headquarters and Office of Manned Space Flight (OMSF) took effect; Mueller directed the revision of Saturn-Apollo flight schedules.

November 7: Apollo Pad Abort Mission 1, using command module (CM) boilerplate 6 was conducted

at White Sands Missile Range, N. Mex.

November 22: Preliminary ground rules for the Spacecraft Development Test Program and gross lunar landing sites selected.

December 31: Samuel C. Phillips (Brig. Gen., USAF) announced as new NASA Deputy Director for Apollo Program.

1964

January 3: Apollo prime contractors issued joint report on spacecraft development test plan.

January 19: George M. Low assigned to MSC as Deputy Director.

January 21: North American Aviation, Inc. (NAA), presented a design concept for the Block II command and service module (CSM), designed for lunar missions.

January 29: Saturn-Apollo 5 flight marked first mission of Block II Saturn with two live stages.

March 9: MSC assigned funds and responsibility for developing scientific instruments for lunar exploration.

March 23: OMSF outlined Saturn-Apollo mission plans.

March 24-26: GAEC held first complete LEM mockup TM-1 inspection and review.

April 8: First Gemini mission performed.

April 14: Project Fire tested heat transfer concepts for Apollo at 40,230 kilometers (25,000 miles) per hour lunar return velocity.

April 21: Basic rules for Apollo space suit operation established.

April 28-30: NAA held basic mockup inspection and review for Block II CSM.

May 4: Apollo Mission Planning Task Force specified the program's mission objectives and ground rules.

May 13: First flight test of Little Joe II using a command module (CM) boilerplate (BP-12) at White Sands Missile Range, N. Mex.

May 28: Apollo Saturn Mission A-101, using CM BP-13 atop SA-6 Saturn I launch vehicle, launched at Cape Kennedy, Fla., to prove spacecraft/launch vehicle compatibility.

June 11: NASA directed North American Aviation, Inc. (NAA), to make certain mandatory changes to both Block I and Block II spacecraft systems.

July 28: Ranger VII mission finally succeeded in televising pictures of lunar surface up to impact.

August 18: Scout launch tested Apollo-type ablator materials at lunar reentry heating levels.

September 14: Ground rules for lunar excursion module guidance and control system firmly defined.

September 18: Apollo Mission A-102, using BP-15 for the command and service modules (CSM) and SA-7 for the launch vehicle, confirmed Saturn Block II and CSM compatibility as well as the launch escape vehicle system.

September 30: NAA conducted formal inspection and review of Block II CSM mockup.

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Preface

Project Apollo, America's program to land men on the moon, aimed at what surely will be recorded as one of the epochal achievements of mankind. For any insight into the significance of this "giant leap," it is essential to reckon with the technology and to appreciate the hard work - and the sacrifices - that made *Apollo 11* possible.

This, the second volume of *The Apollo Spacecraft: A Chronology*, tells a part of this story. It follows the precedents and format of the first in the series (NASA SP-4009). The third volume, now nearly completed, will chronicle developments within Project Apollo through detailed hardware design and early ground and flight testing. A fourth will cover the development phase, recovery from the Apollo 204 fire, the first lunar landing flight, and the lunar exploration phase of the program.

By this series of documented resource books, the authors have hoped to provide a tool for further historical studies of Project Apollo and for attempts to understand scientific and technological change during the decade of the Sixties. Our immediate aim has been to serve not only the needs of scholarship and management, but also the "average American" who might wish to probe behind the headlines of space news.

Largely because our research has relied most heavily on records held at NASA's Manned Spacecraft Center (MSC) in Houston, Texas, the title of this series indicates its bias toward *spacecraft* development. Many NASA chronologies and historical monographs - some completed and some in progress - analyze, describe, and interpret various other aspects of American aeronautical and astronautical progress. In manned space flight, for example, *This New Ocean: A History of Project Mercury* (NASA SP-4101) has been written and a history of Project Gemini is nearing completion. Perhaps someday the full complexity of the interrelated technological and scientific activities of Project Apollo may be synthesized more meaningfully. But for now we have presented a skeletal outline of events that affected conceptual design and early engineering work on both hardware and software for the Apollo spacecraft.

Part I, "Defining Contractual Relations," deals mostly with establishing government-industry working arrangements and preliminary hardware design once the prime contractors were selected. Part II, "Developing Hardware Distinctions," characterizes the period of late 1963 and early 1964 as a time of technological transition. And Part III, "Developing Software Ground Rules," tells schematically how, during much of 1964, preliminary mission planning and ground tests led toward the freezing of hardware design and the movement toward flight testing.

As in previous chronologies for Mercury, Gemini, and Apollo's beginnings, the primary sources used here are NASA and industry correspondence and reports. The materials should serve as a foundation for many analytical monographs and, eventually, a narrative history of the whole Apollo program. The

available documents are so plentiful and comprehensive that the primary historical problem has been one of selection. The text that follows has been edited downward in size several times, but we trust our critical readers to point out its worst sins of omission and commission. Measurements for the most part were originally in the English system, then converted to metric.

The authors of this volume worked with MSC historians James M. Grimwood and Ivan D. Ertel by virtue of a NASA contract (NAS 9-6331) with the University of Houston's Department of History. Professors James A. Tinsley and Loyd S. Swenson, Jr., provided academic support, while NASA historians Eugene M. Emme, Frank W. Anderson, Jr., and William D. Putnam encouraged the processes of research and revision toward publication. Archivists in Washington, notably Lee D. Saegesser, at other NASA Centers, and in Houston, particularly Billie D. Rowell, have been immensely helpful. Courtney G. Brooks and Sally D. Gates edited the final comment edition, and Corinne L. Morris prepared the manuscript copy. Ertel illustrated the text, while Anderson and Carrie E. Karegeannes shepherded the work through the publication process. To these and many other informants, readers, librarians, and historians the authors and editors of this series are indebted.

M.L.M.

J.K.B.

December 1, 1971

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PART 1 (A)

Defining Contractual Relations

November 8, 1962, through December, 1962

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1962

November 8

"Not one or two men will make the landing on the moon, but, figuratively, the entire Nation." That is how NASA's Deputy Administrator, Hugh L. Dryden, described America's commitment to Apollo during a speech in Washington, D.C. "What we are buying in our national space program," Dryden said, "is the knowledge, the experience, the skills, the industrial facilities, and the experimental hardware that will make the United States first in every field of space exploration. . . . The investment in space progress is big and will grow, but the potential returns on the investment are even larger. And because it concerns us all, scientific progress is everyone's responsibility. Every citizen should understand what the space program really is about and what it can do."

U.S. Congress, House, Committee on Science and Astronautics, *Astronautical and Aeronautical Events of 1962*, 88th Cong., 1st Sess. (June 12, 1963), pp. 235-36.

November 9

The Manned Spacecraft Center (MSC) and the Raytheon Company came to terms on the definitive contract for the Apollo spacecraft guidance computer. (See February 8, 1963.)

Manned Space Flight [MSF] Management Council Meeting, November 27, 1962, Agenda Item 2, p. 3.

November 13

North American Aviation, Inc., selected the Aerospace Electrical Division of Westinghouse Electric Corporation to build the power conversion units for the command module (CM) electrical system. The units would convert direct current from the fuel cells to alternating current.

Aviation Daily, November 13, 1962, p. 71.

November 15

The Aerojet-General Corporation reported completion of successful firings of the prototype service propulsion engine. The restartable engine, with an ablative thrust chamber, reached thrusts up to 21,500 pounds. [Normal thrust rating for the service propulsion engine is 20,500.]

Aviation Daily, November 15, 1962, p. 89; *Aviation Week and Space Technology*, 77 (November 19, 1962), p. 40.

November 16

Saturn-Apollo 3 (Saturn C-1, later called Saturn I) was launched from the Atlantic Missile Range. Upper stages of the launch vehicle were filled with 23000 gallons of water to simulate the weight of live stages. At its peak altitude of 167 kilometers (104 miles), four minutes 53 seconds after launch, the rocket was detonated by explosives upon command from earth. The water was released into the ionosphere, forming a massive cloud of ice particles several miles in diameter. By this experiment, known as "Project Highwater," scientists had hoped to obtain data on atmospheric physics, but poor telemetry made the results questionable. The flight was the third straight success for the Saturn C-1 and the first with maximum fuel on board.

MSFC Historical Office, *History of the George C. Marshall Space Flight Center From July 1 Through December 31, 1962* (MHM-6), Vol. I, p. 193; MSFC, "Saturn SA-3 Flight Evaluation," MPR-SAT-63-1, January 8, 1963, Vol. I, pp. 8, 151; *The Washington Post*, November 17, 1962; *The New York Times*, November 17, 1962.

November 17

Four Navy officers were injured when an electrical spark ignited a fire in an altitude chamber, near the end of a 14-day experiment at the U.S. Navy Air Crew Equipment Laboratory, Philadelphia, Pa. The men were participating in a NASA experiment to determine the effect on humans of breathing pure oxygen for 14 days at simulated altitudes.

Edward L. Michel, George B. Smith, Jr., Richard S. Johnston, *Gaseous Environment Considerations and Evaluation Programs Leading to Spacecraft Atmosphere Selection*, NASA Technical Note, TN D-2506 (1965), p. 5.

November 19

About 100 Grumman Aircraft Engineering Corporation and MSC representatives began seven weeks of negotiations on the lunar excursion module (LEM) contract. After agreeing on the scope of work and on operating and coordination procedures, the two sides reached fiscal accord. Negotiations were completed on January 3, 1963. Eleven days later, NASA authorized Grumman to proceed with LEM development. (See March 11, 1963.)

MSC, "Project Apollo Quarterly Status Report No. 2 for Period Ending December 31, 1962," p. 21; "Project Apollo Quarterly Status Report No. 3 for Period Ending March 31, 1963," p. I; NASA Contract No. NAS 9-1100, "Project Apollo Lunar Excursion Module Development Program," January 14, 1963; Clyde B. Bothmer, memorandum for distribution, "Minutes of the Fourteenth Meeting of the Management Council held on Tuesday, January 29, 1963, at the Launch Operations Center, Cocoa Beach, Florida," with enclosure: subject as above, p. 3.

November 19

North American defined requirements for the command and service modules (CSM) stabilization and control system.

North American Aviation, Inc. [hereafter cited as NAA], "Apollo Monthly Progress Report," SID 62-300-8, November 30, 1962, p. 52.

November 20

NASA invited ten industrial firms to submit bids by December 7 for a contract to build a control center at MSC and to integrate ground operational support systems for Apollo and the rendezvous phases of Gemini. On January 28, 1963, NASA announced that the contract had been awarded to the Philco Corporation, a subsidiary of the Ford Motor Company.

NASA News Release 63-14, "Philco to Develop Manned Flight Control Center at Houston," January 28, 1963; *Aviation Daily*, November 20, 1962, p. 111.

November 23

A Goddard Space Flight Center report summarizing recommendations for ground instrumentation support for the near-earth phases of the Apollo missions was forwarded to the Apollo Task Group of the NASA Headquarters Office of Tracking and Data Acquisition (OTDA). This report presented a preliminary conception of the Apollo network.

The tracking network would consist of stations equipped with 9-meter (30-foot) antennas for near-earth tracking and communications and of stations having 26-meter (85-foot) antennas for use at lunar

distances. A unified S-band system, capable of receiving and transmitting voice, telemetry, and television on a single radio-frequency band, was the basis of the network operation.

On March 12, 1963, during testimony before a subcommittee of the House Committee on Science and Astronautics, Edmond C. Buckley, Director of OTDA, described additional network facilities that would be required as the Apollo program progressed. Three Deep Space Instrumentation Facilities with 26-meter (85-foot) antennas were planned: Goldstone, Calif. (completed); Canberra, Australia (to be built); and a site in southern Europe (to be selected). Three new tracking ships and special equipment at several existing network stations for earth-orbit checkout of the spacecraft would also be needed.

Goddard Space Flight Center, Tracking and Data Systems Directorate, "A Ground Instrumentation Support Plan for the Near-Earth Phases of Apollo Missions," November 23, 1962; U.S. Congress, House, Subcommittee on Applications and Tracking of the Committee on Science and Astronautics, *1964 NASA Authorization*, Hearings, 88th Cong., 1st Sess. (1963), pp. 2795-2801.

November 26

At a news conference in Cleveland, Ohio, during the 10-day Space Science Fair there, NASA Deputy Administrator Hugh L. Dryden stated that inflight practice at orbital maneuvering was essential for lunar missions. He believed that landings would follow reconnaissance of the moon by circumlunar and near-lunar-surface flights.

The Plain Dealer, Cleveland, November 27, 1962.

November 27

NASA awarded a \$2.56 million contract to Ling-Temco-Vought, Inc. (LTV), to develop the velocity package for Project Fire, to simulate reentry from a lunar mission. An Atlas D booster would lift an instrumented payload (looking like a miniature Apollo CM) to an altitude of 122,000 meters (400,000 feet). The velocity package would then fire the reentry vehicle into a minus 15 degree trajectory at a velocity of 11,300 meters (37,000 feet) per second. On December 17, Republic Aviation Corporation, developer of the reentry vehicle, reported that design was 95 percent complete and that fabrication had already begun.

Wall Street Journal, November 27, 1962; LTV, Chance Vought Corporation, Astronautics Div., "Fire Velocity Package," (undated), pp. 1-1, 11-4; *Aviation Week and Space Technology*, 77 (December 17, 1962), pp. 53, 55, 57.

November 27

MSC officials met with representatives of Jet Propulsion Laboratory (JPL) and the NASA Office of Tracking and Data Acquisition (OTDA). They discussed locating the third Deep Space Instrumentation

Facility (DSIF) in Europe instead of at a previously selected South African site. (See Volume I of this chronology [NASA SP-4009], September 13, 1960.) JPL had investigated several European sites and noted the communications gap for each. MSC stated that a coverage gap of up to two hours was undesirable but not prohibitive. JPL and OTDA agreed to place the European station where the coverage gap would be minimal or nonexistent. However, the existence of a communications loss at a particular location would not be an overriding factor against a site which promised effective technical and logistic support and political stability. MSC agreed that this was a reasonable approach.

Memorandum, Gerald M. Truszynski, NASA, for file, "Meeting at MSC on Location of DSIF Station," December 3, 1964.

November 27

MSC released a sketch of the space suit assembly to be worn on the lunar surface. It included a portable life support system which would supply oxygen and pressurization and would control temperature, humidity, and air contaminants. The suit would protect the astronaut against solar radiation and extreme temperatures. The helmet faceplate would shield him against solar glare and would be defrosted for good visibility at very low temperatures. An emergency oxygen supply was also part of the assembly.

Four days earlier, MSC had added specifications for an extravehicular suit communications and telemetry (EVSCT) system to the space suit contract with Hamilton Standard Division of United Aircraft Corporation. The EVSCT system included equipment for three major operations:

1. Full two-way voice communication between two astronauts on the lunar surface, using the transceivers in the LEM and CM as relay stations.
2. Redundant one-way voice communication capability between any number of suited astronauts.
3. Telemetry of physiological and suit environmental data to the LEM or CM for relay to earth via the S- band link.

[The EVSCT contract was awarded to International Telephone and Telegraph (ITT) Corporation's Kellogg Division. (See March 26, 1963.)]

Memorandum, Ralph S. Sawyer, MSC, to Crew Systems Div., Attn: James V. Correale, "Extravehicular Suit Communications and Telemetry System Specifications," November 23, 1962; MSC News Release, "Project Apollo Space Suits," November 26, 1962; *The Evening Star*, Washington, November 28, 1962; *The Houston Post*, November 27, 1962.

November 27

Representatives of Hamilton Standard and International Latex Corporation (ILC) met to discuss mating the portable life support system to the ILC space suit configuration. As a result of mockup demonstrations and other studies, over-the-shoulder straps similar to those in the mockup were

substituted for the rigid "horns."

Hamilton Standard, "Monthly Progress Report through November 30, 1962, for Apollo Space Suit Assembly," PR-2-11-62, Item 7.2.

November 27

MSC Director Robert R. Gilruth reported to the Manned Space Flight (MSF) Management Council that formal negotiations between NASA and North American on the Apollo spacecraft development contract would begin in January 1963. He further informed the council that the design release for all Apollo systems, with the exception of the space suit, was scheduled for mid-1963; the suit was scheduled for January 1964.

MSF Management Council Meeting, November 27, 1962, Agenda Item 2, pp. 2-3 [and supplemental page].

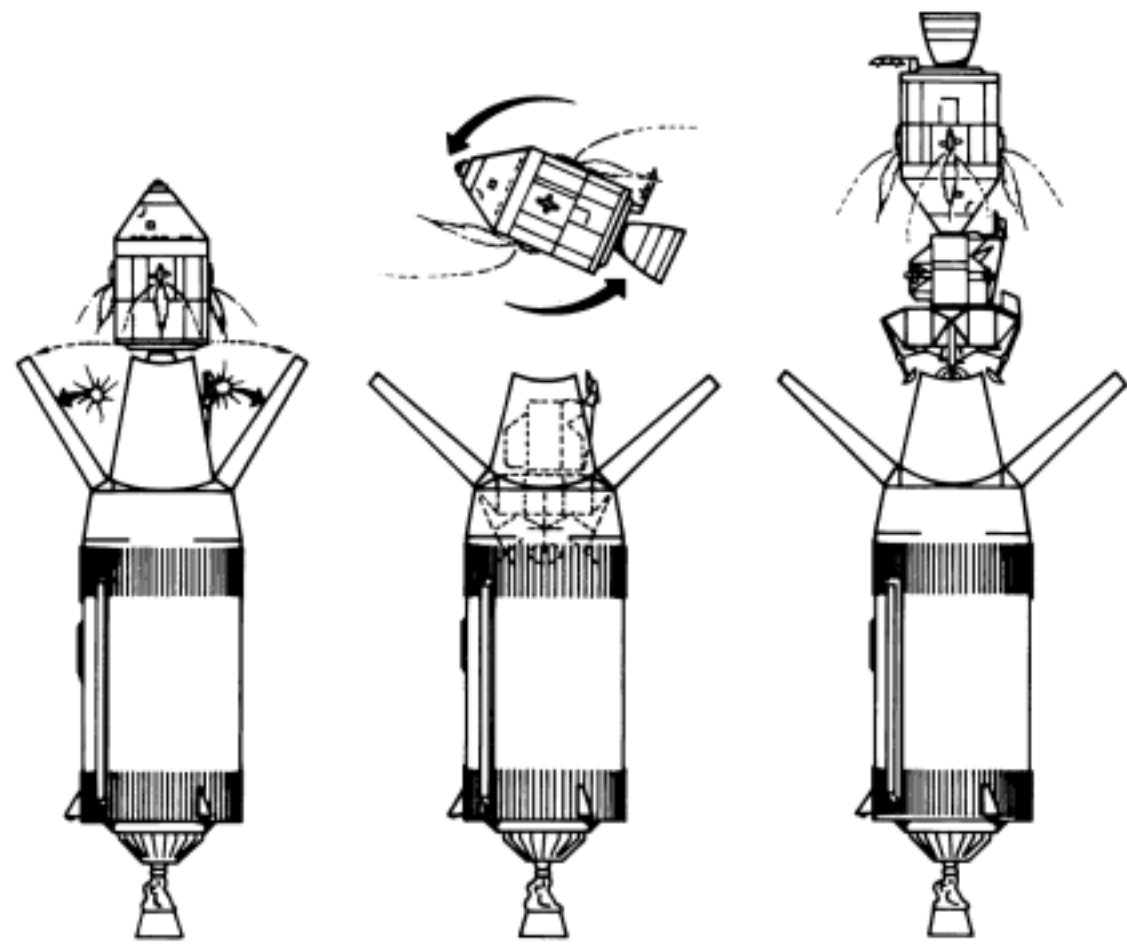
During the Month

AC Spark Plug Division of General Motors Corporation assembled the first CM inertial reference integrating gyro (IRIG) for final tests and calibration. Three IRIGs in the CM navigation and guidance system provided a reference from which velocity and attitude changes could be sensed. Delivery of the unit was scheduled for February 1963. (See February 11, 1963.)

"Apollo Quarterly Status Report No. 2," p. 13.

During the Month

North American completed a study of CSM-LEM transposition and docking. During a lunar mission, after the spacecraft was fired into a trajectory toward the moon, the CSM would separate from the adapter section containing the LEM. It would then turn around, dock with the LEM, and pull the second vehicle free from the adapter. The contractor studied three methods of completing this maneuver: free fly-around, tethered fly-around, and mechanical repositioning. Of the three, the company recommended the free fly-around, based on NASA's criteria of minimum weight, simplicity of design, maximum docking reliability, minimum time of operation, and maximum visibility.



Three phases of activity in the line drawing indicate the techniques of the free fly-around method of the docking exercise between the CSM and the LEM.

Also investigated was crew transfer from the CM to the LEM, to determine the requirements for crew performance and, from this, to define human engineering needs. North American concluded that a separate LEM airlock was not needed but that the CSM oxygen supply system's capacity should be increased to effect LEM pressurization.

On November 29, North American presented the results of docking simulations, which showed that the free flight docking mode was feasible and that the 45-kilogram (100-pound) service module (SM) reaction control system engines were adequate for the terminal phase of docking. The simulations also showed that overall performance of the maneuver was improved by providing the astronaut with an attitude display and some form of alignment aid, such as probe.

MSC, "Abstract of Proceedings, Flight Technology Systems Meeting No. 12, November 27, 1962," November 30, 1962; "Apollo Monthly Progress Report," SID 62-300-8, pp. 11-14.

During the Month

North American reported several problems involving the CM's aerodynamic characteristics; their analysis of CM dynamics verified that the spacecraft could - and on one occasion did - descend in an apex-forward attitude. The CM's landing speed then exceeded the capacity of the drogue parachutes to reorient the vehicle; also, in this attitude, the apex cover could not be jettisoned under all conditions. During low-altitude aborts, North American went on, the drogue parachutes produced unfavorable conditions for main parachute deployment. (See January 18, 1963.)

"Apollo Monthly Progress Report," SID 62-300-8, p. 77.

During the Month

Extensive material and thermal property tests indicated that a Fiberglas honeycomb matrix bonded to the steel substructure was a promising approach for a new heatshield design for the CM. See February 1, 1963.

Ibid., pp. 143-144.

During the Month

Collins Radio Company selected Motorola, Inc., Military Electronics Division, to develop and produce the spacecraft S-band transponder. The transponder would aid in tracking the spacecraft in deep space; also, it would be used to transmit and receive telemetry signals and to communicate between ground stations and the spacecraft by FM voice and television links. The formal contract with Motorola was awarded in mid-February 1963.

Also, Collins awarded a contract to the Leach Corporation for the development of command and service module (CSM) data storage equipment. The tape recorders must have a five-hour capacity for collection and storage of data, draw less than 20 watts of power, and be designed for in-flight reel changes.

Ibid., p. 89; NAA, "Apollo Facts," RBO070163, (undated), pp. 43-44.

During the Month

MSC awarded a \$222,000 contract to the Air Force Systems Command for wind tunnel tests of the Apollo spacecraft at its Arnold Engineering Development Center, Tullahoma, Tenn.

Aviation Week and Space Technology, 77 (November 12, 1962), p. 81.

During the Month

North American made a number of changes in the layout of the CM:

- Putting the lithium hydroxide canisters in the lower equipment bay and food stowage compartments in the aft equipment bay.
- Regrouping equipment in the left-hand forward equipment bay to make pressure suit disconnects easier to reach and to permit a more advanced packaging concept for the cabin heat exchanger.
- Moving the waste management control panel and urine and chemical tanks to the right-hand equipment bay.
- Revising the aft compartment control layout to eliminate the landing impact attenuation system and to add tie rods for retaining the heatshield.
- Preparing a design which would incorporate the quick release of the crew hatch with operation of the center window (drawings were released, and target weights and criteria were established).
- Redesigning the crew couch positioning mechanism and folding capabilities.
- Modifying the footrests to prevent the crew's damaging the sextant.

"Apollo Monthly Progress Report," SID 62-300-8, pp. 36, 71-72, 102, 104, 195.

December 3

The MSC Apollo Spacecraft Project Office (ASPO) outlined the photographic equipment needed for Apollo missions. This included two motion picture cameras (16- and 70-mm) and a 35-mm still camera. It was essential that the camera, including film loading, be operable by an astronaut wearing pressurized gloves. On February 25, 1963, NASA informed North American that the cameras would be government furnished equipment.

Memorandum, Charles W. Frick, MSC, to Office of Asst. Dir. for Information and Control Systems, Attn: Instrumentation and Electronic Systems Div., "Cameras for Apollo Spacecraft," December 3, 1962; letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. Twenty-Six," February 25, 1963.

December 3

The U.S. Army Corps of Engineers, acting for NASA, awarded a \$3.332 million contract to four New York architectural engineering firms to design the Vertical Assembly Building (VAB) at Cape Canaveral. The massive VAB became a space-age hangar, capable of housing four complete Saturn V launch vehicles and Apollo spacecraft where they could be assembled and checked out. The facility would be 158.5 meters (520 feet high) and would cost about \$100 million to build. Subsequently, the Corps of Engineers selected Morrison-Knudson Company, Perini Corp., and Paul Hardeman, Inc., to construct tile VAB.

Orlando Sentinel, December 5, 1962; MSC, *Space News Roundup*, January 9, 1963, p. 6; *The Kennedy Space Center Story* (KSC, 1969), pp. 19-20.

December 4

The first test of the Apollo main parachute system, conducted at the Naval Air Facility, El Centro, Calif., foreshadowed lengthy troubles with the landing apparatus for the spacecraft. One parachute failed to inflate fully, another disreefed prematurely, and the third disreefed and inflated only after some delay. No data reduction was possible because of poor telemetry. North American was investigating.

MSF Management Council Minutes, December 18, 1962, p. 2; NAA, "Apollo Monthly Progress Report," SID 62-300-9, January 15, 1963, p. 20.

December 5

At a meeting held at Massachusetts Institute of Technology (MIT) Instrumentation Laboratory, representatives of MIT, MSC, Hamilton Standard Division, and International Latex Corporation examined the problem of an astronaut's use of optical navigation equipment while in a pressurized suit with helmet visor down. MSC was studying helmet designs that would allow the astronaut to place his face directly against the helmet visor; this might avoid an increase in the weight of the eyepiece. In February 1963, Hamilton Standard recommended adding corrective devices to the optical system rather than adding corrective devices to the helmet or redesigning the helmet. In the same month, ASPO set 52.32 millimeters 2.06 inches as the distance of the astronaut's eye away from the helmet. MIT began designing a lightweight adapter for the navigation instruments to provide for distances of up to 76.2 millimeters (3 inches).

"Apollo Quarterly Status Report No. 2," p. 9; Hamilton Standard Div., "Minutes of Space Suit Navigation System Optical Interface Meeting," HSER 2582-2, December 5, 1962, pp. 1-2.

December 5

The General Electric Policy Review Board, established by the MSF Management Council, held its first meeting. On February 9, the General Electric Company (GE) had been selected by NASA to provide integration analysis (including booster-spacecraft interface), ensure reliability of the entire space vehicle, and develop and operate a checkout system. The Policy Review Board was organized to oversee the entire GE Apollo effort.

Memorandum, James E. Sloan, NASA, to Wernher von Braun, Kurt H. Debus, and Robert R. Gilruth, "General Electric Policy Review Board," December 6, 1962; draft, "General Electric Policy Review Board Charter," December 4, 1962; memorandum, Sloan to Gilruth and Walter C. Williams, "Charter of Policy Review Board for General Electric Manned Lunar Landing Program Effort," January 8, 1963 (charter enclosed).

December 8

With NASA's concurrence, North American released the Request For Proposals on the Apollo mission simulator. A simulated CM, an instructor's console, and a computer complex now supplanted the three part-task trainers originally planned. An additional part-task trainer was also approved. A preliminary report describing the device had been submitted to NASA by North American. The trainer was scheduled to be completed by March 1964.

"Apollo Quarterly Status Report No. 2," p. 34; NAA, "Apollo Monthly Progress Report," SID 62-300-12, May 1, 1963, p. 2.

December 10

NASA Administrator James E. Webb, in a letter to the President, explained the rationale behind the Agency's selection of lunar orbit rendezvous (rather than either direct ascent or earth orbit rendezvous) as the mode for landing Apollo astronauts on the moon. (See Volume I, July 11, 1962.) Arguments for and against any of the three modes could have been interminable: "We are dealing with a matter that cannot be conclusively proved before the fact," Webb said. "The decision on the mode . . . had to be made at this time in order to maintain our schedules, which aim at a landing attempt in late 1967."

John M. Logsdon, "NASA's Implementation of the Lunar Landing Decision," (HHN-81), August 1969, pp. 85, 87.

December 11

NASA authorized North American's Columbus, Ohio, Division to proceed with a LEM docking study.

TWX, J. F. Leonard, NAA, to NASA, [Attn:] D. B. Cherry, December 14, 1962.

December 11

The first static firing of the Apollo tower jettison motor, under development by Thiokol Chemical Corporation, was successfully performed.

"Apollo Monthly Progress Report," SID 62-300-9, p. 14; "Apollo Quarterly Status Report No. 2," p. 6.

December 12

Northrop Corporation's Ventura Division, prime contractor for the development of sea-markers to indicate the location of the spacecraft after a water landing, suggested three possible approaches:

1. A shotgun shell type that would dispense colored smoke.
2. A floating, controlled-rate dispenser (described as an improvement on the current water-soluble

binder method).

3. A floating panel with relatively permanent fluorescent qualities.

Northrop Ventura recommended the first method, because it would produce the strongest color and size contrast and would have the longest life for its weight.

Memorandum, W. E. Oller, Northrop Ventura, to MSC, Attn: P. Armitage, "NAS 9-482, Status of Remainder of Program," December 12, 1962.

December 13

MSC officials, both in Houston and at the Preflight Operations Division at Cape Canaveral, agreed on a vacuum chamber at the Florida location to test spacecraft systems in a simulated space environment during prelaunch checkout.

Memorandum, A. D. Mardel, MSC, to Distribution, "Minutes of meeting on NASA AMR Vacuum Chamber requirements," December 14, 1962.

December 15

The first working model of the crew couch was demonstrated during an inspection of CM mockups at North American. As a result, the contractor began redesigning the couch to make it lighter and simpler to adjust. Design investigation was continuing on crew restraint systems in light of the couch changes. An analysis of acceleration forces imposed on crew members during reentry at various couch back and CM angles of attack was nearing completion.

"Apollo Quarterly Status Report No. 2," pp. 9, 10; NASA-Resident Apollo Spacecraft Project Office (RASPO/NAA), "Consolidated Activity Report . . . , December 1, 1962-January 5, 1963," p. 3.

December 18

MSC Director Robert R. Gilruth reported to the MSF Management Council that tests by Republic Aviation Corporation, the U.S. Air Force School of Aerospace Medicine SAM at Brooks Air Force Base, Tex., and the U.S. Navy Air Crew Equipment Laboratory (ACEL) at Philadelphia, Pa., had established that, physiologically, a spacecraft atmosphere of pure oxygen at 3.5 newtons per square centimeter (five pounds per square inch absolute [psia]) was acceptable. During the separate experiments, about 20 people had been exposed to pure oxygen environments for periods of up to two weeks without showing adverse effects. Two fires had occurred, one on September 10 at SAM and the other on November 17 at ACEL. The cause in both cases was faulty test equipment. On July 11, NASA had ordered North American to design the CM for 3.5 newtons per square centimeter (5-psia), pure-oxygen atmosphere.

MSF Management Council Minutes, December 18, 1962, p. 3; "Apollo Quarterly Status Report No. 2," p. 11; "Abstract of Proceedings, Crew Systems Meeting No. 13, December 18, 1962," December 20, 1962.

December 19

NASA announced that *Ranger VI* (see Volume I, August 29, 1961) would be used for intensive reliability tests. Resultant improvements would be incorporated into subsequent spacecraft (numbers VII-IX), delaying the launchings of those vehicles by "several months." The revised schedule was based on recommendations by a Board of Inquiry headed by Cdr. Albert J. Kelley (USN), Director of Electronics and Control in the NASA Office of Advanced Research and Technology. (See Volume I, October 18, 1962.) The Kelley board, appointed by NASA Space Sciences Director Homer E. Newell after the *Ranger V* flight, consisted of officials from NASA Headquarters, five NASA Centers, and Bellcomm, Inc. The board concluded that increased reliability could be achieved through spacecraft design and construction modifications and by more rigorous testing and checkout. (See January 30, 1964.)

The Washington Post, December 20, 1962; *The Evening Star*, Washington, December 20, 1962; U.S. Congress, House, Subcommittee on Space Sciences and Advanced Research and Technology of the Committee on Science and Astronautics, *1964 NASA Authorization*, Hearings on H. R. 5466, 88th Cong., 1st Sess. (1963), pp. 1597-1598.

December 20

MSC prognosticated that, during landing, exhaust from the LEM's descent engine would kick up dust on the moon's surface, creating a dust storm. Landings should be made where surface dust would be thinnest.

NASA Project Apollo Working Paper No. 1052, "A Preliminary Analysis of the Effects of Exhaust Impingement on the Lunar Surface During the Terminal Phases of Lunar Landing," December 20, 1962,

December 21

North American delivered CM boilerplate (BP) 3, to Northrop Ventura, for installation of an earth-landing system. BP-3 was scheduled to undergo parachute tests at El Centro, Calif., during early 1963.

RASPO/NAA, "Consolidated Activity Report . . . , December 1, 1962-January 5, 1963,"

December 26

The Minneapolis-Honeywell Regulator Company submitted to North American cost proposal and design specifications on the Apollo stabilization and control system, based upon the new Statement of Work drawn up on December 17.

"Apollo Quarterly Status Report No. 2," p. 16.

December 28

North American selected Radiation, Inc., to develop the CM pulse code modulation (PCM) telemetry system. The PCM telemetry would encode spacecraft data into digital signals for transmission to ground stations. The \$4.3 million contract was officially announced on February 15, 1963.

"Apollo Monthly Progress Report," SID 62-300-9, p. 20; NAA, "Apollo Facts," RBO070163, (undated), pp. 44-45; *Space Business Daily*, February 26, 1963, p. 243.

December 28

Lockheed Propulsion Company successfully static fired four launch escape system pitch-control motors. In an off-the-pad or low-altitude abort, the pitch-control motor would fix the trajectory of the CM after its separation from the launch vehicle.

"Apollo Monthly Progress Report," SID 62-300-9, p. 14; NAA, "Quarterly Reliability Status Report," SID 62-557-4, January 31, 1964, pp. 242, 246.

December 28

North American's Rocketdyne Division completed the first test firings of the CM reaction control engines.

Ralph B. Oakley, *Historical Summary, S&ID Apollo Program* (NAA, Space and Information Systems Div., January 20, 1966), p. 8; "Apollo Monthly Progress Report," SID 62300-9, p. 13.

During the Month

MSC prepared the Project Apollo lunar landing mission design. This plan outlined ground rules, trajectory analyses, sequences of events, crew activities, and contingency operations. It also predicted possible planning changes in later Apollo flights.

"Apollo Quarterly Status Report No. 2," p. 4.

During the Month

In the first of a series of reliability-crew safety design reviews on all systems for the CM, North American examined the spacecraft's environmental control system (ECS). The Design Review Board

approved the overall ECS concept, but made several recommendations for further refinement. Among these were:

- The ECS should be made simpler and the system's controls should be better marked and located.
- Because of the pure oxygen environment, all flammable materials inside the cabin should be eliminated.
- Sources of possible atmospheric contamination should be further reviewed, with emphasis upon detecting and controlling such toxic gases inside the spacecraft.

"Quarterly Reliability Status Report," SID 62-557-4.

During the Month

NASA and General Dynamics/Convair (GD/C) began contract negotiations on the Little Joe II launch vehicle, which was used to flight-test the Apollo launch escape system. The negotiated cost was nearly \$6 million. GD/C had already completed the basic structural design of the vehicle. (See February 18, 1963.)

General Dynamics, Convair Div., *Little Joe II Test Launch Vehicle, NASA Project Apollo: Final Report*, GDC-66-042 (May 1966), Vol. I, pp. 1-2, 1-4, 4-2, 4-3.

During the Month

North American reported three successful static firings of the launch escape motor. The motor would pull the CM away from the launch vehicle if there were an abort early in a mission.

"Apollo Quarterly Status Report No. 2," p. 6; "Quarterly Reliability Status Report," SID 62-557-4, p. 242.

During the Month

MSC reported that the general arrangement of the CM instrument panel had been designed to permit maximum manual control and flight observation by the astronauts.

"Apollo Quarterly Status Report No. 2," pp. 8, 9.

During the Month

MSC Flight Operations Division examined the operational factors involved in Apollo water and land landings. Analysis of some of the problems leading to a preference for water landing disclosed that:

- Should certain systems on board the CM fail, the spacecraft could land as far as 805 kilometers 500 miles from the prime recovery area. This contingency could be provided for at sea, but serious difficulties might be encountered on land.
- Because Apollo missions might last as long as two weeks, weather forecasting for the landing zone probably would be unreliable.
- Hypergolic fuels were to remain on board the spacecraft through landing. During a landing at sea, the bay containing the tanks would flood and seawater would neutralize the liquid fuel or fumes from damaged tanks. On land, the possibility of rupturing the tanks was greater and the danger of toxic fumes and fire much more serious.
- Should the CM tumble during descent, the likelihood of serious damage to the spacecraft was less for landings on water.
- On land, obstacles such as rocks and trees might cause serious damage to the spacecraft.
- The spacecraft would be hot after reentry. Landing on water would cool the spacecraft quickly and minimize ventilation problems.
- The requirements for control during reentry were less stringent in a sea landing, because greater touchdown dispersions could be allowed.
- Since the CM must necessarily be designed for adequate performance in a water landing all aborts during launch and most contingencies required a landing at sea, the choice of water as the primary landing surface could relieve some constraints in spacecraft design. (See February 1 and March 5, 1963; February 25, 1964.)

Memorandum, Christopher C. Kraft, Jr., MSC, to Mgr., ASPO, "Review of Operational Factors Involved in Water and Land Landings," undated (ca. December 1962).

During the Month

The contract for the development and production of the CSM C-band transponder was awarded to American Car and Foundry Industries, Inc., by Collins Radio Company. The C-band transponder was used for tracking the spacecraft. Operating in conjunction with conventional, earth-based, radar equipment, it transmitted response pulses to the Manned Space Flight Network,

"Apollo Quarterly Status Report No. 2," p. 18; "Apollo Monthly Progress Report," SID 62-300-9, p. 10.

During the Quarter

Grumman agreed to use existing Apollo components and subsystems, where practicable, in the LEM. This promised to simplify checkout and maintenance of spacecraft systems.

MSC, "Contract Implementation Plan, Lunar Excursion Module, Project Apollo," November 11, 1962, p. 5; *Aviation Week and Space Technology*, 78 (January 14, 1963), p. 39.

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Part 1 (B)

Defining Contractural Relations

January 1963 through March 1963

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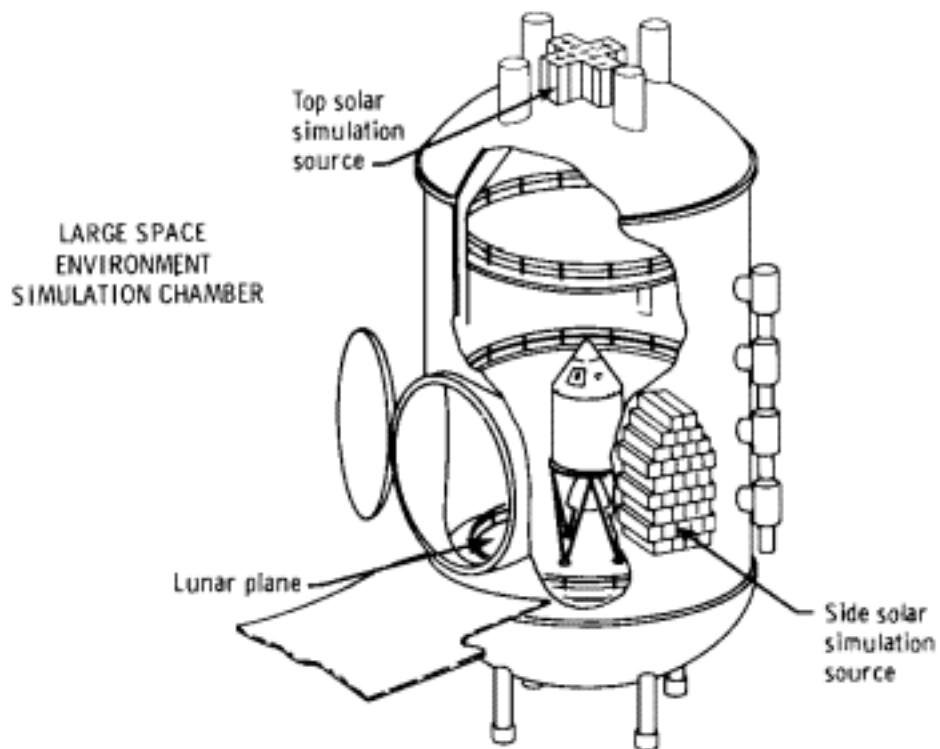
[1963 February](#)

[1963 March](#)

1963

January 2

MSC awarded a \$3.69 million contract to the Radio Corporation of America



A drawing of the larger chamber, including the position of simulated solar sources.

RCA Service Company to design and build two vacuum chambers at MSC. The facility was used in astronaut training and spacecraft environmental testing. using carbon arc: lamps, the chambers simulated the sun's intensity, permitting observation of the effects of solar heating encountered on a lunar mission. At the end of July, MSC awarded RCA another contract (worth \$3,341,750) for these solar simulators.

MSC Release 63-1, "Contract Awarded to RCA Services Company" [January 2, 1963]; MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, July 21-August 17, 1963," p. 3.

January 8

After studying the present radar coverage provided by ground stations for representative Apollo trajectories, North American recommended that existing C-band radars be modified to increase ranging limits. The current capability for tracking to 920 kilometers (500 nautical miles), while satisfactory for near-earth trajectories, was wholly inadequate for later Apollo missions. Tracking capability should be extended to 59,000 kilometers (32,000 nautical miles), North American said; and to improve tracking accuracy, transmitter power and receiver sensitivity should be increased.

Memorandum, C. H. Feltz, NAA, to MSC, Attn: J. T. Markley, "Contract No. NAS 9-150, Research and Development for Project Apollo Spacecraft, C-Band Coverage Preliminary Report," January 8, 1963.

January 8

Joseph F. Shea, Director of the Office of Systems in NASA's Office of Manned Space Flight (OMSF), briefed MSC officials on the nature and scope of NASA's contract with Bellcomm for systems engineering support. Also, Shea familiarized them with the organization and operation of the Office of Systems vis-a-vis Bellcomm. [Bellcomm, a separate corporation formed by American Telephone and Telegraph and Western Electric early in 1962, specifically at NASA's request, furnished engineering support to the overall Apollo program.] Bellcomm's studies, either in progress or planned, included computer support, environmental hazards, mission safety and reliability, communications and tracking, trajectory analyses, and lunar surface vehicles.

Memorandum, Paul E. Purser, MSC, to Distribution, "Operations of OMSF Office of Systems and Bellcomm," January 14, 1963.

January 10

MSC and OMSF agreed that an unmanned Apollo spacecraft must be flown on the Saturn C-1 before a manned flight. SA-10 was scheduled to be the unmanned flight and SA-111, the first manned mission.

Memorandum, John H. Disher, NASA, to MSC, Attn: Paul E. Purser, "Review of Apollo Quarterly Status Report No. 2," January 23, 1963.

January 16

The MSC Flight Operations Division's Mission Analysis Branch analyzed three operational procedures for the first phase of descent from lunar orbit:

1. The first was a LEM-only maneuver. The LEM would transfer to an orbit different from that of the CSM but with the same period and having a pericyynthion of 15,240 meters (50,000 feet). After one orbit and reconnaissance of the landing site, the LEM would begin descent maneuvers.
2. The second method required the entire spacecraft (CSM/LEM) to transfer from the initial circular orbit to an elliptical orbit with a pericynthion of 15,240 meters (50,000 feet).
3. The third technique involved the LEM's changing from the original 147-kilometer (80-nautical-mile) circular orbit to an elliptic orbit having a pericynthion of 15,240 meters (50,000 feet). The CSM, in turn, would transfer to an elliptic orbit with a pericynthion of 65 kilometers (30 nautical miles). This would enable the CSM to keep the LEM under observation until the LEM began its descent to the lunar surface.

Comparisons of velocity changes and fuel requirements for the three methods showed that the second technique would use much more fuel than the others and, therefore, was not recommended for further consideration.

[Apocynthion and pericynthion are the high and low points, respectively, of an object in orbit around the moon (as, for example, a spacecraft sent from earth). Apolune and perilune also refer to these orbital parameters, but these latter two words apply specifically to an object launched from the moon itself.]

Memorandum, Stephen Huzar, MSC, to Chief, BOD, "Comparison of Fuel Requirements for Three Near-Moon Orbital Techniques Associated With the Planning of the Lunar Landing Mission," January 16, 1963.

January 16-February 15

North American awarded Airborne Instruments Laboratory, a division of Cutler-Hammer, Inc., a contract for the CM recovery antenna system. NAA,

"Apollo Monthly Progress Report," SID 62-300-10, March 1, 1963, p. 3.

January 16-February 15

Representatives of North American, Langley Research Center, Ames Research Center, and MSC discussed CM reentry heating rates. They agreed on estimates of heating on the CM blunt face, which absorbed the brunt of reentry, but afterbody heating rates were not as clearly defined. North American was studying Project Mercury flight data and recent Apollo wind tunnel tests to arrive at revised estimates.

"Apollo Quarterly Status Report No. 3," p. 33; "Apollo Monthly Progress Report," SID 62-300-10, p. 7.

January 17

Christopher C. Kraft, Jr., of MSC's Flight Operations Division (FOD), advised ASPO that the digital up-data link being developed for the Gemini program appeared acceptable for Apollo as well. In late October 1962, representatives of FOD and ASPO had agreed that an independent up-data link a means by which the ground could feed current information to the spacecraft's computer during a mission was essential for manned Apollo flights. Kraft proposed that the Gemini-type link be used for Apollo as well, and on June 13 MSC ordered North American to include the device in the CM.

Memorandum, Christopher C. Kraft, Jr., MSC, to Mgr., ASPO, "Apollo Up-Data Link," January 17, 1963; letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. Fifty-Four," June 13, 1963.

January 17

President John F. Kennedy sent his budget request for Fiscal Year 1964 to Congress. The President recommended a NASA appropriation of \$5.712 billion, \$3.193 billion of which was for manned space flight. Apollo received a dramatic increase - \$1.207 billion compared with \$435 million the previous year. NASA Administrator James E. Webb nonetheless characterized the budget, about half a billion dollars less than earlier considered, as one of "austerity." While it would not appreciably speed up the lunar landing timetable, he said, NASA could achieve the goal of placing a man on the moon within the decade.

The Houston Post, January 18, 1963.

January 18

Two aerodynamic strakes were added to the CM to eliminate the danger of a hypersonic apex-forward trim point on reentry. [During a high-altitude launch escape system (LES) abort, the crew would undergo excessive g forces if the CM were to trim apex forward. During a low-altitude abort, there was the potential problem of the apex cover not clearing the CM. See November 1962. The strakes, located in the yaw plane, had a maximum span of one foot and resulted in significant weight penalties. The size of the strakes had to be increased later because of changes in the CM which moved the center of gravity

forward and because of the additional ablative material needed to combat the increased heating of the strakes during reentry. Removal of the strakes would cause a major redesign to permit the apex cover to be jettisoned in the low angle-of-attack (apex forward) region. In the summer of 1963, however, MSC and North American representatives agreed that the strakes should be removed and an apex-mounted flap be added. The flap could be jettisoned with the LES tower during normal missions and retained with the CM during a LES abort.

North American then suggested a "tower flap dual mode" approach. This concept incorporated fixed surfaces at the upper end of the LES tower which would be exposed to the air stream after jettison of the expended rocket casing. For aborts below 9,140 meters (30,000 feet), the jettison motor would pull away the expended motor casing, the LES tower, and apex cover. The contractor carried out extensive wind tunnel tests of this configuration and reported to MSC during October that a 0.5941-square-meter (920-square-inch) planer flap located in the upper bay of the LES, coupled with a more favorable CM center of gravity, would be required to solve the reentry problem.

An independent investigation of deployable aerodynamic surfaces, or canards, at the forward end of the LES rocket motor was also being conducted. These canards would act as lifting surfaces to destabilize the LES and cause it to reorient the spacecraft to a heatshield-forward position. (See November 12, 1963, February 7 and 25, 1964.)

"Apollo Monthly Progress Report," SID 62-300-9, p. 6; *ibid.*, SID 62-300-10, p. 5; *ibid.*, SID 62-300-11, April 1, 1963, p. 7; *ibid.*, SID 62-300-12, p. 8; *ibid.*, SID 62-300-15, August 1, 1963, p. 5; *ibid.*, SID 62-300-16, September 1, 1963, p. 8; *ibid.*, SID 62-300-17, October 1, 1963, p. 5; *ibid.*, SID 62-300-18, November 1, 1963, p. 3; *ibid.*, SID 62-300-19, December 1, 1963, p. 5; *ibid.*, SID 62-300-20, January 1, 1964, p. 5; *ibid.*, SID 62-300-21, February 1, 1964, p. 3; *ibid.*, SID 62 300-23, April 1, 1964, p. 3; "ASPO Weekly Activity Report, September 19-25, 1963," p. 3; "ASPO Weekly Activity Report, September 26-October 2, 1963," p. 2; "ASPO Status Report For Period Ending October 16, 1963"; "ASPO Status Report For Period October 16-November 12, 1963"; "ASPO Status Report For Period December 18-January 14, 1964"; "ASPO Status Report For Week Ending December 4, 1963"; "ASPO Status Report For Week Ending December 17, 1963"; "ASPO Status Report For Week Ending January 7, 1964"; "Monthly ASPO Status Report For Period January 16-February 12, 1964"; "Apollo Quarterly Status Report No. 3," p. 32; "Apollo Quarterly Status Report No. 4 for Period Ending June 30, 1963," p. 28; "Apollo Quarterly Status Report No. 5 for Period Ending September 30, 1963," p. 40; "Apollo Quarterly Status Report No. 6 for Period Ending December 31, 1963," p. 37; MSC, "Weekly Activity Report for the Office of the Director, Manned Space Flight, June 30July 6, 1963," p. 4; "Minutes of NASA-NAA Technical Management Meeting, February 25, 1964"; Oakley, *Historical Summary, S&ID Apollo Program*, p. 12.

January 18

NASA's Flight Research Center (FRC) announced the award of a \$3.61 million contract to Bell Aerosystems Company of Bell Aerospace Corporation for the design and construction of two manned

lunar landing research vehicles. The vehicles would be able to take off and land under their own power, reach an altitude of about 1,220 meters (4,000 feet), hover, and fly horizontally. A fan turbojet engine would supply a constant upward push of five-sixths the weight of the vehicle to simulate the one-sixth gravity of the lunar surface. Tests would be conducted at FRC.

Astronautics and Aeronautics, 1963 (NASA SP-4004), p. 17; *Daily Press*, Newport News, Va., January 13, 1963; *Wall Street Journal*, January 22, 1963; *Aviation Daily*, January 24, 1963, p. 161.

January 23

The Hamilton Standard space suit contract was amended to include supplying space suit communications and telemetry equipment. (See November 27, 1962.)

Hamilton Standard, "Monthly Progress Report for the Period of January 1 through 31, 1963, for Apollo Space Suit Assembly," PR-4-1-63, p. 1.

January 24

The first evaluation of crew mobility in the International Latex Corporation (ILC) pressure suit was conducted at North American to identify interface problems. Three test subjects performed simulated flight tasks inside a CM mockup. CM spatial restrictions on mobility were shown. Problems involving suit sizes, crew couch dimensions, and restraint harness attachment, adjustment, and release were appraised. Numerous items that conflicted with Apollo systems were noted and passed along to ILC for correction in the continuing suit development program. (See March 26-28.)

"Project Apollo Spacecraft, Test Program Weekly Activities Report (Period, 21 January 1963 through 27 January 1963)," p. 6.

January 26

MSC announced new assignments for the seven original astronauts: L. Gordon Cooper, Jr., and Alan B. Shepard, Jr., would be responsible for the remaining pilot phases of Project Mercury; Virgil I. Grissom would specialize in Project Gemini; John H. Glenn, Jr., would concentrate on Project Apollo; M. Scott Carpenter would cover lunar excursion training; and Walter M. Schirra, Jr., would be responsible for Gemini and Apollo operations and training. As Coordinator for Astronaut Activities, Donald K. Slayton would maintain overall supervision of astronaut duties.

Specialty areas for the second generation were: trainers and simulators, Neil A. Armstrong; boosters, Frank Borman; cockpit layout and systems integration, Charles Conrad, Jr.; recovery system, James A. Lovell, Jr.; guidance and navigation, James A. McDivitt; electrical, sequential, and mission planning, Elliot M. See, Jr.; communications, instrumentation, and range integration, Thomas P. Stafford; flight control systems, Edward H. White II; and environmental control systems, personal equipment, and

survival equipment, John W. Young.

MSC Fact Sheet No. 113, "Specialized Assignments for MSC Astronauts and Flight Crew Personnel," January 26, 1963; *The Washington Post*, January 27, 1963.

January 28

NASA announced the selection of the Philco Corporation as prime contractor for the Mission Control Center (MCC) at MSC. To be operational in mid-1964, MCC would link the spacecraft with ground controllers at MSC through the worldwide tracking network.

NASA News Release 63-14, "Philco to Develop Manned Flight Mission Control Center at Houston," January 28, 1963; *Wall Street Journal*, January 29, 1963.

January 28

Following a technical conference on the LEM electrical power system (EPS), Grumman began a study to define the EPS configuration. Included was an analysis of EPS requirements and of weight and reliability for fuel cells and batteries. Total energy required for the LEM mission, including the translunar phase, was estimated at 61.3 kilowatt-hours. Upon completion of this and a similar study by MSC, Grumman decided upon a three-cell arrangement with an auxiliary battery. Capacity would be determined when the EPS load analysis was completed. (See March 7.)

"Apollo Quarterly Status Report No. 3," pp. 27-28.



Ground was broken for the MSC Operations and Checkout Building at Merritt Island January 28, 1963. Participants were, left to right, Walter C. Williams, Director of Flight Operations, MSC; G. Merritt Preston, Director of Pre-Flight Operations Division, MSC; Kurt H. Debus, Director, Launch Operations Center; D. Brainerd Holmes, Director, NASA Office of Manned Space Flight; Wernher von Braun, Marshall Space Flight Center; Col. H. R. Parfitt, District Engineer, U.S. Army; and Col. E. Richardson, U.S. Air Force.

January 30

Grumman and NASA announced the selection of four companies as major LEM subcontractors:

1. Rocketdyne for the descent engine (see February 13)
2. Bell Aerosystems Company for the ascent engine (see February 25)
3. The Marquardt Corporation for the reaction control system (see March 11)
4. Hamilton Standard for the environmental control system see (March 4).

MSC News Release 63-14, January 30, 1963; *Aviation Daily*, January 30, 1963, p. 210; *Wall Street Journal*, January 31, 1963.

During the Month

MSC awarded a contract to Chance Vought Corporation for a study of guidance system techniques for the LEM in an abort during lunar landing.

NASA News Release 63-41, "January Contracts," March 4, 1963.

February 1

NASA authorized North American to extend until June 10 the CM heatshield development program. This gave the company time to evaluate and recommend one of the three ablative materials still under consideration. The materials were subjected to tests of thermal performance, physical and mechanical properties, and structural compatibility with the existing heatshield substructure. North American sought also to determine the manufacturing feasibility of placing the materials in a Fiberglas honeycomb matrix bonded to a steel substructure. (See November 1962.)

Letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. Thirteen, Revision 2," March 11, 1963.

February 1

Walter C. Williams, MSC's Associate Director, defined the Center's criteria on the location of earth landing sites for Gemini and Apollo spacecraft: site selection as well as mode of landing (i.e., land versus water) for each mission should be considered separately. Constraints on trajectory, landing accuracy, and landing systems must be considered, as well as lead time needed to construct landing area facilities. Both Gemini and Apollo flight planning had to include water as well as land landing modes. (See December 1962.) Although the Apollo earth landing system was designed to withstand the shock of coming down on varying terrains, some experience was necessary to verify this capability. Because of the complexity of the Apollo mission and because the earth landing system did not provide a means of avoiding obstacles, landing accuracy was even more significant for Apollo than for Gemini. With so

many variables involved, Williams recommended that specific landing locations for future missions not be immediately designated. (See March 5 and February 25, 1964.)

Memorandum, Walter C. Williams, MSC, to NASA Headquarters, Attn: OMSF, "Designation of Landing Sites for Projects Gemini and Apollo," February 1, 1963.

February 6

Aerojet-General Corporation, Sacramento, Calif., began full-scale firings of a service propulsion engine with a redesigned injector baffle.

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, January 27-February 23, 1963," p. 56.

February 7

NASA announced a simplified terminology for the Saturn booster series: Saturn C-1 became "Saturn I," Saturn C-1B became "Saturn IB," and Saturn C-5 became "Saturn V."

MSC Fact Sheet No. 136, "NASA Simplifies Names of Saturn Launch Vehicles," February 7, 1963.

February 8

MSC issued a definitive contract for \$15,029,420 to the Raytheon Company, Space and Information Systems Division, to design and develop the CM onboard digital computer. The contract was in support of the MIT Instrumentation Laboratory, which was developing the Apollo guidance and navigation systems. Announcement of the contract was made on February 11.

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, January 27-February 23, 1963," p. 29; MSC News Release 63-18, February 11, 1963; *Missiles and Rockets*, 12 (February 18, 1963), p. 42.

February 11

The first inertial reference integrating gyro produced by AC Spark Plug was accepted by NASA and delivered to the MIT Instrumentation Laboratory. (See November 1962.)

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, January 27-February 23, 1963," p. 57.

February 12

NASA selected the Marion Power Shovel Company to design and build the crawler-transport, a device to haul the Apollo space vehicle (Saturn V, complete with spacecraft and associated launch equipment) from the Vertical Assembly Building to the Merritt Island, Fla., launch pad, a distance of about 5.6 kilometers (3.5 miles). The crawler would be 39.6 meters (130 feet) long, 35 meters (115 feet) wide, and 6 meters (20 feet) high, and would weight 2.5 million kilograms (5.5 million pounds). NASA planned to buy two crawlers at a cost of \$4 to 5 million each. Formal negotiations began on February 20 and the contract was signed on March 29.

Saturn Illustrated Chronology (MHR-3, August 10, 1964), p. 73; NASA News Release 63-27, "Marion to Build NASA Crawler," February 12, 1963.

February 13

In a reorganization of ASPO, MSC announced the appointment of two deputy managers. Robert O. Piland, deputy for the LEM, and James L. Decker, deputy for the CSM, would supervise cost, schedule, technical design, and production. J. Thomas Markley was named Special Assistant to the Apollo Manager, Charles W. Frick. Also appointed to newly created positions were Caldwell C. Johnson, Manager, Spacecraft Systems Office, CSM; Owen E. Maynard, Acting Manager, Spacecraft Systems Office, LEM; and David W. Gilbert, Manager, Spacecraft Systems Office, Guidance and Navigation.

MSC News Release 63-27, February 13, 1963.

February 13

Grumman began discussions with Rocketdyne on the development of a throttleable LEM descent engine. Engine specifications (helium injected, 10:1 thrust variation) had been laid down by MSC. (See May 1.)

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, January 27-February 23, 1963," p. 57; "Apollo Quarterly Status Report No. 3," p. 25.

February 15



A boilerplate spacecraft is dropped in the impact test facility at NAA's Downey, Calif., plant. The tower was 43.6 meters (143 feet) high, the pendulum pivot was 38.1 meters (125 feet), and maximum impact velocity was 12.2 meters (40 feet) per second vertical and 15.2 meters (50 feet) per second horizontal. (NAA photo)

The North American Apollo impact test facility at Downey, Calif., was completed. This facility consisted mainly of a large pool with overhead framework and mechanisms for hydrodynamic drop tests of the CM. Testing at the facility began with the drop of boilerplate 3 on March 11.

Oakley, *Historical Summary, S&ID Apollo Program*, p. 8; "Apollo Monthly Progress Report," SID 62-300-11, pp. 10, 21.

February 18

NASA issued a definitive contract for \$6,322,643 to General Dynamics Convair for the Little Joe II test vehicle. (See May 11, 1962, Vol. I.) A number of changes defined by contract change proposals were incorporated into the final document:

- Four instead of five vehicles to be manufactured and delivered
- Launching from White Sands Missile Range (WSMR), N.M., instead of Cape Canaveral
- Additional support equipment, better definition of vehicle design, and responsibility for launch support.

Little Joe II Test Launch Vehicle, NASA Project Apollo: Final Report, Vol. I, pp. 1-2, 1-4; MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, January 27-February 23, 1963," p. 28.

February 18

North American selected Bell Aerosystems Company to provide propellant tanks for the CSM reaction control system. These tanks were to be the "positive expulsion" type (i.e., fuel and oxidizer would be contained inside flexible bladder; pressure against one side of the device would force the propellant through the RCS lines).

"Apollo Monthly Progress Report," SID 62-300-10, p. 3; *Aviation Daily*, February 18, 1963, p. 312.

February 19

North American shipped CM boilerplate 19 to Northrop Ventura for use as a parachute test vehicle.

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, January 27-February 23, 1963," p. 55.

February 20

At a meeting of the MSC-MSFC Flight Mechanics Panel, it was agreed that Marshall would investigate

"engine-out" capability (i.e., the vehicle's performance should one of its engines fail) for use in abort studies or alternative missions. Not all Saturn I, IB, and V missions included this engine-out capability. Also, the panel decided that the launch escape system would be jettisoned ten seconds after S-IV ignition on Saturn I launch vehicles. (See March 28.)

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, January 27-February 23, 1963," p. 58.

February 20

In a reorganization of OMSF, Director D. Brainerd Holmes appointed Joseph F. Shea as Deputy Director for Systems and George M. Low as Deputy Director for Programs. All major OMSF directorates had previously reported directly to Holmes. In the new organizational structure, Director of Systems Studies William A. Lee, Director of Systems Engineering John A. Gautraud, and Director of Integration and Checkout James E. Sloan would report to Shea. Director of Launch Vehicles Milton W. Rosen, Director of Space Medicine Charles H. Roadman, and the Director of Spacecraft and Flight Missions (then vacant) would report to Low. William E. Lilly, Director of Administration, would provide administrative support in both major areas.

NASA News Release 63-32, "Holmes Names Two Deputies," February 20, 1963; *The Washington Post*, February 21, 1963.

February 21

MSC issued a Request for Proposals (due by March 13) for a radiation altimeter system. Greater accuracy than that provided by available radar would be needed during the descent to the lunar surface, especially in the last moments before touchdown. Preliminary MSC studies had indicated the general feasibility of an altimeter system using a source-detector-electronics package. After final selection and visual observation of the landing site, radioactive material would be released at an altitude of about 30 meters 100 feet and allowed to fall to the surface. The detector would operate in conjunction with electronic circuitry to compute the spacecraft's altitude. Studies were also under way at MSC on the possibility of using laser beams for range determination.

Memorandum, George W. Brandon, MSC, to Asst. Dir. for Information and Control Systems, "Request for Proposal, Low Level Radiation Altimeter System," November 13, 1962; *Aviation Daily*, February 21, 1963, p. 335.

February 24-March 23

The MSC Lunar Surface Experiments Panel held its first meeting. This group was formed to study and evaluate lunar surface experiments and the adaptability of Surveyor and other unmanned probes for use with manned missions.

MSC, "Consolidated Monthly Activity Report for the Office of the Director, Manned Space Flight, February 24-March 23, 1963," p. 44.

February 25

Grumman began initial talks with the Bell Aerosystems Company on development of the LEM ascent engine. Complete specifications were expected by March 2.

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, January 27-February 23, 1963," p. 28.

February 25

MSC ordered North American to provide batteries, wholly independent of the main electrical system in the CM, to fire all pyrotechnics aboard the spacecraft.

Letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. Twenty-Eight," February 25, 1963.

February 25



Aerial view of the Michoud Operations Plant, New Orleans, La

NASA announced the signing of a formal contract with The Boeing Company for the S-IC (first stage) of the Saturn V launch vehicle, the largest rocket unit under development in the United States. The \$418,820,967 agreement called for the development and manufacture of one ground test and ten flight articles. Preliminary development of the S-IC, which was powered by five F-1 engines, had been in progress since December 1961 under a \$50 million interim contract. Booster fabrication would take place primarily at the Michoud Operations Plant, New Orleans, La., but some advance testing would be done at MSFC and the Mississippi Test Operations facility.

NASA News Release 63-37, "NASA Contracts with Boeing for Saturn V Booster," February 25, 1963; *Aviation Daily*, February 27, 1963, p. 361.

February 26

Two aerospace technologists at MSC, James A. Ferrando and Edgar C. Lineberry, Jr., analyzed orbital constraints on the CSM imposed by the abort capability of the LEM during the descent and hover phases

of a lunar mission. Their study concerned the feasibility of rendezvous should an emergency demand an immediate return to the CSM.

Ferrando and Lineberry found that, once abort factors are considered, there exist "very few" orbits that are acceptable from which to begin the descent. They reported that the most advantageous orbit for the CSM would be a 147-kilometer (80-nautical-mile) circular one.

Memorandum, James A. Ferrando and Edgar C. Lineberry, Jr., to Chief, Flight Operations Div., "The Influence of LEM Abort Capability Upon the Selection of the Command Module Lunar Orbit," February 26, 1963.

February 26

NASA selected Ford, Bacon, and Davis, Inc., to design MSC's flight acceleration facility, including a centrifuge capable of spinning a simulated CM and its crew at gravity forces equal to those experienced in space flight.

Space Business Daily, February 26, 1963, p. 243; *Aviation Daily*, February 26, 1963, p. 358.

February 27

Aviation Daily reported an announcement by Frank Canning, Assistant LEM Project Manager at Grumman, that a Request for Proposals would be issued in about two weeks for the development of an alternate descent propulsion system. Because the descent stage presented what he called the LEM's "biggest development problem," Canning said that the parallel program was essential.

Aviation Daily, February 27, 1963, p. 362.

February 27

The Apollo Mission Planning Panel held its organizational meeting at MSC. The panel's function was to develop the lunar landing mission design, coordinate trajectory analyses for all Saturn missions, and develop contingency plans for all manned Apollo missions.

Membership on the panel included representatives from MSC, MSFC, NASA Headquarters, North American, Grumman, and MIT, with other NASA Centers being called on when necessary. By outlining the most accurate mission plan possible, the panel would ensure that the spacecraft could satisfy Apollo's anticipated mission objectives. Most of the panel's influence on spacecraft design would relate to the LEM, which was at an earlier stage of development than the CSM. The panel was not given responsibility for preparing operational plans to be used on actual Apollo missions, however.

MSC, "Minutes of Meeting on Apollo Mission Planning Panel Organization Meeting, February 27,

1963," March 7, 1963.

February 27

Elgin National Watch Company received a subcontract from North American for the design and development of central timing equipment for the Apollo spacecraft. [This equipment provided time-correlation of all spacecraft time-sensitive events. Originally, Greenwich Mean Time was to be used to record all events, but this was later changed. (See August 30-September 5, 1963.)]

Chicago Tribune, February 27, 1963; *Wall Street Journal*, February 28, 1963.

During the Month

Grumman began fabrication of a one-tenth scale model of the LEM for stage separation tests. In launching from the lunar surface, the LEM's ascent engine fires just after pyrotechnic severance of all connections between the two stages, a maneuver aptly called "fire in the hole."

Also, Grumman advised that, from the standpoint of landing stability, a five-legged LEM was unsatisfactory. Under investigation were a number of landing gear configurations, including retractable legs. (See April 17 and May 20-22.)

Grumman Aircraft Engineering Corporation [hereafter cited as GAEC], "Monthly Progress Report No. 1, LPR-10-1, March 10, 1963," pp. 5, 6, 8.

During the Month

NASA amended the GE contract, authorizing the company's Apollo Support Department to proceed with the PACE program. (See March 25, 1964.) [PACE (prelaunch automatic checkout equipment) would be used for spacecraft checkout. It would be computer-directed and operated by remote control.]

GE, "Support Program Monthly Progress Report, February 1963," NASw-410-MR-2. [NOTE: Use of the acronym "PACE" was subsequently dropped at the insistence of a company claiming prior rights to the name.]

March 4

Grumman began initial discussions with Hamilton Standard on the development of the LEM environmental control system.

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, January 27-February 23, 1963," p. 57; "Consolidated Monthly Activity Report for the Office of the Director,

Manned Space Flight, February 24-March 23, 1963," p. 8.

March 4

As a parallel to the existing Northrop Ventura contract, and upon authorization by NASA, North American awarded a contract for a solid parachute program to the Pioneer Parachute Company. [A solid parachute is one with solid (unbroken) gores; the sole opening in the canopy is a vent at the top. Ringsail parachutes (used on the Northrop Ventura recovery system) have slotted gores. In effect, each panel formed on the gores becomes a "sail."] (See June 28.)

"Apollo Quarterly Status Report No. 3," p. 18; letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. Twenty-Seven," February 25, 1963.

March 4

MSC "acquired" under a loan agreement an amphibious landing craft from the Army. Equipment to retrieve Apollo boilerplate spacecraft and other objects used in air drops and flotation tests was installed. The vessel, later named the *Retriever*, arrived at its Seabrook, Tex., docking facility late in June.

MSC News Release 63-38, "MSC Acquires Test Vehicle," March 4, 1963; MSC, *Space News Roundup*, June 26, 1963, p. 1.

March 5

MSC awarded a \$67,000 contract to The Perkin-Elmer Corporation to develop a carbon dioxide measurement system, a device to measure the partial carbon dioxide pressure within the spacecraft's cabin. Two prototype units were to be delivered to MSC for evaluation. About seven months later, a \$249,000 definitive contract for fabrication and testing of the sensor was signed. (See May 6.)

MSC, "Consolidated Monthly Activity Report for the Office of the Director, Manned Space Flight, February 24-March 23, 1963," p. 30; "Consolidated Activity Report for the Office of the Director, Manned Space Flight, September 22-October 19, 1963," p. 47.

March 5

NASA announced an American agreement with Australia, signed on February 26, that permitted the space agency to build and operate several new tracking stations "down under." A key link in the Jet Propulsion Laboratory's network of Deep Space Instrumentation Facilities would be constructed in Tidbinbilla Valley, 18 kilometers (11 miles) southwest of Canberra. Equipment at this site included a 26-meter (85-foot) parabolic dish antenna and electronic equipment for transmitting, receiving, and processing radio signals from spacecraft. Tracking stations would be built also at Carnarvon and Darwin.

NASA News Release 63-47, "NASA to Establish Deep Space Tracking Facility in Australia," March 5, 1963; *Aviation Daily*, March 8, 1963, p. 52.

March 5

The Mission Analysis Branch (MAB) of MSC's Flight Operations Division cited the principal disadvantages of the land recovery mode for Apollo missions. (See February 1.) Of primary concern was the possibility of landing in an unplanned area and the concomitant dangers involved. For water recovery, the main disadvantages were the establishment of suitable landing areas in the southern hemisphere and the apex-down flotation problem. MAB believed no insurmountable obstacles existed for either approach. (See February 25, 1964.)

Memorandum, John Bryant, MSC, to Chief, FOD, "Operational Considerations in the Selection of Primary Land or Sea Return Areas for Apollo," March 5, 1963.

March 6

North American completed construction of Apollo boilerplate (BP) 9, consisting of launch escape tower and CSM. It was delivered to MSC on March 18, where dynamic testing on the vehicle began two days later. On April 8, BP-9 was sent to MSFC for compatibility tests with the Saturn I launch vehicle.

MSC, "Consolidated Monthly Activity Report for the Office of the Director, Manned Space Flight, February 24-March 23, 1963," p. 50; Oakley, *Historical Summary, S&ID Apollo Program*, p. 8; *Birmingham Post-Herald*, April 5, 1963; *The Huntsville Times*, April 9, 1963; *The Birmingham News*, April 9, 1963.

March 6

The first Block I Apollo pulsed integrating pendulum accelerometer, produced by the Sperry Gyroscope Company, was delivered to the MIT Instrumentation Laboratory. [Three accelerometers were part of the guidance and navigation system. Their function was to sense changes in spacecraft velocity.]

MSC, "Consolidated Monthly Activity Report for the Office of the Director, Manned Space Flight, February 24-March 23, 1963," p. 53.

March 7

Grumman representatives presented their technical study report on power sources for the LEM. (See January 28.) They recommended three fuel cells in the descent stage (one cell to meet emergency requirements), two sets of fluid tanks, and two batteries for peak power loads. For industrial competition to develop the power sources, Grumman suggested Pratt and Whitney Aircraft and GE for the fuel cells, and Eagle-Picher, Electrical Storage Battery, Yardney, Gulton, and Delco-Remy for the batteries.

"Activity Report, RASPO/GAEC, 3/3/63-3/9/63" (undated), pp. 1-2.

March 8

North American moved CM boilerplate (BP) 6 from the manufacturing facilities to the Apollo Test Preparation Interim Area at Downey, Calif. During the next several weeks, BP-6 was fitted with a pad adapter, an inert launch escape system, and a nose cone, interstage structure, and motor skirt. (See July 1-2 and November 7.)

MSC, "Postlaunch Memorandum Report for Apollo Pad Abort I," November 13, 1963, pp. A1-1 through A1-5.

March 10

Grumman presented its first monthly progress report on the LEM. In accordance with NASA's list of high-priority items, principal engineering work was concentrated on spacecraft and subsystem configuration studies, mission plans and test program investigations, common usage equipment surveys, and preparation for implementing subcontractor efforts.

"Monthly Progress Report No. 1," LPR-10-1, p. 4.

March 11

Grumman completed its first "fire-in-the-hole" model test. (See February 1963.) Even though preliminary data agreed with predicted values, they nonetheless planned to have a support contractor, the Martin Company, verify the findings.

"Activity Report, RASPO/GAEC, 3/10/63-3/16/63" (undated), p. 2.

March 11

NASA announced signing of the contract with Grumman for development of the LEM. (See November 19, 1962.) Company officials had signed the document on January 21 and, following legal reviews, NASA Headquarters had formally approved the agreement on March 7. Under the fixed-fee contract (NAS 9-1100) (\$362.5 million for costs and \$25.4 million in fees) Grumman was authorized to design, fabricate, and deliver nine ground test and 11 flight vehicles. The contractor would also provide mission support for Apollo flights. MSC outlined a developmental approach, incorporated into the contract as "Exhibit B, Technical Approach," that became the "framework within which the initial design and operational modes" of the LEM were developed.

NASA-MSC, "Lunar Excursion Module, Project Apollo, Exhibit B, Technical Approach, Contract NAS 9-1100," December 20, 1962, p. 1; MSF Management Council Meeting, January 29, 1963, Agenda Item 3, "MSC Status Report," pp. 23, 26; MSF Management Council Minutes, January 29, 1963, p. 3; MSC, "Consolidated Monthly Activity Report for the Office of the Director, Manned Space Flight, February 24-March 23, 1963," p. 29; "Apollo Quarterly Status Report No. 3," p. 1; NASA News Release 63-51, "Contract Signed to Develop Lunar Excursion Module," March 11, 1963.

March 11

Grumman began early contract talks with the Marquardt Corporation for development of the LEM reaction control system.

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, January 27-February 23, 1963," p. 57; "Consolidated Monthly Activity Report for the Office of the Director, Manned Space Flight, February 24-March 23, 1963," p. 7.

March 13

The first stage of the Saturn SA-5 launch vehicle was static fired at MSFC for 144.44 seconds in the first long-duration test for a Block II S-1. The cluster of eight H-1 engines produced 680 thousand kilograms (1.5 million pounds) of thrust. An analysis disclosed anomalies in the propulsion system. In a final qualification test two weeks later, when the engines were fired for 143.47 seconds, the propulsion problems had been corrected.

MSFC Historical Office, History of the George C. Marshall Space Flight Center from January 1 through June 30, 1963 (MHM-7), Vol. I, pp. 21-22; The Huntsville Times, March 14, 1963.

March 14

A bidders' conference was held at Grumman for a LEM mechanically throttled descent engine to be developed concurrently with Rocketdyne's helium injection descent engine. (See February 27.) Corporations represented were Space Technology Laboratories; United Technology Center, a division of United Aircraft Corporation; Reaction Motors Division, Thiokol Chemical Corporation; and Aerojet-General Corporation. Technical and cost proposals were due at Grumman on April 8.

"Activity Report, RASPO/GAEC, 3/10/63-3/16/63" (undated), p. 1.

March 14

Homer E. Newell, Director of NASA's Office of Space Sciences, summarized results of studies by Langley Research Center and Space Technology Laboratories on an unmanned lunar orbiter spacecraft. These studies had been prompted by questions of the reliability and photographic capabilities of such

spacecraft. Both studies indicated that, on a five-shot program, the probability was 0.93 for one and 0.81 for two successful missions; they also confirmed that the spacecraft would be capable of photographing a landed Surveyor to assist in Apollo site verification.

Memorandum, Newell, NASA, to Dir., OMSF, "Questions on the unmanned lunar orbiter," March 14, 1963, with four enclosures; Bruce K. Byers, "Lunar Orbiter: a Preliminary History" (HHN-71), August 1969, pp. 21-22.

March 20

John A. Hornbeck, president of Bellcomm, testified before the House Committee on Science and Astronautics' Subcommittee on Manned Space Flight concerning the nature and scope of Bellcomm's support for NASA's Apollo program. In answer to the question as to how Bellcomm would decide "which area would be the most feasible" for a lunar landing, Hornbeck replied, ". . . the safety of the landing - that will be the paramount thing." He said that his company was studying a number of likely areas, but would "not recommend a specific site at the moment." Further, "Preliminary studies . . . suggest that the characteristics of a 'good' site for early exploration might be (1) on a lunar sea, (2) 10 miles [16 kilometers] from a continent, and (3) 10 miles [16 kilometers] from a postmarial crater." This type of site, Hornbeck said, would permit the most scientific activity practicable, and would enable NASA's planners to design future missions for even greater scientific returns.

U.S. Congress, House, Subcommittee on Manned Space Flight of the Committee on Science and Astronautics, *1964 NASA Authorization*, Hearings on H.R. 5466 (Superseded by H.R. 7500), [No. 3] Part 2(a), 88th Cong., 1st Sess. (1963), p. 378.

March 21

MSC awarded the Philco Corporation a definitive contract (worth almost \$33.8 million) to provide flight information and flight control display equipment (with the exception of the realtime computer complex) for the Mission Control Center at MSC. NASA Headquarters approved the contract at the end of the month.

MSC, "Consolidated Monthly Activity Report for the Office of the Director, Manned Space Flight, February 24-March 23, 1963," p. 29; "Apollo Quarterly Status Report No. 3," p. 49; *Space Business Daily*, April 4, 1963, p. 432.

March 25

General Dynamics Convair completed structural assembly of the first launcher for the Little Joe II test program. During the next few weeks, electrical equipment installation, vehicle mating, and checkout were completed. The launcher was then disassembled and delivered to WSMR on April 25, 1963.

Little Joe II Test Launch Vehicle, NASA Project Apollo: Final Report, Vol. I, pp. 1-4 and 1-6.

March 25-31

North American analyzed lighting conditions in the CM and found that glossy or light-colored garments and pressure suits produced unsatisfactory reflections on glass surfaces. A series of tests were planned to define the allowable limits of reflection on windows and display panel faces to preclude interference with crew performance.

"Project Apollo Spacecraft Test Program, Weekly Activity Report (Period 25 March 1963 through 31 March 1963)," p. 5.

March 26

Hamilton Standard Division awarded a contract to ITT/Kellogg for the design and manufacture of a prototype extravehicular suit telemetry and communications system to be used with the portable life support system. (See November 27, 1962.)

Memorandum, Michael B. Luse, MSC, to Crew Systems Division, Attn: M. I. Radnofsky, "Extra-Vehicular Suit Telemetry and Communication System," March 11, 1964.

March 26

MSC announced the beginning of CM environmental control system tests at the AiResearch Manufacturing Company simulating prelaunch, ascent, orbital, and reentry pressure effects. Earlier in the month, analysis had indicated that the CM interior temperature could be maintained between 294 K (70 degrees F) and 300 K (80 degrees F) during all flight operations, although prelaunch temperatures might rise to a maximum of 302 K (84 degrees F).

"Apollo Monthly Progress Report," SID 62-300-11, p. 12; MSC News Release 63-61, March 26, 1963.

March 26-28

A meeting was held at North American to define CM-space suit interface problem areas. (See January 24.) Demonstrations of pressurized International Latex suits revealed poor crew mobility and task performance inside the CM, caused in part by the crew's unavoidably interfering with one another.

Other items received considerable attention: A six-foot umbilical hose would be adequate for the astronaut in the CM. The location of spacecraft water, oxygen, and electrical fittings was judged satisfactory, as were the new couch assist handholds. The astronaut's ability to operate the environmental control system (ECS) oxygen flow control valve while couched and pressurized was questionable. Therefore, it was decided that the ECS valve would remain open and that the astronaut would use the

suit control valve to regulate the flow. It was also found that the hand controller must be moved about nine inches forward.

Memorandum, J. F. Saunders, Jr., RASPO/NAA, to L. McMillion, MSC, "Data Transmittal," April 5, 1963, with enclosures: Agenda and Minutes of Meeting, "Command Module-Space Suit Interface Meeting No. 4, NAA, Downey - 26, 27, 28 March 1963."

March 27

The Apollo Mission Planning Panel (see February 27) set forth two firm requirements for the lunar landing mission. First, both LEM crewmen must be able to function on the lunar surface simultaneously. MSC contractors were directed to embody this requirement in the design and development of the Apollo spacecraft systems. Second, the panel established duration limits for lunar operations. These limits, based upon the 48-hour LEM operation requirement, were 24 hours on the lunar surface and 24 hours in flight on one extreme, and 45 surface hours and 3 flight hours on the other. Grumman was directed to design the LEM to perform throughout this range of mission profiles.

MSC, "Abstract of Meeting on Apollo Mission Planning Meeting No. 1, March 27, 1963," March 29, 1963; memorandum, Robert V. Battey, MSC, to Action Committee, "Errata to Abstract of Mission Planning Panel Meeting No. 1," April 1, 1963.

March 28

NASA launched Saturn SA-4 from Cape Canaveral. The S-I Saturn stage reached an altitude of 129 kilometers (80 statute miles) and a peak velocity of 5,906 kilometers (3,660 miles) per hour. This was the last of four successful tests for the first stage of the Saturn I vehicle. After 100 seconds of flight, No. 5 of the booster's eight engines was cut off by a preset timer. That engine's propellants were rerouted to the remaining seven, which continued to burn. This experiment confirmed the "engine-out" capability that MSFC engineers had designed into the Saturn I. (See February 20.)

Saturn Illustrated Chronology, pp. 76-77; *History of Marshall . . . January 1-June 30, 1963*, Vol. I, pp. 16-18.



During a visit to NAA during March 1963, Astronauts M. Scott Carpenter, John H. Glenn, Jr., and Walter M. Schirra, Jr., took time out to "try the spacecraft of for size." The spacecraft mockup was one of the items inspected as they toured the NAA spacecraft facilities at Downey, Calif.

During the Month

North American selected two subcontractors to build tankage for the SM: Allison Division of General Motors Corporation to fabricate the fuel and oxidizer tanks; and Airite Products, Inc., those for helium storage.

"Apollo Monthly Progress Report," SID 62-300-11, p. 3.

During the Month

RCA completed a study on ablative versus regenerative cooling for the thrust chamber of the LEM ascent engine. Because of low cooling margins available with regenerative cooling, Grumman selected the ablative method, which permitted the use of either ablation or radiation cooling for the nozzle extension. (See September 19-October 16.)

"Apollo Quarterly Status Report No. 3," p. 26; GAEC, "Monthly Progress Report No. 2," LPR-10-2, April 10, 1963, p. 12.

During the Month

Grumman met with representatives of North American, Collins Radio Company, and Motorola, Inc., to discuss common usage and preliminary design specifications for the LEM communications system. These discussions led to a simpler design for the S-band receiver and to modifications to the S-band transmitter (required because of North American's design approach).

"Monthly Progress Report No. 2," LPR-10-2, p. 15.

During the Month

MSC sent MIT and Grumman radar configuration requirements for the LEM. The descent equipment would be a three-beam doppler radar with a two-position antenna. Operating independently of the primary guidance and navigation system, it would determine altitude, rate of descent, and horizontal velocity from 7,000 meters (20,000 feet) above the lunar surface. The LEM rendezvous radar, a gimbaled antenna with a two-axis freedom of movement, and the rendezvous transponder mounted on the antenna would provide tracking data, thus aiding the LEM to intercept the orbiting CM. The SM would be equipped with an identical rendezvous radar and transponder.

"Apollo Quarterly Status Report No. 3," p. 23.

During the Quarter

MSC reported that preliminary plans for Apollo scientific instrumentation had been prepared with the cooperation of NASA Headquarters, Jet Propulsion Laboratory, and the Goddard Space Flight Center. The first experiments would not be selected until about December 1963, allowing scientists time to

prepare proposals. Prime consideration would be given to experiments that promised the maximum return for the least weight and complexity, and to those that were man-oriented and compatible with spacecraft restraints. Among those already suggested were seismic devices (active and passive), and instruments to measure the surface bearing strength, magnetic field, radiation spectrum, soil density, and gravitational field. MSC planned to procure most of this equipment through the scientific community and through other NASA and government organizations.

Ibid., p. 30.

During the Quarter

To provide a more physiologically acceptable load factor orientation during reentry and abort, MSC was considering revised angles for the crew couch in the CM. To reduce the couch's complexity, North American had proposed adjustments which included removable calf pads and a movable head pad. (See April 3.)

Ibid., p. 6.

During the Quarter

MSC reported that stowage of crew equipment, some of which would be used in both the CM and the LEM, had been worked out. Two portable life support systems and three pressure suits and thermal garments were to be stowed in the CM. Smaller equipment and consumables would be distributed between modules according to mission phase requirements.

Ibid., p. 22.

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Part 1 (C)

Defining Contractural Relations

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April 1

Grumman began "Lunar Hover and Landing Simulation IIIA," a series of tests simulating a LEM landing. Crew station configuration and instrument panel layout were representative of the actual vehicle.

Through this simulation, Grumman sought primarily to evaluate the astronauts' ability to perform the landing maneuver manually, using semiautomatic as well as degraded attitude control modes. Other items evaluated included the flight control system parameters, the attitude and thrust controller configurations, the pressure suit's constraint during landing maneuvers, the handling qualities and operation of LEM test article 9 as a freeflight vehicle, and manual abort initiation during the terminal landing maneuver.

GAEC, "Final Report: Lunar Landing Simulation IIIA," LED-770-4, April 1, 1964, p. 1.

April 2

The Soviet Union announced the successful launch of the *Lunik IV* probe toward the moon. The 1,412-kilogram (3,135-pound) spacecraft's mission was not immediately disclosed, but Western observers speculated that an instrumented soft landing was planned. On April 6, at 4:26 a.m. Moscow time, *Lunik IV* passed within 8,499 kilometers (5,281 miles) of the moon. The Soviet news agency, Tass, reported that data had been received from the spacecraft throughout its flight and that radio communication

would continue for a few more days.

The Washington Post, April 3 and 5, 1963; *The New York Times*, April 3, 1963; *The Sunday Star*, Washington, April 7, 1963.

April 3

Charles W. Frick resigned as ASPO Manager and Robert O. Piland was named Acting ASPO Manager.

MSC Announcement 178, "New Assignment of Personnel," April 3, 1963.

April 3

At a North American design review, NASA representatives expressed a preference for a fixed CM crew couch. This would have the advantages of simplified design, elimination of couch adjustments by the crew, and better placement of the astronauts to withstand reentry loads. NASA authorized North American to adopt the concept following a three-week study by the company to determine whether a favorable center of gravity could be achieved without a movable couch.

Use of the fixed couch required relocation of the main and side display panels and repositioning of the translational and rotational hand controllers. During rendezvous and docking operations, the crew would still have to adjust their normal body position for proper viewing.

"Apollo Monthly Progress Report," SID 62-300-12, p. 11; *ibid.*, SID 62-300-13, June 1, 1963, pp. 1, 7-8.

April 10

North American awarded a \$9.5 million letter contract to the Link Division of General Precision, Inc., for the development and installation of two spacecraft simulators, one at MSC and the other at the Launch Operations Center. Except for weightlessness, the trainers would simulate the entire lunar mission, including sound and lighting effects. (See December 8, 1962.)

"Apollo Quarterly Status Report No. 4," p. 40; "Apollo Monthly Progress Report," SID 62-300-12, p. 2; *Aviation Daily*, May 1, 1963, p. 1.

April 10

Wesley E. Messing, MSC WSMR Operations Manager, notified NASA, North American, and General Dynamics/Convair (GD/C) that Phase I of the range's launch complex was completed. GD/C and North American could now install equipment for the launch of boilerplate 6 and the Little Joe II vehicle.

TWX, Messing to MSC (Attn: W. C. Williams and R. O. Piland), NASA Hqs (Attn: G. M. Low), GD/G (Attn: J. B. Hurt), and NAA, S&ID (Attn: J. L. Pearce), April 10, 1963.

April 16-May 15

North American chose Simmonds Precision Products, Inc., to design and build an electronic measurement and display system to gauge the service propulsion system propellants. Both a primary and a backup system were required by the contract, which was expected to cost about 2 million.

"Apollo Monthly Progress Report," SID 62-300-13, p. 2; *Space Business Daily*, June 26, 1963, p. 824.

April 16-May 15

On the basis of wind tunnel tests and analytical studies, North American recommended a change in the planned test of the launch escape system (LES) using boilerplate 22. In an LES abort, the contractor reported, 18,300 meters (60,000 feet) was the maximum altitude at which high dynamic pressure had to be considered. Therefore North American proposed an abort simulation at that altitude, where maximum dynamic pressures were reached, at a speed of Mach 2.5.

The abort test would demonstrate two possibly critical areas:

1. Any destabilizing effect of large LES motor plumes on the CM
2. The ability of the CM's reaction control system to arrest CM rotation following tower jettison.

"Apollo Quarterly Status Report No. 4," pp. 28, 29; "Apollo Monthly Progress Report," SID 62-300-13, p. 5; MSC, "Postlaunch Report for Apollo Mission A-003" (BP-22) (June 28, 1965), p. 2-1; memorandum, J. D. Reed, MSC, to Distr., "Meeting on BP-22 Test Objectives and Trajectories, June 30, 1964," July 2, 1964.

April 16-May 15

North American simplified the CM water management system by separating it from the freon system. A 4.5-kilogram (10-pound) freon tank was installed in the left-hand equipment bay. Waste water formed during prelaunch and boost, previously ejected overboard, could now be used as an emergency coolant. The storage capacity of the potable water tank was reduced from 29 to 16 kilograms (64 to 36 pounds) and the tank was moved to the lower equipment bay to protect it from potential damage during landing. These and other minor changes caused a reduction in CM weight and an increase in the reliability of the CM's water management system.

"Apollo Quarterly Status Report No. 4," p. 7; "Apollo Monthly Progress Report," SID 62-300-13, p. 13.



Examining a one-eighth scale model of the LEM are, left to right, Congressman George P. Miller, Chairman of the House Committee on Science and Astronautics; Joseph M. Gavin, Grumman vice president; and Robert S. Mullaney, Grumman Apollo Program Manager.

April 17

At a mechanical systems meeting at MSC, customer and contractor achieved a preliminary configuration freeze for the LEM. After "considerable discussion," Grumman agreed to begin designing systems and subsystems based on this configuration, bearing in mind that certain unresolved areas (the docking system scanning telescope location and function, and the outcome of visibility studies) would have a substantial effect on the final configuration. Several features of the design of the two stages were agreed upon:

Descent

four cylindrical propellant tanks (two oxidizer and two fuel); four- legged deployable landing gear (see February)

Ascent

a cylindrical crew cabin (about 234 centimeters [92 inches] in diameter) and a cylindrical tunnel (pressurized) for equipment stowage; an external equipment bay.

GAEC, "Monthly Progress Report No. 3," LPR-10-6, May 10, 1963, pp. 3, 4, 7-8.

April 18

North American signed a 6 million definitive contract with Lockheed Propulsion Company for the development of solid propellant motors for the launch escape system. Work on the motors had begun on February 13, 1962, when Lockheed was selected.

"Apollo Facts," p. 38; *Space Business Daily*, June 27, 1963, p. 834.

April 25-26

At ASPO's request, Wayne E. Koons of the Flight Operations Division visited North American to discuss several features of spacecraft landing and recovery procedures. Koon's objective, in short, was to recommend a solution when ASPO and the contractor disagreed on specific points, and to suggest alternate courses when the two organizations agreed. A question had arisen about a recovery hoisting loop. Neither group wanted one, as its installation added weight and caused design changes. In another area, North American wanted to do an elaborate study of the flotation characteristics of the CM. Koons recommended to ASPO that a full-scale model of the CM be tested in an open-sea environment.

There were a number of other cases wherein North American and ASPO agreed on procedures which simply required formal statements of what would be done. Examples of these were:

- Spacecraft reaction control fuel would be dumped before landing (in both normal and abort operations)
- The "peripheral equipment bay" would be flooded within 10 minutes after landing
- Location aids would be dye markers and recovery antennas.

Memorandum, W. E. Koons, MSC, to Chief, Flight Operations Div., "Report of visit to NAA, S&ID, Downey, Calif., 25-26 April 1963," May 7, 1963.

April 30

The Apollo Spacecraft Mission Trajectory Sub-Panel discussed earth parking orbit requirements for the lunar mission. The maximum number of orbits was fixed by the S-IVB's 4.5-hour duration limit. Normally, translunar injection (TLI) would be made during the second orbit. The panel directed North American to investigate the trajectory that would result from injection from the third, or contingency, orbit. The contractor's study must reckon also with the effects of a contingency TLI upon the constraints of a free return trajectory and fixed lunar landing sites.

Minutes of Second Meeting of the Apollo Spacecraft Mission Trajectory Sub-Panel, April 30, 1963.

During the Month

NASA issued a technical note reporting that scientists at Ames Research Center Hypervelocity Ballistic Range, Moffett Field, Calif., were conducting experiments simulating the impact of micrometeoroids on the lunar surface. The experimenters examined the threat of surface debris, called secondary ejecta, that would be thrown from resultant craters. Data indicated that secondary particles capable of penetrating an astronaut's space suit nearly equaled the number of primary micrometeoroids. Thus the danger of micrometeoroid impact to astronauts on the moon may be almost double what was previously thought.

Donald E. Gault, Eugene M. Shoemaker, and Henry J. Moore, *Spray Ejected From the Lunar Surface by Meteoroid Impact*, NASA TN D-1767, April 1963, p. 1; *Aviation Week and Space Technology*, 78 (January 14, 1964), pp. 54-55, 57, 59.

During the Month

NASA and General Dynamics/Convair (GD/C) negotiated a second Little Joe II launch vehicle contract. (See February 18.) For an additional \$337,456, GD/C expanded its program to include the launch of a qualification test vehicle before the scheduled Apollo tests. This called for an accelerated production schedule for the four launch vehicles and their pair of launchers. An additional telemetry system and an instrumentation transmitter system were incorporated in the qualification test vehicle, which was equipped with a simulated payload. At the same time, NASA established earlier launch dates for the first two Apollo Little Joe II missions.

Little Joe II Test Launch Vehicle, NASA Project Apollo: Final Report, Vol. I, p. 4-3.

During the Month

Grumman reported to MSC the results of studies on common usage of communications. Television cameras for the two spacecraft would be identical (see May 2); the LEM transponder would be as similar as possible to that in the CSM.

"Monthly Progress Report No. 3," LPR-10-6, p. 21.

During the Month

Grumman recommended that the LEM reaction control system (RCS) be equipped with dual interconnected tanks, separately pressurized and employing positive expulsion bladders. The design would provide for an emergency supply of propellants from the main ascent propulsion tanks. The RCS oxidizer to fuel ratio would be changed from 2.0:1 to 1.6:1. MSC approved both of these changes.

Ibid., p. 20; "Apollo Quarterly Status Report No. 3," p. 20.

May 1

Grumman reported that it had advised North American's Rocketdyne Division to go ahead with the lunar excursion module descent engine development program. Negotiations were complete and the contract was being prepared for MSC's review and approval. The go-ahead was formally issued on May 2. (See January 30, February 13, and November 21.)

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, April 28-May 18, 1963," p. 32; "Apollo Quarterly Status Report No. 4," p. 21; GAEC, "Monthly Progress Report No. 4," LPR-10-7, June 10, 1963, p. 2.

May 2

NASA, North American, Grumman, and RCA representatives determined the alterations needed to make the CM television camera compatible with that in the LEM: an additional oscillator to provide synchronization, conversion of operating voltage from 115 AC to 28 DC, and reduction of the lines per frame from 400 to 320.

NAA, "Apollo Monthly Progress Report," SID 62-300-44, July 1, 1963, p. 9.

May 3

At El Centro, Calif., Northrop Ventura conducted the first of a series of qualification tests for the Apollo earth landing system (ELS). The test article, CM boilerplate 3, was dropped from a specially modified Air Force C-133. The test was entirely successful. The ELS's three main parachutes reduced the spacecraft's rate of descent to about 9.1 meters (30 feet) per second at impact, within acceptable limits.

MSC News Release 63-85, May 3, 1963; "Apollo Monthly Progress Report," SID 62-300-13, p.10.



A NASA team inspected progress on Little Joe II in San Diego, Calif., May 6, 1963. Left to right, Walter C. Williams, MSC Deputy Director; Acting Apollo Project Manager Robert O. Piland; Convair Little Joe II Program Manager J. B. Hurt; and James C. Elms, MSC Deputy Director.

May 6

NASA authorized North American to procure carbon dioxide sensors as part of the environmental control system instrumentation on early spacecraft flights. (See March 5.)

Letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. Forty-Three," May 6, 1963.

May 6

Astronauts M. Scott Carpenter, Walter M. Schirra, Jr., Neil A. Armstrong, James A. McDivitt, Elliot M. See, Jr., Edward H. White II, Charles Conrad, Jr., and John W. Young participated in a study in LTV's Manned Space Flight Simulator at Dallas, Tex. Under an MSC contract, LTV was studying the astronauts' ability to control the LEM manually and to rendezvous with the CM if the primary guidance system failed during descent. (See September and October 10, 1963, and April 24, 1964.)

MSC News Release 63-81, May 6, 1963.

May 7

MSC announced a reorganization of ASPO:

Acting Manager:

Robert O. Piland

Deputy Manager, Spacecraft:

Robert O. Piland

Assistant Deputy Manager for CSM:

Caldwell C. Johnson

Deputy Manager for System Integration:

Alfred D. Mardel

Deputy Manager LEM:

James L. Decker

Manager, Spacecraft Systems Office:

David W. Gilbert

Manager, Project Integration Office:

J. Thomas Markley

MSC Announcement No. 193, "Reorganization of the Apollo Spacecraft Project Office," May 7, 1963.

May 10

The first meeting of the LEM Flight Technology Systems Panel was held at MSC. The panel was formed to coordinate discussions on all problems involving weight control, engineering simulation, and environment. The meeting was devoted to a review of the status of LEM engineering programs.

Memorandum, Gerald L. Hunt, MSC, to Chief, Flight Operations Div., "LEM Flight Technology System Meeting No. 1," May 20, 1963, with enclosures.

May 10

MSC Director Robert R. Gilruth announced a division of management responsibilities between operations and development within MSC. Walter C. Williams, Deputy Director for Mission Requirements and Flight Operations, would develop mission plans and rules, crew training, ground support and mission control complexes, and would manage all MSC flight operations. At the same time, he would serve as Director of Flight Operations in the NASA Headquarters OMSF with complete mission authority during flight tests of Mercury, Gemini, and Apollo. James C. Elms, Deputy Director for Development and Programs, would manage all MSC manned space flight projects and would plan, organize, and direct MSC administrative and technical support.

MSC News Release 63-88, May 10, 1963.

May 10

NASA Associate Administrator Robert C. Seamans, Jr., directed that a Communications and Tracking Steering Panel and a Working Group be organized. They would develop specifications, performance requirements, and implementation plans for the Manned Space Flight Network in support of the Apollo flight missions.

Memorandum, Robert C. Seamans, Jr., NASA, to Director, Office of Manned Space Flight, et al., "Functional organization to develop specifications, performance requirements and implementation plans for the Manned Space Flight Network," May 10, 1963.

Early in the Month

Grumman selected Space Technology Laboratories (STL) to develop and fabricate a mechanically throttled descent engine for the LEM, paralleling Rocketdyne's effort. (See February 27 and March 14.) Following NASA and MSC concurrence, Grumman began negotiations with STL on June 1.

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, April 28-May 18, 1963," p. 32; "Monthly Progress Report No. 4," LPR-10-7, p. 44; "Activity Report, Apollo Spacecraft Project Office, May 16-June 13, 1963," p. 8.

May 14

Grumman submitted to NASA a Quality Control Program Plan for the LEM, detailing efforts in management, documentation, training, procurement, and fabrication.

GAEC, "Report No. 1, Grumman Monthly Quality Status Report for Lunar Excursion Module," LPR-50-1, February 14, 1964.

May 15

Grumman, reporting on the Lunar Landing Research Vehicle's (LLRV) application to the LEM development program, stated the LLRV could be used profitably to test LEM hardware. Also included was a development schedule indicating the availability of LEM equipment and the desired testing period.

"Monthly Progress Report No. 4," LPR-10-7, p. 39.

May 15-16

Faith 7, piloted by Astronaut L. Gordon Cooper, Jr., was launched from Cape Canaveral. An Atlas rocket boosted the Mercury spacecraft into a 161.3 by 267 kilometer (100.2 by 165.9 statute mile) orbit. After 22 orbits, Cooper manually fired the retrorockets and the spacecraft reentered the atmosphere, landing safely in the Pacific Ocean 34 hours, 19 minutes, and 49 seconds after liftoff. Astronaut Cooper was reported in good condition. Cooper's one-day flight turned out to be the final Mercury flight. (See June 12.)

James M. Grimwood, *Project Mercury: A Chronology* (NASA SP-4001, 1963), pp. 191-193.

May 20

In support of NASA's manned space flight programs, Ames Research Center awarded a \$150,000 contract to Westinghouse Electric Corporation for a one-year study of potential physiological damage in space caused by cosmic radiation.

NASA News Release 63-107, "NASA Awards Contract for Study of Space Radiation," May 20, 1963.

May 20-22

At a meeting on mechanical systems at MSC, Grumman presented a status report on the LEM landing gear design and LEM stowage height. (See February and April 17.) On May 9, NASA had directed the contractor to consider a more favorable lunar surface than that described in the original Statement of Work. Accordingly, Grumman recommended an envelope of LEM S-IVB clearance of 152.4 centimeters (40 inches) for a landing gear radius of 457 centimeters (180 inches). Beyond this radius, a

different gear scheme was considered more suitable but would require greater clearances. The landing gear envelope study was extended for one month to establish a stowed height of the LEM above the S-IVB for adapter design. (See June 3 and October 2.)

"Monthly Progress Report No. 4," LPR-10-7, p. 13.

May 22

Grumman representatives met with the ASPO Electrical Systems Panel (ESP). From ESP, the contractor learned that the communications link would handle voice only. Transmission of physiological and space suit data from the LEM to the CM was no longer required. VHF reception of this data and S-band transmission to ground stations was still necessary. In addition, Grumman was asked to study the feasibility of a backup voice transmitter for communications with crewmen on the lunar surface should the main VHF transmitter fail.

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, May 19-June 15, 1963," pp. 54-55; "Monthly Progress Report No. 4," LPR-10-7, p. 21.

May 23

NASA Headquarters, MSC, Jet Propulsion Laboratory, MSFC, North American, and Grumman agreed that the LEM and CSM would incorporate phase-coherent S-band transponders. [The S-band system provides a variety of communications services. Being phase-coherent meant that it could also provide Mission Control Center with information about the vehicle's velocity and position, and thus was a means of tracking the spacecraft.] Each would have its own allocated frequencies and would be compatible with Deep Space Instrumentation Facilities.

"Apollo Quarterly Status Report No. 4," p.22; "Monthly Progress Report No. 4," LPR-10-7, p. 21; MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, May 19-June 15, 1963," p. 62; interview, telephone, Alfred B. Eickmeier, MSC, March 5, 1970.

May 23

MIT suggested a major redesign of the Apollo guidance computer to make the CM and LEM computers as similar as possible. NASA approved the redesign and the Raytheon Company, subcontractor for the computer, began work.

Raytheon Company, Space and Information Systems Div., "Quarterly Technical Report No. 4," FR-3-87, April 1-June 30, 1963.

May 23-24

Meeting in Bethpage, N. Y., officials from MSC, Grumman, Hamilton Standard, International Latex, and North American examined LEM-space suit interface problems. This session resulted in several significant decisions:

- Suit evaluation would include a vehicle mockup in an aircraft flying zero and one-sixth g trajectories.
- The suit assembly emergency oxygen supply would serve also as the backup pressurization and oxygen supply during crew transfer from the CM to the LEM.
- The four-hour operating requirement for the portable life support system (PLSS) should not be considered for normal operation.
- Pending final design of a waste management system, Grumman would retain provisions for stowage of human wastes.
- The thermal garment would not normally be worn inside the LEM.
- The PLSS battery would be charged before earth launch.
- Prototype Apollo space suits were to be delivered to Grumman as soon as possible for evaluation and vehicle design.

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, May 19-June 15, 1963," pp. 59-60.

May 24

North American demonstrated problems with side-arm controller location and armrest design inside the CM. Major difficulties were found when the subject tried to manipulate controls while wearing a pressurized suit. North American had scheduled further study of these design problems.

"Project Apollo Spacecraft Test Program, Weekly Activity Report (Period 27 May 1963 through 2 June 1963)," p. 5.

May 28

MSC Director Robert R. Gilruth reported to the MSF Management Council that the lunar landing mission duration profiles, on which North American would base the reliability design objectives for mission success and crew safety and which assumed a 14-day mission, had been documented and approved. The contractor had also been asked to study two other mission profile extremes, a 14-day mission with 110-hour transearth and translunar transfer times and the fastest practicable lunar landing mission.

MSF Management Council Meeting, May 28, 1963, Agenda Item 2, "Technical Highlights," p. 4.

May 29

Grumman presented its LEM engineering and simulation plans to MSC, stating that their existing facilities and contracted facilities at North American in Columbus, Ohio, and at LTV would be used throughout 1963. Two part-task LEM simulators would be operational at Grumman early in 1964, with a complete mission simulator available in 1965. MSC had approved the contractor's procurement of two visual display systems for use in the simulators.

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, May 19-June 15, 1963," pp. 62, 63; GAEC, "Monthly Progress Report No. 6," LPR-10-16, August 10, 1963, p. 5.

May 29

The Operational Evaluation and Test Branch of MSC's Flight Operations Division considered three methods of providing a recovery hoisting loop on the CM: loop separate from the spacecraft and attached after landing, use of the existing parachute bridle, and loop installed as part of the CM equipment similar to Mercury and Gemini. Studies showed that the third method was preferable. (See April 25-26.)

Memorandum, Christopher C. Kraft, Jr., MSC, to Mgr., ASPO, "Command module recovery hoisting loop," May 29, 1963.

May 30

Rocketdyne reported to Grumman on the LEM descent stage engine development program. Revised measurements for the engine were: diameter, 137 centimeters (54 inches); length, 221 centimeters (87 inches) (30.5 centimeters [twelve inches] more than the original constraint that Grumman had imposed on Rocketdyne).

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, May 19-June 15, 1963," p. 61; "Apollo Quarterly Status Report No. 4," p. 21.

During the Month

In its first estimates of reliability for the LEM, Grumman reported a 0.90 probability for mission success and 0.994 for crew safety. (The probabilities required by NASA were 0.984 and 0.9995, respectively.)

"Monthly Progress Report No. 4," LPR-10-7, p. 26.

During the Month

After a detailed comparison of titanium and aluminum propellant tanks for the LEM descent stage, Grumman selected the lighter titanium.

Ibid., p. 7.

During the Month

Grumman studied the possibility of using the portable life support system lithium hydroxide cartridges in the LEM environmental control system, and determined that such common usage was feasible. This analysis would be verified by tests at Hamilton Standard.

Ibid., p. 12.

During the Month

Grumman completed the LEM M-1 mockup and began installing equipment in the vehicle. Also, the contractor began revising cabin front design to permit comparisons of visibility. (See September 16-18.)

Ibid., p. 8.

During the Month

NASA and General Dynamics Convair negotiated a major change on the Little Joe II launch vehicle contract. (See February 18.) It provided for two additional launch vehicles which would incorporate the attitude control subsystem (as opposed to the early fixed-fin version). On November 1, MSC announced that the contract amendment was being issued. NASA Headquarters' approval followed a week later.

Little Joe II Test Launch Vehicle, NASA Project Apollo: Final Report, Vol. I, p. 4-3; MSC News Release 63-223, November 1, 1963; MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, October 20-November 16, 1963," p. 57.

June 3

MSC informed MSFC that the length of the spacecraft-Saturn V adapter had been increased from 807.7 centimeters to 889 centimeters (318 inches to 350 inches). The LEM would be supported in the adapter from a fixed structure on the landing gear. (See October 2.)

"Apollo Quarterly Status Report No. 4," p. 16.

June 3

North American announced that it had selected ITT's Industrial Products Division to provide battery chargers for the CSM, designed for an operational lifetime of 40,000 hours.

Space Business Daily, June 4, 1963, p. 712.

June 4

The \$889.3 million definitive Apollo contract with North American was delivered to NASA Headquarters for review and approval. The target date for approval was extended to June 30. (See August 14.)

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, May 19-June 15, 1963," p. 33.

June 5

NASA announced that it would select 10 to 15 new astronauts to begin training in October. Civilian applications were due July 1; those from military personnel, prescreened by their services, were due July 15. New selection criteria reduced the maximum age to 35 years and eliminated the requirement for test pilot certifications.

NASA News Release 63-122, "NASA to Select New Astronauts," June 5, 1963.

June 6

The Operational Evaluation and Test Branch of MSC's Flight Operations Division made the following recommendations on Apollo postlanding water survival equipment:

- Development should continue on a three-man life raft for the Apollo mission.
- A 12-hour-duration dye marker packet should be passively deployed on impact. An additional 18 hours of dye marker should be stored in the survival kit.
- Two radio beacons of the type being developed for Gemini should be included in the survival kit.
- Water egress safety features in the Mercury and Gemini space suits should be included in the Apollo space suit.
- All Apollo equipment which might be involved in water egress, survival, and recovery situations should be configured for water landings.

Memorandum, Christopher C. Kraft, Jr., MSC, to Mgr., ASPO, "Apollo postlanding water survival equipment," June 6, 1963.

June 10

North American completed a backup testing program (authorized by MSC on November 20, 1962) on a number of ablative materials for the CM heatshield. Only one of the materials (Avcoat 5026-39) performed satisfactorily at low temperatures. During a meeting on June 18 at MSC, company

representatives discussed the status of the backup heatshield program. This was followed by an Avco Corporation presentation on the primary heatshield development. As a result, MSC directed North American to terminate its backup program. Shortly thereafter, MSC approved the use of an airgun to fill the honeycomb core of the heatshield with ablative material.

"Apollo Quarterly Status Report No. 4," p. 15; MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, June 16-July 20, 1963," p. 69; MSC, "Weekly Activity Report for the Office of the Director, Manned Space Flight, June 16-22, 1963," p. 8.

June 10

NASA issued a \$1,946,450 definitive contract to Aerojet-General Corporation for Algol solid-propellant motors for GD/C's Little Joe II vehicles.

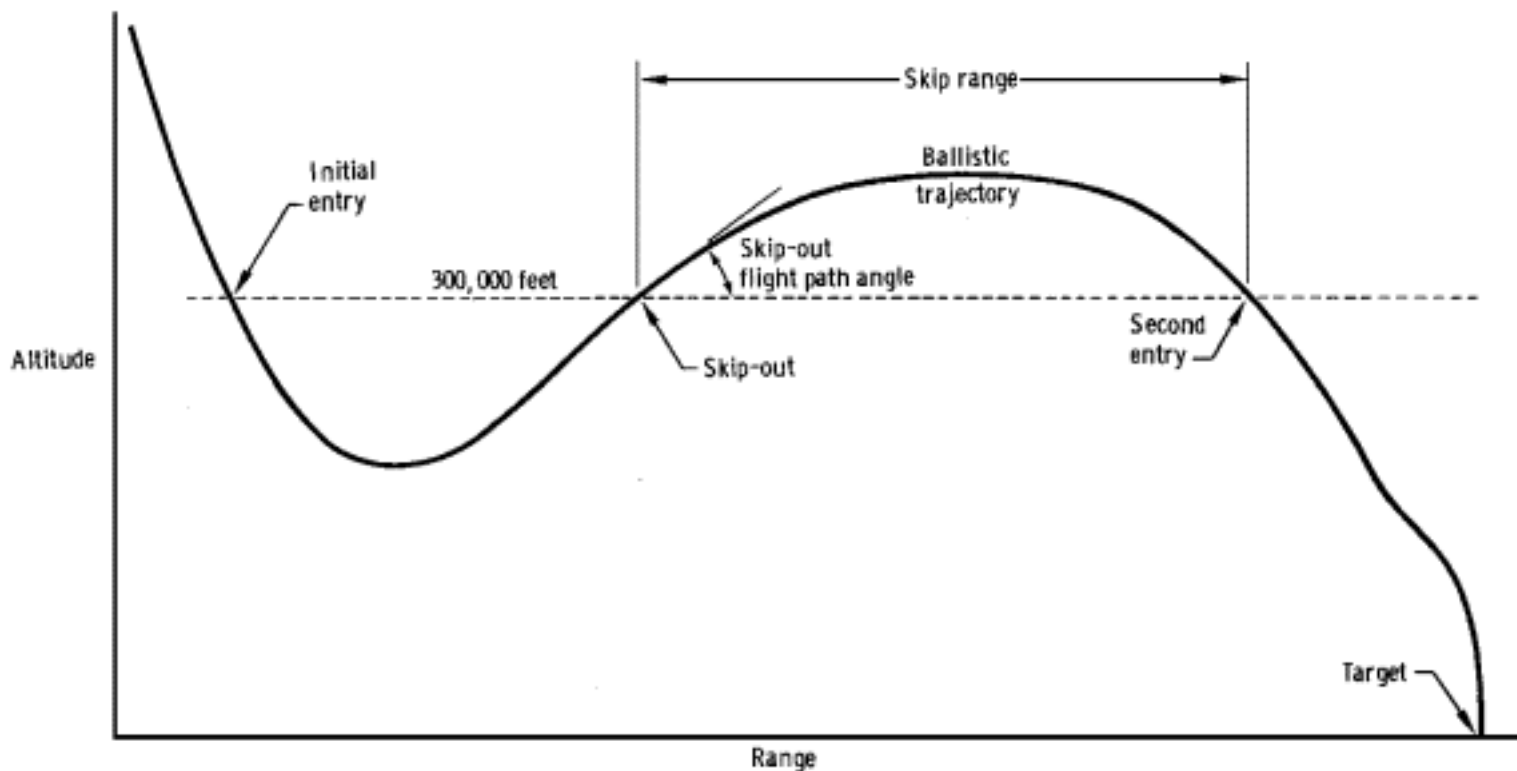
MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, May 19-June 15, 1963," p. 33.

June 10

Christopher C. Kraft, Jr., of the MSC Flight Operations Division, urged that an up-data link (UDL) (see January 17) be included on the LEM. In general, the UDL would function when a great deal of data had to be transmitted during a time-critical phase. It would also permit utilization of the ground operational support system as a relay station for the transmission of data between the CM and LEM. In case of power failure aboard the LEM, the UDL could start the computer faster and more reliably than a manual voice link, and it could be used to resume synchronization in the computer timing system.

Memorandum, Christopher C. Kraft, Jr., MSC, to Mgr., ASPO, "Up-Digital-Link to the Lunar Excursion Module," June 10, 1963.

June 12



A sketch prepared by John Gurley demonstrates the spacecraft's skip when entering the earth's atmosphere.

The Mission Analysis Branch (MAB) of MSC's Flight Operations Division studied the phenomenon of a spacecraft's "skip" when reentering the earth's atmosphere from lunar trajectories and how that skip relates to landing accuracies. When an Apollo CM encounters the earth's atmosphere (this study used 91,440 meters [300,000 feet] as the practical altitude), the vehicle bounces or "skips" back above the atmosphere. From this point, the spacecraft follows a ballistic trajectory until it re-encounters the atmosphere. During this skip portion of reentry, there is no control of the vehicle's flight trajectory. The length of this skip is, therefore, determined by the angle and speed at the start of this ballistic trajectory. The distance of the skip in turn determines the spacecraft's landing area. Variations in both speed and angle at the start of the skip thus are directly related to landing accuracy, but the effect of these variations is felt much more in shallow than in steep trajectories. In light of these factors, MAB recommended that, for Apollo flights, the skip phase of reentry be made at the steepest practicable angle consistent with maximum allowable acceleration forces.

Memorandum, John R. Gurley, MSC, to Chief, Flight Operations Div., "A Study of Skip Range Sensitivities and Allowable Errors in Exit Conditions Applicable to the Apollo Missions," June 12, 1963.

June 12

NASA Administrator James E. Webb, testifying before the Senate space committee, said that NASA did

not plan any further Mercury flights. Project Mercury, America's first manned space flight program, thus was ended.

Lloyd S. Swenson, Jr., James M. Grimwood, and Charles C. Alexander, *This New Ocean: A History of Project Mercury* (NASA SP-4201, 1966), p. 503.

June 12

D. Brainerd-Holmes announced his resignation as NASA's Deputy Associate Administrator and Director of Manned Space Flight, effective sometime in the fall. He had joined NASA in 1961 and was returning to industry.

NASA News Release 63-133, "Holmes Returns to Industry as Mercury Concludes," June 12, 1963.

June 14

NASA Headquarters approved a definitive contract for \$35,844,550 with AC Spark Plug for the manufacture and testing of navigation and guidance equipment for the CM. This superseded a letter contract of May 30, 1962.

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, May 19-June 15, 1963," p. 33; NASA News Release 63-136, "Contract Signed with AC Spark Plug for Apollo Guidance System," June 14, 1963; AC Spark Plug, "Apollo Guidance and Navigation System Participating Contractor Quarterly Technical Progress Report," January 1963, p. 2-1.

June 14

MSC conducted the final inspection of the Little Joe II launch complex at WSMR.

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, May 19-June 15, 1963," p. 31.

June 14-15

At its plant in Binghamton, N. Y., Link Division of General Precision, Inc., held a mockup review of the Apollo mission simulator. A number of modifications in the instructor's console were suggested.

"Apollo Quarterly Status Report No. 4," p. 40.

June 14-19

The Soviet Union launched *Vostok V*, piloted by Lt. Col. Valery F. Bykovsky. Two days later Lt. Valentina V. Tereshkova, the first spacewoman, followed in *Vostok VI*. Purposes of the dual mission were to study the medical-biological effects of prolonged space flight upon humans and to perfect spacecraft systems. On its first orbit, *Vostok VI* came within about three miles of *Vostok V*, apparently the closest distance achieved during the flight, and established radio contact. Both cosmonauts landed safely on June 19. The space spectacular featured television coverage of Bykovsky that was viewed in the West as well as in Russia.

U.S. Congress, Senate, Committee on Aeronautical and Space Sciences, *Soviet Space Programs, 1962-1965; Goals and Purposes, Achievements, Plans, and International Implications*, Staff Report, 89th Cong., 2nd Sess. (December 30, 1966), pp. 180-181.

June 16-July 20

MSC and Grumman assessed crew visibility requirements for the LEM. The study included a series of helicopter flights in which simulated earthshine lighting conditions and LEM window configurations were combined with helicopter landings along representative LEM trajectories. These flights simulated the LEM's attitude, velocity, range, and dive angle in the final approach trajectory.

"Apollo Quarterly Status Report No. 4," p. 18; MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, June 16-July 20, 1963," p. 27.

June 16-July 20

MSC reported that crew systems engineers at the Center were assessing feasibility of having the LEM crew stand rather than sit. MSC requested Grumman also to look into having the crew fly the vehicle from a standing position. The concept was formally proposed at the August 27 crew systems meeting and was approved at the NASA-Grumman review of the LEM M-1 mockup on September 16-18.

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, June 16-July 20, 1963," p. 77; "Monthly Progress Report No. 6," LPR-10-16, p. 12; MSC, "Apollo Spacecraft Project Office Activity Report, June 14-July 18, 1963," p. [15].

June 20

North American signed (and NASA approved) a definitive contract with Allison Division of General Motors for the service propulsion system propellant tanks.

MSC, "Weekly Activity Report for the Office of the Director, Manned Space Flight, June 23-29, 1963," p. 6.

June 21-27

MSC met with those contractors participating in the development of the LEM guidance and navigation system. (See October 18.) Statements of Work for the LEM design concept were agreed upon. (Technical directives covering most of the work had been received earlier by the contractors.)

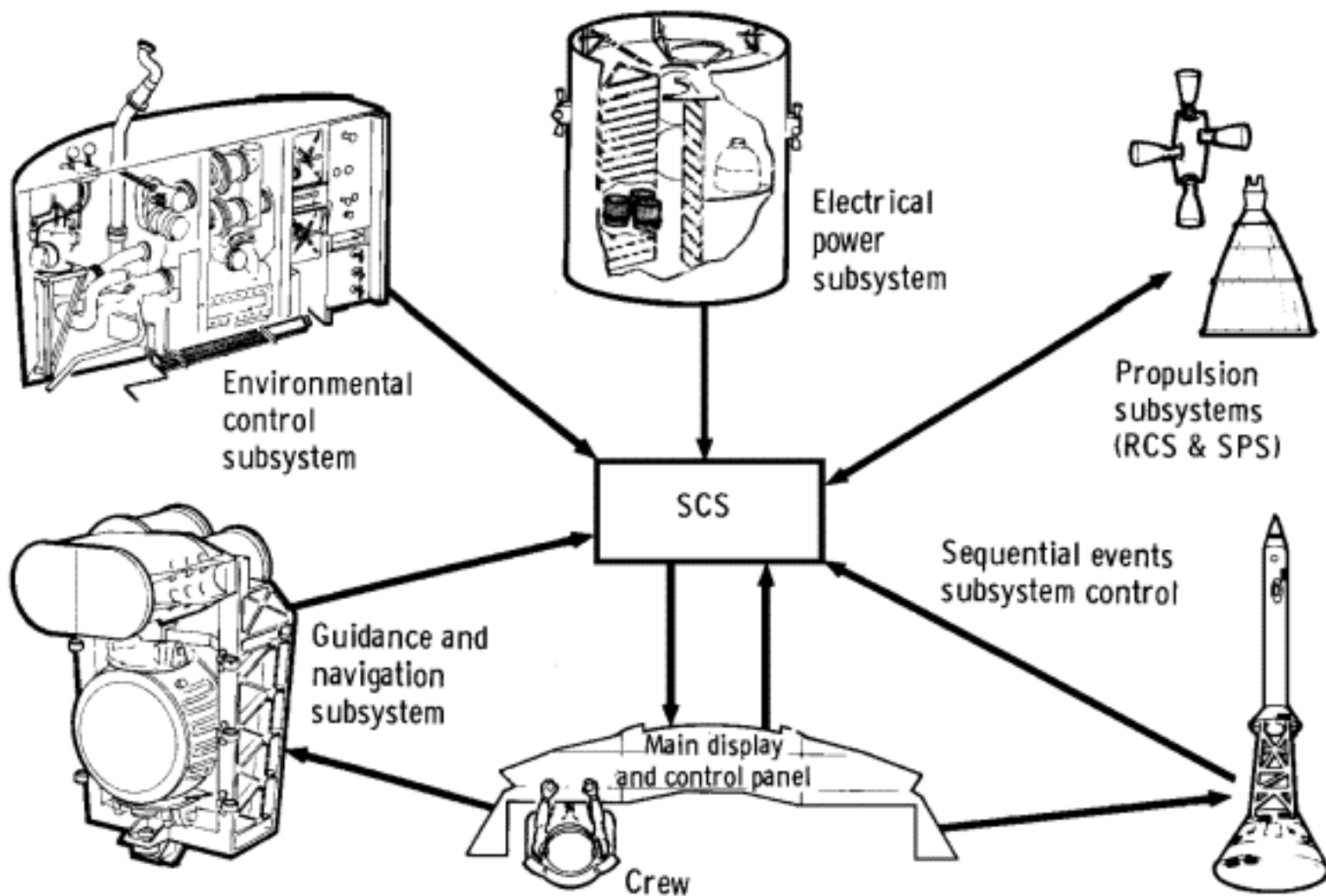
MSC, "Activity Report, Apollo Spacecraft Project Office, For Period June 21-27, 1963,"

June 21-27

North American awarded a contract, valued at \$2.8 million, to Avien, Inc., to develop the steerable S-band antenna for the CSM. (See June 11-18, 1964.)

Ibid.; *Space Business Daily*, July 18, 1963, p. 95.

June 22



Relationship of SCS to other Apollo subsystems. (NAA drawing)

North American officially froze the design of the CM's stabilization and control system.

"Abstract of Proceedings, Command Module Stabilization and Control Systems Meeting No. 16," June 27, 1963, p. 1; MSC, "Activity Report, Apollo Spacecraft Project Office, For Period June 21-27, 1963," p. 2.

June 25

MSC Director Robert R. Gilruth reported to the MSF Management Council that the LEM landing gear design freeze was now scheduled for August 31. Grumman had originally proposed a LEM configuration with five fixed legs, but LEM changes had made this concept impractical. (See February and April 17.) The weight and overall height of the LEM had increased, the center of gravity had been moved upward, the LEM stability analysis had expanded to cover a wider range of landing conditions, the cruciform descent stage had been selected, and the interpretation of the lunar model had been revised. These changes necessitated a larger gear diameter than at first proposed. This, in turn, required deployable rather than fixed legs so the larger gear could be stored in the Saturn V adapter. MSC had therefore adopted a four-legged deployable gear, which was lighter and more reliable than the five-legged configuration. (See October 2.)

"Lunar Excursion Module Design Status" (undated), prepared for Gilruth's presentation at the June 25, 1963, meeting of the MSF Management Council, held at the Manned Spacecraft Center.

June 26

The first full-scale firing of the SM engine was conducted at the Arnold Engineering Development Center. At the start of the shutdown sequence, the engine thrust chamber valve remained open because of an electrical wiring error in the test facility. Consequently the engine ran at a reduced chamber pressure while the propellant in the fuel line was exhausted. During this shutdown transient, the engine's nozzle extension collapsed as a result of excessive pressure differential across the nozzle skin.

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, June 16-July 20, 1963," p. 68.

June 26

MSC announced that it had contracted with the Martin Company to develop a frictionless platform to simulate the reactions of an extravehicular astronaut in five degrees of freedom-pitch, yaw, roll, forward-backward, and side-to-side. MSC Crew Systems Division would use the simulator to test and evaluate space suits, stabilization devices, tethering lines, and tools.

MSC News Release 63-108, June 26, 1963.

June 28

A cluster of two Pioneer tri-conical solid parachutes was tested; both parachutes failed. Because of this unsatisfactory performance, the Pioneer solid-parachute program was officially canceled on July 15. (See March 4.)

Letter, C. D. Sword, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. Twenty-Seven, Revision 1," July 15, 1963; "Apollo Spacecraft Project Office Activity Report, June 14-July 18, 1963," p. [5].

June 28

NASA announced its concurrence in Grumman's selection of RCA as subcontractor for the LEM electronics subsystems and for engineering support. Under the \$40 million contract, RCA was responsible for five LEM subsystem areas: systems engineering support, communications, radar, inflight testing, and ground support. RCA would also fabricate electronic components of the LEM stabilization and control system. [Engineers and scientists from RCA had been working at Grumman on specific projects since February.]

NASA News Release 63-143, "RCA Subcontractor to Grumman for LEM," June 28, 1963; "Monthly Progress Report No. 1," LPR-10-1, p. 2.

June 28

The CSM data storage equipment was modified to incorporate a fast-dump capability. Data could thus be recorded at a low speed for later playback at high speed to ground stations.

Letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. Fifty-Nine," June 28, 1963.

During the Month

North American reported that mission success predictions continued to be less than the apportioned values. For example, the environmental control subsystem had a predicted mission reliability of 0.9805, compared to a 0.997675 apportionment.

"Apollo Quarterly Status Report No. 4," pp. 32, 33.

During the Month

Planning and final details of LTV abort simulation negotiations with Grumman were completed. The abort experiments, to be conducted at LTV's aerospace simulation facility in Dallas, Tex., were scheduled to begin in October. (See April 24, 1964.)

GAEC, "Monthly Progress Report No. 5," LPR-10-11, July 10, 1963, p. 19.

During the Month

MSC reported that two portable life support systems would be stowed in the LEM and one in the CM. Resupplying water, oxygen, and lithium hydroxide could be done in a matter of minutes; however, battery recharging took considerably longer, and detailed design of a charger was continuing.

"Apollo Quarterly Status Report No. 4," pp. 24, 25.

During the Month

Grumman completed the LEM circuit design for suit and cabin pressure control systems. Also the contractor formulated a detailed plan for the evaluation of red and white cockpit lighting; equipment for the test had already been received.

"Monthly Progress Report No. 5," LPR-10-11, pp. 13, 20.

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Part 1 (D)

Defining Contractural Relations

July 1963 through August 20, 1963

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July 1-2

North American shipped Apollo CM boilerplate 6 and its ground support equipment to WSMR. (See November 7.)

"Apollo Quarterly Status Report No, 4," pp. 35, 36; MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, June 16-July 20, 1963," p. 35.

July 3

Space Technology Laboratories received Grumman's go-ahead to develop the parallel descent engine for the LEM. (See February 27, March 14, and early May.) At the same time, Grumman ordered Bell Aerosystems Company to proceed with the LEM ascent engine. The contracts were estimated at \$18,742,820 and \$11,205,415, respectively.

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, June 16-July 20, 1963," p. 37; "Monthly Progress Report No. 6," LPR-10-16, p. 50.

July 9-10

North American held a review of the CM main display console, which would be compatible with the fixed couch and new panel location. The contractor's drawings and comments by the astronauts were then reviewed by MSC.

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, June 16-July

20, 1963," p. 71.

July 10

As proposed by Joseph F. Shea, Deputy Director (Systems), OMSF, about six weeks earlier, the MSF Management Council established the Panel Review Board with broad supervisory and appeal powers over inter-Center panels. (See Volume I, November 8, 1961.) Board members were the Deputy Director (Systems), OMSF, and technical experts from MSC, MSFC, and the Launch Operations Center. OMSF's representative was the chairman.

Recommendations of the board were not binding. If a Center Director decided against a board recommendation, he would, however, discuss and clear the proposed action with the Director of OMSF.

When the Panel Review Board assumed its duties, the Space Vehicle Review Board was abolished. (See Volume I, October 3, 1961.)

Memorandum, D. Brainerd Holmes, NASA, to Distr., "Panel Review Board," July 10, 1963; MSF Management Council Minutes, May 28, 1963, pp. 3-4.

July 10

The Marquardt Corporation began testing the prototype engine for the SM reaction control system. Preliminary data showed a specific impulse slightly less than 300 seconds.

NAA, "Project Apollo Spacecraft Test Program, Weekly Activity Report (Period 8 July 1963 through 14 July 1963)," p. 2.

July 10

North American reported that it had tried several types of restraint systems for the sleeping area in the equipment bay area of the CM. A "net" arrangement worked fairly well and was adaptable to the constant wear garment worn by the crew. However, North American believed that a simpler restraint system was needed, and was pursuing several other concepts.

Ibid., p, 4.

July 10

Aero Spacelines' "Pregnant Guppy," a modified Boeing Stratocruiser, won airworthiness certification by the Federal Aviation Agency. The aircraft would be used to transport major Apollo spacecraft and launch vehicle components.

Saturn Illustrated Chronology, p. 82; *Orlando Sentinel*, July 12, 1963.

July 12

MSC signed a definitive contract, valued at \$36.2 million, with International Business Machines (IBM) for the realtime computer complex in the MSC Mission Control Center. IBM was responsible for the design of the computer center, mission and mathematical analyses, programming equipment engineering, computer and program testing, maintenance and operation, and documentation. The complex, consisting of four IBM 7094 computers with their associated equipment, would monitor and analyze data from Gemini and Apollo missions.

NASA News Release 63-151, "Contract Signed with IBM for Computer Equipment," July 12, 1963; *Space Business Daily*, July 15, 1963, p. 74.

July 15

MSC had received 271 applications for the astronaut program. (See June 5.) Seventy-one were military pilots (one from the Army, 34 from the Navy, 26 from the Air Force, and 10 from the Marines). Of the 200 civilians applying, three were women. (See October 18.)

Astronautics and Aeronautics, 1963 (NASA SP-4004), p. 273; *The Houston Post*, July 17, 1963.

July 15-16

The Little Joe II qualification test vehicle was shipped from the General Dynamics Convair plant to WSMR, where the test launch was scheduled for August. (See August 28.)

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, June 16-July 20, 1963," p. 35; *Little Joe II Test Launch Vehicle, NASA Project Apollo: Final Report*, Vol. I, p. 1-6; TWX, NASA Resident Office, WSMR, to MSC, "Activity Report for MSC-WSMR Office for June 16 through July 20," July 23, 1963.

July 16

MSC directed North American to concentrate on the extendable boom concept for CSM docking with the LEM. The original impact type of docking had been modified:

1. The primary mode employed an extendable probe. It would establish initial contact and docking at a separation distance sufficient to prevent dangerous impact as a result of pilot error.
2. The backup mode consisted of free-flying the two modules together. Mean relative impact velocities established during free-flying docking simulation studies would be used as the design

impact velocities.

North American and Grumman began a hardware testing and flight simulation program in late September to evaluate the feasibility of several types of extendable probe tether systems. The two companies were to determine the stiffness required of the docking structure for compatibility with the stabilization and control system. (See November 19-20.)

"Apollo Monthly Progress Report," SID 62-300-16, pp. 3, 9; MSC, "Weekly Activity Report for the Office of the Director, Manned Space Flight, July 28-August 3, 1963," p. 2; "Monthly Progress Report No. 6," LPR-10-16, p. 3.

July 16

Grumman presented the results of a study on LEM visibility. A front-face configuration with triangular windows was tentatively accepted by MSC for the ascent stage. Further investigation would be directed toward eliminating the "dead spots" to improve the configuration's visibility.

"Monthly Progress Report No. 6," LPR-10-16, p. 3.

July 16-August 15

North American reported that Lockheed Propulsion Company had successfully completed development testing of the launch escape system pitch control motor. (See December 28, 1962.)

"Apollo Monthly Progress Report," SID 62-300-16, p. 18.

July 18

MSC authorized North American to fit the launch escape system with a redundant tower separation device. This equipment incorporated an explosive bolt and shaped charge cutter.

Letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. Sixty-Two," July 18, 1963.

July 18

Grumman selected Pratt and Whitney to develop fuel cells for the LEM. Current LEM design called for three cells, supplemented by a battery for power during peak consumption beyond what the cells could deliver. Grumman and Pratt and Whitney completed contract negotiations on August 27, and MSC issued a letter go-ahead on September 5. Including fees and royalties, the contract was worth \$9.411 million.

MSC, "Weekly Activity Report for the Office of the Director, Manned Space Flight, July 21-27, 1963," p. 8; MSC, "ASPO Weekly Activity Report, September 5-11, 1963," p. 5; GAEC, "Monthly Progress Report No. 7," LPR-10-22, September 10, 1963, p. 2.

July 18

North American, Grumman, and Hamilton Standard, meeting at MSC with Crew Systems Division engineers, agreed that the portable life support system (PLSS) would have three attaching points for stowage in the spacecraft. In addition, it was agreed that the PLSS should not be used for shoulder restraint in the LEM.

"Monthly Progress Report No. 6," LPR-10-16, p. 12; MSC, "Apollo Spacecraft Project Office Activity Report, June 14-July 18, 1963," p. [8].

July 19

Grumman directed the Marquardt Corporation to begin development of the LEM reaction control system thrusters. Negotiations had begun on March 11 on the definitive subcontract, a cost-plus-incentive-fee type with a total estimated cost of \$10,871,186.

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, July 21-August 17, 1963," p. 36; "Monthly Progress Report No. 6," LPR-10-16, p. 50; GAEC, "Monthly Progress Report No. 8," LPR-10-24, October 10, 1963, p. 49.

July 20

NASA launched a Scout rocket with a nose cone of experimental heatshield material from Wallops Island, Va. The rocket was intentionally destroyed when it deviated from its course a few seconds after liftoff. The nose cone had been expected to reenter the atmosphere at 27,934 kilometers (18,600 miles) per hour to test the material's thermal performance under heating loads near those of a lunar reentry.

NASA News Release 63-153, "Reentry Experiment Will Test Ablation Material," July 17, 1963; *The Houston Chronicle*, July 20, 1963.

July 23

George E. Mueller, Vice President for Research and Development of Space Technology Laboratories, was named NASA Deputy Associate Administrator for Manned Space Flight to succeed D. Brainerd Holmes, effective September 1.

NASA News Release 63-162, "NASA Names New Head for Manned Space Flight; Succeeds Holmes,"

July 23, 1963.

July 23

Grumman authorized Hamilton Standard to begin development of the environmental control system (ECS) for the LEM. The cost-plus-incentive-fee contract was valued at \$8,371,465. The parts of the ECS to be supplied by Hamilton Standard were specified by Grumman.

"Monthly Progress Report No. 6," LPR-10-16, p. 50; MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, July 21-August 17, 1963," p. 36.

July 28-August 3

ASPO reported that a different type of stainless steel would be used for the CM heatshield. The previous type proved too brittle at cryogenic temperatures. Aside from their low temperature properties, the two metals were quite similar and no fabrication problems were anticipated.

MSC, "Weekly Activity Report for the Office of the Director, Manned Space Flight, July 28-August 3, 1963," p. 4.

July 28-August 3

ASPO ordered Grumman to design identical connectors for both ends of the space suit hoses in the LEM. This arrangement, called the "buddy concept," would permit one portable life support system to support two crewmen and thus would eliminate the need for a special suit-to-suit hose. (See August 26, 1964.)

Ibid., p. 6.

July 30-31

MIT and Grumman representatives discussed installing the inertial measurement unit and the optical telescope in the LEM. Of several possible locations, the top centerline of the cabin seemed most promising. Grumman agreed to provide a preliminary structural arrangement of the guidance components so that MIT could study problems of installation and integration.

"Monthly Progress Report No. 6," LPR-10-16, pp. 6, 7.

August 1

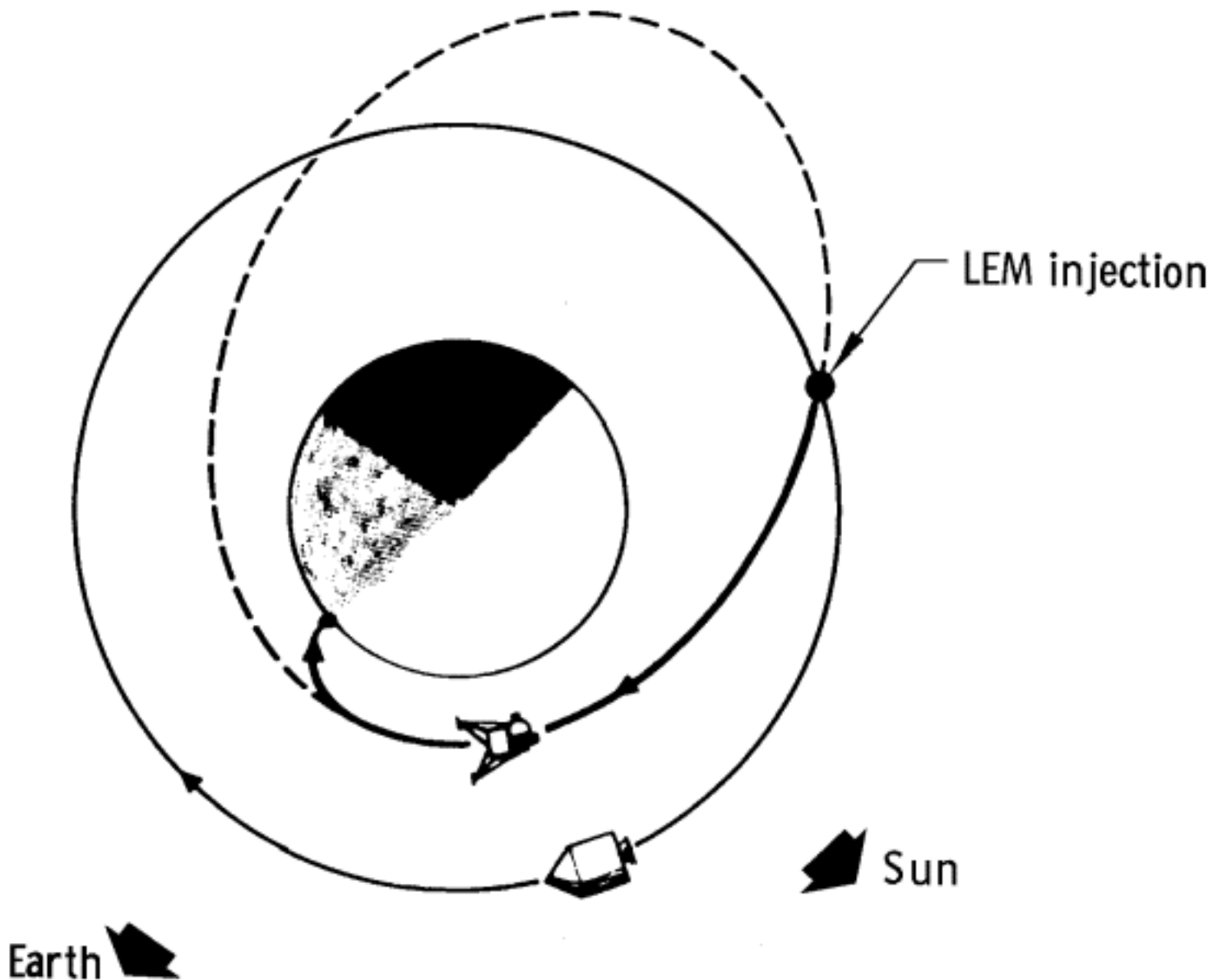
North American, NASA, and Grumman representatives discussed three methods of descent from lunar

parking orbit:

1. descent of the LEM only (the minimum energy Hohmann transfer),
2. the combined descent of both spacecraft, and
3. the synchronous equal period method.

While neither contractor felt that weight factors should be of primary concern, Grumman favored the Hohmann transfer and North American the combined descent, which represented the extremes of energy requirements. After considering reliability, fuel consumption, and operational flexibility, NASA chose the synchronous method as the prime mission mode but recommended continued investigation of the other two techniques.

Memorandum, John E. Gerstle, Jr., and Joe D. Payne, MSC, to Chief, Flight Operations Div., "LEM Descent Profile," August 20, 1963.



A briefing aid depicted the equal-period orbit method of LEM descent to the lunar surface from lunar orbit.

August 2

North American asked MSC if Grumman was designing the LEM to have a thrusting capability with the CSM attached and, if not, did NASA intend to require the additional effort by Grumman to provide this capability. North American had been proceeding on the assumption that, should the service propulsion system (SPS) fail during translunar flight, the LEM would make any course corrections needed to ensure a safe return trajectory. [The Guidance and Control Panel, at a meeting on November 29, 1962, had stated that a LEM would be included on all Saturn V flights, thus providing a backup propulsion in case of SPS failure.] On August 6, Robert O. Piland, Acting ASPO Manager, responded by asking North American to investigate the operational and systems aspects of this backup mode before a final decision was made.

TWX, H. G. Osbon, NAA, to MSC, Attn: Robert O. Piland, August 2, 1963; letter, Piland to NAA, Attn: E. E. Sack, "LEM Propulsion System as Backup to SM Propulsion System," August 6, 1963.

August 5

In what was to have been an acceptance test, the Douglas Aircraft Company static fired the first Saturn S-IV flight stage at Sacramento, Calif. An indication of fire in the engine area forced technicians to shut down the stage after little more than one minute's firing. A week later the acceptance test was repeated, this time without incident, when the vehicle was fired for over seven minutes. [The stage became part of the SA-5 launch vehicle, the first complete Saturn I to fly. See January 29, 1964.]

History of Marshall . . . January 1-June 30, 1963, Vol. I, p. 16; *The Huntsville Times*, August 6, 1963; *The Houston Post*, August 13, 1963.

August 9-10

The Panel Review Board (see July 10) held its first meeting at the Launch Operations Center (LOC). The board established an Executive Secretariat, composed of Bert A. Denicke (OMSF), Joachim P. Kuettner (MSFC), Emil P. Bertram (LOC), and Philip R. Maloney (MSC). Among other actions, the board abolished the GE Policy Review Board (see December 5, 1962).

MSC, "Apollo Spacecraft Project Office Activity Report, July 19-August 15, 1963," p. 1.

August 14

NASA Administrator James E. Webb signed the definitive contract with North American for the development of the Apollo CSM. This followed by almost two years North American's selection as prime contractor, The \$938.4 million cost-plus-fixed-fee agreement was the most valuable single research and development contract in American history. The contract called for the initial production (i. e., through May 15, 1965) of 11 mockups, 15 boilerplate vehicles, and 11 production articles. (See September 1, 1964.)

Space News Roundup, August 21, 1963; Oakley, *Historical Summary, S&ID Apollo Program*, pp. 11, 24-25; *Space Business Daily*, August 19, 1963, p. 255.

Mid-month

ITT's Kellogg Division delivered to Hamilton Standard the first operational prototype space suit communications system. (See November 27, 1962.)

Aviation Week and Space Technology, 79 (August 19, 1963), p. 29; *Space Business Daily*, August 20, 1963, p. 263.

August 15

At a meeting on the LEM electrical power system, Grumman presented its latest load analysis, which placed the LEM's mission energy requirements at 76.53 kilowatt-hours. (See January 28.) The control energy level for the complete LEM mission had been set at 54 kilowatt-hours and the target energy level at 47.12 kilowatt-hours. Grumman and MSC were jointly establishing ground rules for an electrical power reduction program.

MSC, "ASPO Weekly Activity Report, August 15-21, 1963," p. 4.

August 15-September 21

MSC Crew Systems Division conducted mobility tests of the Apollo prototype space suit inside a mockup of the CM. Technicians also tested the suit on a treadmill. The subjects' carbon dioxide buildup did not exceed two percent; their metabolic rates were about 897,000 joules (850 BTU) per hour at vent pressure, 1,688,000 joules at 2.4 newtons per square centimeter (1,600 BTU at 3.5 psi), and 2,320,000 joules at 3.5 newtons per square centimeter (2,200 BTU at 5.0 psi).

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, August 18-September 21, 1963," p. 40.

Week of August 18

MSC completed a comparison of 17-volt and 28-volt batteries for the portable life support system. The study showed that a 28-volt battery would provide comparable energy levels without increase in size and weight and would be compatible with the spacecraft electrical system.

MSC, "Weekly Activity Report for the Office of the Director, Manned Space Flight, August 18-24, 1963," p. 6.

August 21

John P. Bryant, of the Flight Operations Division's (FOD) Mission Analysis Branch (MAB), reported to FOD that the branch had conducted a rough analysis of the effects of some mission constraints upon the flexibility possible with lunar launch operations. (As a base, MAB used April and May 1968, called "a typical two-month period.") First, Bryant said, MAB used the mission rules demanded for the Apollo lunar landing (e.g., free-return trajectory; predetermined lunar landing sites; and lighting conditions on the moon - "by far the most restrictive of the lot"). Next, MAB included a number of operational constraints, ones "reasonably representative of those expected for a typical flight," but by no means an "exhaustive" list:

- A minimum daily launch window of three hours.
- A 26-degree maximum azimuth variation.
- An earth landing within 40 degrees of the equator.
- A minimum of three successive daily launch windows.
- A daylight launch with at least three hours of daylight following liftoff.
- Transposition and docking in sunlight.
- Use of but one of the two daily windows available for translunar injection.

Bryant advised that, taken just by themselves, these various constraints, both mission and operational, had a "restrictive effect" and that operational flexibility was thereby "dramatically curtailed." Moreover, "there are still a number of possible constraints which have not been considered which could still further affect the size of the ultimate launch window" (and the list was "increasing almost daily"): requirements for tracking coverage and for lighting during rendezvous and reentry; and restrictions imposed by solar activity, launch environment, and - no small matter - weather conditions at the launch site.

"The consequences," Bryant concluded, "of imposing an ever-increasing number of these flight restrictions is obvious - the eventual loss of almost all operational flexibility. The only solution is . . . [a] meticulous examination of every constraint which tends to reduce the number of available launch opportunities," looking toward eliminating "as many as possible."

Memorandum, John Bryant, MSC, to Chief, Flight Operations Div., "Planning Apollo missions with imposed operational constraints," September 5, 1963.

Week of August 22-29

An Ad Hoc Rendezvous Working Group was formed at MSC to study the possibility of substituting a unified S-band system for the rendezvous X-band radar on the LEM and CSM.

"ASPO Weekly Activity Report, August 22-29, 1963," p. 7; MSC, "Weekly Activity Report for the Office of the Director, Manned Space Flight, September 1-7, 1963," p. 11.

August 26

MSC received proposals for the visual displays for the LEM simulator. Because of the changed shape of that vehicle's windows, however, Grumman had to return those proposals to the original bidders, sending revised proposals to MSC in December. Farrand Optical Company was selected to develop the display, and the Center approved Grumman's choice. Negotiations between Grumman and Farrand were completed during March 1964.

"Apollo Quarterly Status Report No. 5," pp. 55-56; MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, August 18-September 21, 1963," p. 28; "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, December 22, 1963-January 18, 1964," p. 39; GAEC, "Monthly Progress Report No. 14," LPR-10-30, April 10, 1964, p. 35.

August 27

The MSF Management Council decided that, as part of the proposed reorganization of NASA Headquarters (see October 9), a Deputy Associate Administrator for Manned Space Flight would become responsible for all manned space flight activities within NASA.

MSF Management Council Meeting, August 27, 1963, Agenda Item 10, "Responsibility of the Deputy Associate Administrator for Manned Space Flight For Technical Matters,"

August 27

A LEM crew systems meeting was held at Grumman. The standing arrangement proposed for the crew (see June 16-July 20) promised to reduce the weight of the LEM by as much as 27.2 kilograms (60 pounds), and would improve crew mobility, visibility, control accessibility, and ingress-egress. Pending more comprehensive analysis, crew systems designers also favored the revised front-face configuration (see July 16).

MSC, "ASPO Weekly Activity Report, August 22-29, 1963," p. 7.

August 28

The Little Joe II qualification test vehicle was launched from WSMR. Its objectives were to prove the

Little Joe's capability as an Apollo spacecraft test vehicle and to determine base pressures and heating on the missile. These aims were achieved. The lone failure was a malfunction in the destruct system.

Little Joe II Test Launch Vehicle, NASA Project Apollo: Final Report, Vol. I, pp. 1-11, 1-13, 1-17.

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Part 2 (A)

Developing Hardware Distinctions

August 30, 1963 through September 1963

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1963

August 30

NASA Associate Administrator Robert C. Seamans, Jr., approved the Lunar Orbiter program. Objectives of the program were reconnaissance of the moon's topography, investigation of its environment, and collection of selenodetic information. (See May 12, 1964.)

The document called for five flight and three test articles. The Lunar Orbiter spacecraft would be capable of photographing the moon from a distance of 22 miles above the surface. Overall cost of the program was estimated at between \$150 and \$200 million.

NASA Office of Space Sciences (OSS) Review, "Lunar Orbiter Program Status Report," September 4, 1963; *Space Business Daily*, September 3, 1963, p. 327; NASA Project Approval Document, "Research and Development Project: Lunar Orbiter," Cost No. 84-800-804, undated; memorandum, Dir., OSS, to Langley Research Center, Attn: Floyd L. Thompson, "Implementation of the Lunar Orbiter Project," August 30, 1963. See also Bruce K. Byers, "Lunar Orbiter: A Preliminary History" (NASA HHN-71, Comment Edition), p. 30.

Week of August 30

North American defined the maximum, nominal, and minimum CM ablation heatshield thicknesses for lunar reentry. The maximum and minimum limits represented variations that might arise as studies progressed.

MSC, "ASPO Weekly Activity Report, August 30-September 4, 1963," p. 3.

During the Month

Grumman built a full-scale cardboard model of the LEM to aid in studying problems of cockpit geometry, specifically the arrangement of display panels. This mockup was reviewed by MSC astronauts and the layout of the cockpit was revised according to some of their suggestions.

Also Grumman reported that a preliminary analysis showed the reaction control system plume heating of the LEM landing gear was not a severe problem. [This difficulty had been greatly alleviated by the change from five to four landing legs on the vehicle. (See April 17 and May 20-22.)]

"Monthly Progress Report No. 7," LPR-10-22, pp. 7, 25.

During the Month

At a meeting at MSC, Grumman representatives submitted the cost proposal for LEM test articles LTA-8 and LTA-9, and suggested a testing program for the two vehicles: LTA-8 should be used for restrained integrated systems testing in the altitude propulsion test facilities at the Atlantic Missile Range; LTA-9 should be used for manned atmospheric tethered operation tests. The contractor also recommended an early flight demonstration program to verify the helicopter tether operation potential, which promised greatly increased mission test capability over fixed-base tether facilities. The tether method (helicopter or fixed-base) should be determined after the verification. LTA-8 should be considered as a constraint to LEM-5, and LTA-9 as a constraint to the lunar landing mission.

Ibid., pp. 45, 46.

September 1-7

MSC reported that design of the control and displays panel for the CM was about 90 percent complete. North American was expected to release the design by September 20. Qualification testing of the panels would begin around December 1.

MSC, "Weekly Activity Report for the Office of the Director, Manned Space Flight, September 1-7, 1963," p. 3.

September 4

Director Robert R. Gilruth established the MSC Manned Spacecraft Criteria Board to set up engineering, design, and procedural standards for manned spacecraft and associated systems. The board was composed of Maxime A. Faget, Chairman; James A. Chamberlin; Kenneth S. Kleinknecht; F. John Bailey, Jr.; G. Barry Graves; Jacob C. Moser; and Norman F. Smith, Secretary. Board criteria would

become MSC policy; and - unless specific waivers were obtained, compliance by project offices was mandatory.

MSC Circular No. 85, "MSC Manned Spacecraft Criteria Board," September 17, 1963.

September 4

MSC Flight Operations Division (FOD) recommended a series of water impact tests to establish confidence in the CM's recovery systems under a variety of operating conditions. FOD suggested several air drops with water landings under various test conditions. Among these were release of the main parachutes at impact, deployment of the postlanding antennas, actuation of the mechanical location aids, and activation of the recovery radio equipment.

Memorandum, Christopher C. Kraft, Jr., MSC, to Mgr., ASPO, "Recommendation for a water landing operational qualification test series using AFRM 005," September 4, 1963.

September 5-11

MSC began a study to define the stability limits of a 457-centimeter (180inch) radius LEM gear configuration. The study, in two phases, sought to examine factors affecting stability (such as lunar slope, touchdown velocity and direction, and the effects of soil mechanics) in direct support of the one-sixth model and full-scale drop test programs and to complete definition of landing capabilities of the LEM. (See October 2.)

MSC, "ASPO Weekly Activity Report, September 5-11, 1963," pp. 7-8.

September 6

MSC announced a \$7.658 million definitive contract with Kollsman Instrument Corporation for the CM guidance and navigation optical equipment, including a scanning telescope, sextant, map and data viewer, and related ground support equipment. MSC had awarded Kollsman a letter contract on May 28, 1962, and had completed negotiations for the definitive contract on March 29, 1963. "The newly signed contract calls for delivery of all hardware to AC Spark Plug by August 1, 1964."

MSC News Release 63-147, September 6, 1963; MSC, "Weekly Activity Report for the Office of the Director, Manned Space Flight, May 27-June 3, 1962," p. 12; Kollsman Instrument Corporation, "Apollo Program Quarterly Progress Report No. 3," March 31, 1963, p. 2; *ibid.*, "Apollo Program Quarterly Progress Report No. 6," December 31, 1963, pp. 10-11.

September 6

MSC Flight Operations Division (FOD) established a 72-hour lifetime for Apollo recovery aids. This limitation was derived from considerations of possible landing footprints, staging bases, and aircraft range and flying time to the landing areas. Primary location aids were the spacecraft equipment (VHF AM transceiver, VHF recovery beacon, and HE transceiver) and the VHF survival radio. Because of battery limitations, current planning called for only a 24-hour usage of the VHF recovery beacon. If electronic aids were needed beyond this time the VHF survival radio would be used. If the spacecraft were damaged or lost, the VHF survival radio would be the only electronic location aid available. MSC had recently selected the Sperry Phoenix Company to produce the Gemini VHF survival radio, which was expected to meet the Apollo requirements. FOD recommended that the current contract with Sperry Phoenix be extended to provide the units needed for Apollo missions.

Memorandum, Christopher C. Kraft, Jr., MSC, to ASPO, Attn: L. N. McMillion, "Apollo VHF survival radio," undated (ca, September 1963).

September 6

At El Centro, Calif., CM boilerplate (BP) 3, a parachute test vehicle, was destroyed during tests simulating the new BP-6 configuration (without strakes or apex cover). Drogue parachute descent, disconnect, and pilot mortar fire appeared normal. However, one pilot parachute was cut by contact with the vehicle and its main parachute did not deploy. Because of harness damage, the remaining two main parachutes failed while reefed. Investigation of the BP-3 failure resulting in rigging and design changes on BP-6 and BP-19.

"Apollo Monthly Progress Report," SID 62-300-17, p. 11; *ibid.*, SID 62-300-18, pp. 15-16.

September 9

MSC ordered North American to make provisions in the CM to permit charging the 28-volt portable life support system battery from the spacecraft battery charger.

On the following day, the Center informed North American also that a new mechanical clock timer system would be provided in the CM for indicating elapsed time from liftoff and predicting time to and duration of various events during the mission.

Letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. Eighty-Two," September 9, 1963; *ibid.*, "Contract Change Authorization No. Eighty-Four," September 10, 1963.



A design engineering inspection (DEI) and Apollo program design review were held at NAA's El Segundo, Calif., facilities September 10-12, 1963. About 70 NASA personnel members participated in the DEI of boilerplate 12 before it was shipped to WSMR to test the launch escape system. The following two days approximately 100 NASA employees including personnel from most NASA Centers and Headquarters attended the program design review. Topics included structural design, the propulsion, power, and electrical systems, guidance and navigation, simulation and trainers, ground support equipment, and a program hardware summary.

September 12

NASA announced that, in the future, unmanned lunar landing spacecraft e.g., Rangers and Surveyors) will be assembled in "clean rooms" and treated with germ-killing substances to reduce the number of microbes on exposed surfaces. These sterilization procedures, less stringent than earlier methods, were intended to prevent contamination of the lunar surface and, at the same time, avoid damage to sensitive electronic components. Heat sterilization was suspected as one of the reasons for the failure of Ranger

spacecraft.

The Washington Post, September 13, 1963.

September 16

A tone warning signal was added to the CM instrumentation system. If a system malfunctioned, this warning would be heard through both the master caution and warning subsystem and the astronauts' earphones.

Letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. Eighty-Nine," September 16, 1963.

September 16

The launch escape system was modified so that, under normal flight conditions, the crew could jettison the tower. On unmanned Saturn I flights, tower jettison was initiated by a signal from the instrument unit of the S-IV (second) stage.

Letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. Ninety-One," September 16, 1963.

September 16-18

NASA representatives held a formal review of Grumman's LEM M-1 mockup, a full-scale representation of the LEM's crew compartment. MSC decided that (1) the window shape (triangular) and visibility were satisfactory; (2) a standing position for the crew was approved, although, in general, it was believed that restraints restricted crew mobility; (3) the controllers were positioned too low and lacked suitable arm support for fine control; and (4) crew station arrangement was generally acceptable, although specific details required further study. (See June 16-July 20 and August 27.)

MSC, "ASPO Weekly Status Report, September 19-25, 1963."

September 17

LTV presented the preliminary results of a manual rendezvous simulation study. Their studies indicated that a pilot trained in the technique could accomplish lunar launch and rendezvous while using only two to three percent more fuel than the automatic system. (See May 6 and October 10, 1963, and April 24, 1964.)

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, September 22-

October 19, 1963," p. 31.

September 18

The AiResearch Manufacturing Company announced that it had been awarded a \$20 million definitive contract for the CM environmental system. [AiResearch had been developing the system under a letter contract since 1961. See Volume I, December 21, 1961.]

The Houston Post, September 19, 1963.

September 19

MSC made several changes in the CM's landing requirements. Impact attenuation would be passive, except for that afforded by the crew couches and the suspension system. The spacecraft would be suspended from the landing parachutes in a pitch attitude that imposed minimum accelerations on the crew. A crushable structure to absorb landing shock was required in the aft equipment bay area.

Letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. Ninety-Three," September 19, 1963.

September 19-25

The space suit umbilical disconnects were being redesigned to the "buddy concept" and for interchangeability between the CM and the LEM. (See September 29, 1964.) MSC was reviewing methods for a crewman to return to the LEM following space suit failure on the lunar surface. (See July 28 August 3.)

MSC, "ASPO Weekly Activity Report, September 19-25, 1963," p. 4.

September 19-25

North American incorporated an automatic radiator control into the CM's environmental control system to eliminate the need for crew attention during lunar orbit.

Recent load analysis at North American placed the power required for a 14-day mission at 577 kilowatt-hours, a decrease of about 80 kilowatt-hours from earlier estimates.

Ibid., pp. 2, 3.

September 19-October 16

Grumman directed Bell Aerosystems Company to establish the ablative nozzle extension as the primary design for the LEM's ascent stage engine. The radiation-cooled nozzle design, a weight-saving alternative, must be approved by NASA. See March; also January and May 4-11, 1964.

MSC, "ASPO Monthly Activity Report, September 19-October 16, 1963," p. 18.

September 20

President John F. Kennedy, during an address before the United Nations General Assembly, suggested the possibility of Russian-American "cooperation" in space. Though not proposing any specific program, Kennedy stated that, "in a field where the United States and the Soviet Union have a special capacity - the field of space - there is room for new cooperation, for further joint efforts in the regulation and exploration of space. I include among these possibilities," he said, "a joint expedition to the moon. . . . Surely we should explore whether the scientists and astronauts of our two countries - indeed, of all the world - cannot work together in the conquest of space, sending some day in this decade to the moon, not the representatives of a single nation, but the representatives of all humanity."

During a news conference in Houston that same day, several NASA officials commented on the President's address. Associate Administrator Robert C. Seamans, Jr., stated that Kennedy's proposals came as no great surprise. He said that many "large areas" for cooperation exist, such as exchanges of scientific information and in space tracking, but emphasized that no cosmonauts would be flying in Apollo spacecraft. Deputy Associate Administrator George E. Mueller shared Seamans' views, comparing future U.S.-U.S.S.R. cooperation in space to joint explorations in Antarctica. Scientists from both nations work together, but "they get there in different ships." Just three days earlier, MSC Director Robert R. Gilruth had told the National Rocket Club that a joint American-Russian space flight - especially one to the moon - would present almost insuperable technological difficulties. "I tremble at the thought of the integration problems . . .," he said. Gilruth cautioned his audience that he was speaking "not as an international politician," but as an engineer. The task of mating American and Russian spacecraft and launch vehicles would make such international cooperation "hard to do in a practical sort of way." And at the September 20 MSC news conference he added that such problems "are very difficult even when they [hardware components] are built by American contractors."

Robert L. Rosholt, *An Administrative History of NASA, 1958-1963* (NASA SP-4101), p. 288; *Astronautics and Aeronautics, 1963*, pp. 343, 347; *The Houston Chronicle*, September 19, 20, 21, 1963.

September 22-29

North American checked out the test fixture that was slated for the astronaut centrifuge training program, resolving interfaces between test fixture, centrifuge, and the test conductor's console, and familiarizing astronauts with controls and displays inside the spacecraft.

On October 1, North American delivered the test fixture to the U.S. Navy Aviation Medical

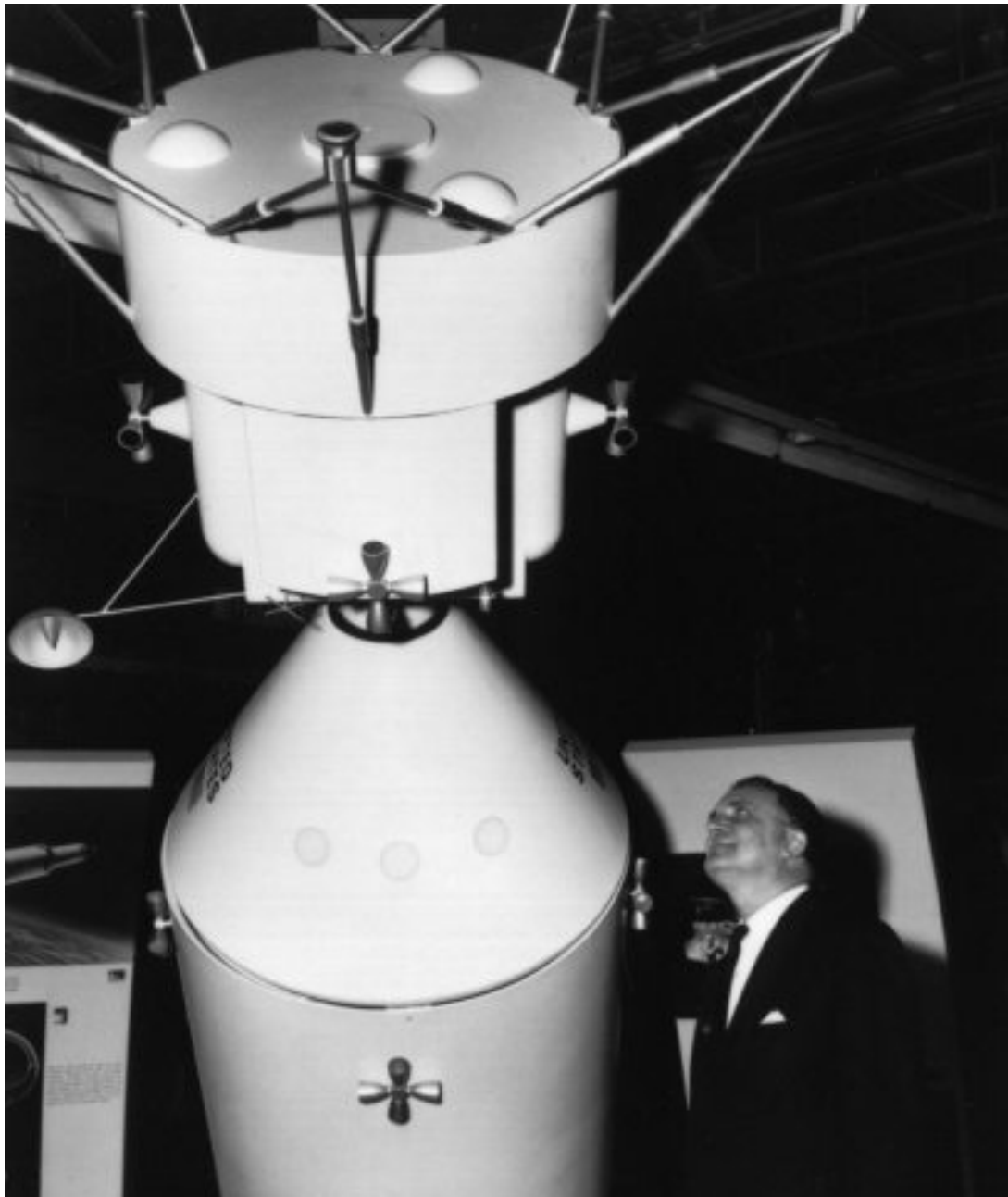
Acceleration Laboratory, where the first phase of the manned centrifuge program was scheduled to begin that month.

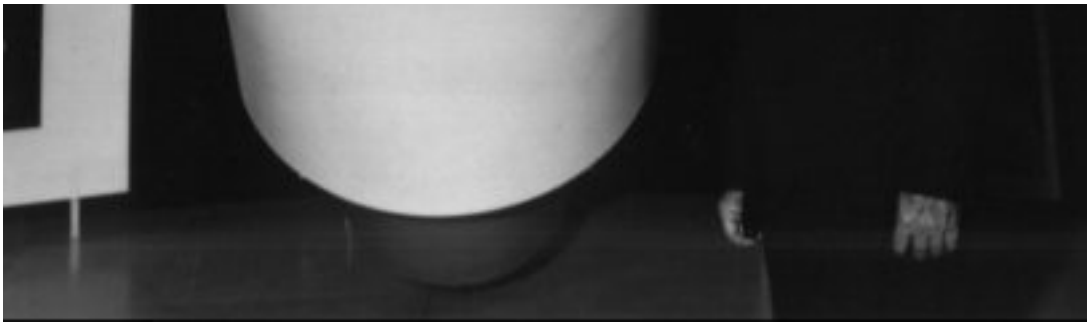
"Apollo Monthly Progress Report," SID 62-300-48, pp. 4-5; MSC, "ASPO Weekly Activity Report, October 3-9, 1963," p. 3.

September 24

MSC advised North American that the television camera in the CM was being modified so that ground personnel could observe the astronauts and flight operations. Television images would be transmitted directly to earth via the Deep Space Instrumentation Facility.

Letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. Ninety-Five," September 24, 1963.





NASA Administrator James E. Webb examined a docked configuration of the Apollo spacecraft model during a visit to Houston September 24, 1963.

September 25-26

MSC representatives reviewed Grumman's program for thermal testing for the LEM, to be conducted with the test model 2 (TM-2) vehicle. Because the vehicle's configuration had changed so extensively, the Center canceled the currently planned TM-2 ascent stage and ordered another stage to be substituted. TM-2's descent stage needed only small design changes to make it suitable for the program.

MSC," ASPO Weekly Activity Report, September 26-October 2, 1963," p. 12.

September 26

At a meeting at MSC, Grumman representatives presented 18 configurations of the LEM electrical power system, recommending a change from three to two fuel cells, still supplemented by an auxiliary battery system, with continued study on tankage design. On December 10, ASPO authorized the contractor to proceed with this configuration.

Letter, Owen E. Maynard, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Electrical Power Subsystem Configuration Recommendation," December 10, 1963; MSC, "ASPO Weekly Activity Report, September 26- October 2, 1963," p. 11.

September 26

OMSF, MSC, and Bellcomm representatives, meeting in Washington, D.C., discussed Apollo mission plans: OMSF introduced a requirement that the first manned flight in the Saturn IB program include a LEM. ASPO had planned this flight as a CSM maximum duration mission only.

- Bellcomm was asked to develop an Apollo mission assignment program without a Saturn I.
- MSFC had been asking OMSF concurrence in including a restart capability in the S-IVB (second) stage during the Saturn IB program.

ASPO would agree to this, but only if the H-1 engine were uprated from 85,275 to 90,718 kilograms (188,000 to 200,000 pounds) of thrust, resulting in a 907-kilogram (2,000-pound) payload gain.

MSC, "ASPO Weekly Activity Report, September 26-October 2, 1963."

September 26-27

MSC representatives visited Grumman for a preliminary evaluation of the Apollo space suit integration into the LEM. A suit failure ended the exercise prematurely. Nonetheless, leg and foot mobility was good, but the upper torso and shoulder needed improvement.

On October 11, MSC Crew Systems Division (CSD) tested the suit's mobility with the portable life support system (PLSS). CSD researchers found that the PLSS did not restrict the wearer's movement because the suit supported the weight of the PLSS. Shifts in the center of gravity appeared insignificant. The PLSS controls, because of their location, were difficult to operate, which demanded further investigation.

Ibid.; MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, September 22-October 19, 1963," p. 48.

September 26-October 2

North American recommended that the portable life support system in the CM be deleted. Current planning placed two units in the LEM and one in the CM.

MSC, "ASPO Weekly Activity Report, September 26-October 2, 1963," p. 3.

September 30

MSC awarded Texas Instruments, Inc., a \$194,000 contract to study experiments and equipment needed for scientific exploration of the lunar surface. The analysis was to be completed by the end of May 1964. (See March 17, 1964.)

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, September 22-October 19, 1963," p. 41; "Apollo Quarterly Status Report No. 6," p. 34; MSC News Release 63-171, October 16, 1963.

September 30

Qualification testing began on fuel tanks for the service propulsion system (SPS). The first article tested developed a small crack below the bottom weld, which was being investigated, but pressurization caused

no expansion of the tank. During mid-October, several tanks underwent proof testing. And, on November 1, the first SPS helium tank was burst-tested.

MSC, "ASPO Status Report for Period Ending October 16, 1963"; "ASPO Status Report for Period October 16-November 12, 1963"; "ASPO Status Report for Period Ending October 23, 1963."



David G. Hoag, technical director of the Apollo guidance and navigation system design program at MIT's Instrumentation Laboratory, inspected a mockup of the inertial measurement unit in the system.



Director of the Laboratory Dr. C. Stark Draper posed beside a mockup of the guidance and navigation system.

During the Month

The interrelationships between all major LEM test vehicles, including all test constraints and documentation requirements, were developed. This logic study, prepared by Grumman and forwarded to MSC, stressed the feasibility of alterations in the LEM test program as needed.

"Monthly Progress Report No. 8," LPR-10-24, p. 45.

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Part 2 (B)

Developing Hardware Distinctions

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1963

October 2

At a LEM Mechanical Systems Meeting in Houston, Grumman and MSC agreed upon a preliminary configuration freeze for the LEM-adapter arrangement. The adapter would be a truncated cone, 876 centimeters (345 inches) long. The LEM would be mounted inside the adapter by means of the outrigger trusses on the spacecraft's landing gear. This configuration provided ample clearance for the spacecraft, both top and bottom (i.e., between the service propulsion engine bell and the instrument unit of the S-IVB). (See June 3 and December 5.)

At this same meeting, Grumman presented a comparison of radially and laterally folded landing gears (both of 457-centimeter [180-inch] radius). The radial-fold configuration, MSC reported, promised a weight savings of 22-2 kilograms (49 pounds). MSC approved the concept, with an 876-centimeter (345-inch) adapter. Further, an adapter of that length would accommodate a larger, lateral fold gear (508 centimeters [200 inches]), if necessary. During the next several weeks, Grumman studied a variety of gear arrangements (sizes, means of deployment, stability, and even a "bending" gear). At a subsequent LEM Mechanical Systems Meeting, on November 10, Grumman presented data (design, performance, and weight) on several other four-legged gear arrangements - a 457-centimeter (180-inch), radial fold "tripod" gear (i.e., attached to the vehicle by three struts), and 406.4-centimeter (160-inch) and 457-centimeter (180-inch) cantilevered gears. As it turned out, the 406.4-centimeter (160-inch) cantilevered gear, while still meeting requirements demanded in the work statement, in several respects was more stable than the larger tripod gear. In addition to being considerably lighter, the cantilevered design

offered several added advantages:

- A reduced stowed height for the LEM from 336.5 to 313.7 centimeters (132.5 to 123.5 inches).
- A shorter landing stroke (50.8 instead of 101.6 centimeters) (20 instead of 40 inches).
- Better protection from irregularities (protuberances) on the surface.
- An alleviation of the gear heating problem (caused by the descent engine's exhaust plume).
- Simpler locking mechanisms.
- A better capability to handle various load patterns on the landing pads.

Because of these significant (and persuasive) factors, MSC approved Grumman's change to the 406.4-centimeter (160-inch) cantilevered arrangement as the design for the LEM's landing gear. By mid-November, MSC reported to OMSF that Grumman was pursuing the 406.4-centimeter (160-inch) cantilevered gear. Although analyses would not be completed for some weeks, the design was "shown . . . to be the lightest gear available to date. . . . Tentative estimates indicate a gear stowed height reduction of about 9" [22.9 centimeters], which will still accommodate the 180" [45.7 centimeter] cantilever or 200" [508-centimeter] lateral fold gear as growth potential." Grumman's effort continued at "firming up" the design, including folding and docking mechanisms.

GAEC, "Monthly Progress Report No. 9," LPR-10-25, November 10, 1963, pp. 3, 12; MSC, "ASPO Weekly Activity Report, September 26-October 2, 1963," p. 15; "ASPO Monthly Activity Report, September 19-October 16, 1963," p. 5; MSC, "Weekly-Activity Report for the Office of the Director, Manned Space Flight, September 8-14, 1963," pp. 10-II; "Weekly Activity Report for the Office of the Director, Manned Space Flight, November 17-23, 1963," pp. 9-10; MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, October 20-November 16, 1963," p. 36; "Apollo Quarterly Status Report No. 6," p. 27; "ASPO Status Report for Period Ending October 16, 1963"; "ASPO Weekly Status Report, November 12-19, 1963"; "Monthly Progress Report No. 7," LPR-10-22, p. 10; "Monthly Progress Report No. 8," LPR-10-24, p. 11; GAEC, "Monthly Progress Report No. 10," LPR-10-26, December 10, 1963, p. 10; GAEC, "Monthly Progress Report No. 11," LPR-10-27, January 10, 1964, p. 11.

October 8

NASA announced the appointment of Joseph F. Shea as ASPO Manager effective October 22. He had been Deputy Director (Systems) in OMSF. George M. Low, OMSF Deputy Director (Programs), would direct the Systems office as well as his own. Robert O. Piland, Acting Manager of ASPO since April 3, resumed his former duties as Deputy Manager.

NASA News Release 63-226, "Shea to Head Apollo Spacecraft Development at Manned Spacecraft Center," October 8, 1963; MSC News Release 63-163, October 8, 1963; MSC Announcement No. 263, "Manager, Apollo Spacecraft Program Office," October 22, 1963.

October 8

Verne C. Fryklund, Jr., of NASA's Office of Space Sciences (OSS), in a memorandum to MSC Director Robert R. Gilruth, recommended some general guidelines for Apollo scientific investigations of the moon (which OSS already was using). "These guidelines," Fryklund told Gilruth, ". . . should be followed in the preparation of your plans," and thus were "intended to place some specific constraints on studies. . . . The primary scientific objective of the Apollo project," Fryklund said, was, of course, the "acquisition of comprehensive data about the moon." With this as a starting point, he went on, ". . . it follows that the structure of the moon's surface, gross body properties and large-scale measurements of physical and chemical characteristics, and observation of whatever phenomena may occur at the actual surface will be the prime scientific objectives." Basically, OSS's guidelines spelled out what types of activity were and were not part of Apollo's immediate goals. These activities were presumed to be mostly reconnaissance, "to acquire knowledge of as large an area as possible, and by as simple a means as possible, in the limited time available." The three principal scientific activities "listed in order of decreasing importance" were: (1) "comprehensive observation of lunar phenomena," (2) "collection of representative samples," and (3) "emplacement of monitoring equipment."

These guidelines had been arrived at after extensive consultation within NASA as a whole as well as with the scientific community.

Memorandum, Verne C. Fryklund, Jr., NASA Office of Space Sciences (OSS), to Director, MSC, "Scientific Guidelines for the Apollo Project," October 8, 1963; OSS, "NASA Program Planning in Space Sciences," September 1963, pp. VI-3 through VI-8.

October 8

At MSC, the Spacecraft Technology Division reported to ASPO the results of a study on tethered docking of the LEM and CSM. The technology people found that a cable did not reduce the impact velocities below those that a pilot could achieve during free flyaround, nor was fuel consumption reduced. In fact, when direct control of the spacecraft was attempted, the tether proved a hindrance and actually increased the amount of fuel required.

MSC, "Flight Crew Operations Division, Activity Report, September 16-October 21, 1963," pp. 2-3.

October 9

NASA Administrator James E. Webb announced a major reorganization of NASA Headquarters, effective November 1, to consolidate management of major programs and direction of research and development centers and to realign Headquarters management of agency-wide support functions. On October 28, NASA Headquarters announced a similar reorganization within OMSF, also to take effect on November 1, to strengthen NASA Headquarters' control of the agency's manned space flight programs. In effect, these administrative adjustments "recombined program and institutional management by placing the field centers under the Headquarters program directors instead of under general management (i.e., the Associate Administrator)."

NASA News Release 63-225, "NASA Announces Reorganization," October 9, 1963; NASA News Release 63-241, "NASA Realigns Office of Manned Space Flight," October 28, 1963; Rosholt, *Administrative History of NASA, 1958-1963*, pp. 289-96.

October 10

LTV announced the results of tests performed by astronauts in the Manned Space Flight Mission Simulator in Dallas, Tex. (See May 6 and September 17, 1963, and April 24, 1964.) These indicated that, should the primary guidance and navigation system fail, LEM pilots could rendezvous with the CM by using a circular slide rule to process LEM radar data.

Tulsa Daily World, October 11, 1963; *The Houston Post*, October 11, 1963.

October 14

Langley Research Center's Lunar Landing Research Facility was nearing completion. A gantry structure 121.9 meters (400 feet) long and 76.2 meters (250 feet) high would suspend a model of the LEM. It would sustain five-sixths of the model's weight, simulating lunar gravity, and thus would enable astronauts to practice lunar landings. (See Volume I, Summer 1961.)

Aviation Week and Space Technology, 79 (October 14, 1963), pp. 83, 86; MSC, *Space News Roundup*, November 27, 1963, p. 8.

October 14

ASPO established criteria for combustion stability in the service propulsion engine. The engine had to recover from any instability, whether induced or spontaneous, within 20 milliseconds during qualification testing.

MSC, "ASPO Monthly Activity Report, September 19-October 16, 1963," p. 3.

October 15

The Guidance and Performance Sub-Panel, at its first meeting, began coordinating work at MSC and MSFC. The sub-panel outlined tasks for each Center: MSFC would define the dispersions comprising the launch vehicle performance reserves, prepare a set of typical translunar injection errors for the Saturn V launch vehicle, and give MSC a typical Saturn V guidance computation for injection into an earth parking orbit. MSC would identify the constraints required for free-return trajectories and provide MSFC with details of the MIT guidance method. Further, the two Centers would exchange data each month showing current launch vehicle and spacecraft performance capability. (For operational vehicles,

studies of other than performance capability would be based on control weights and would not reflect the current weight status.)

Memorandum, Secretaries, Guidance and Performance Sub-Panel, MSFC and MSC, to Distr., "Minutes of First Guidance and Performance Sub-Panel Meeting," October 16, 1963.

October 16-17

MSC discussed commonality of displays and controls with its two principal spacecraft contractors. A review of panel components suggested that Grumman might use the same vendors as North American for such items as switches, potentiometers, and indicators.

MSC, "ASPO Activity Report, October 16-22, 1963," pp. 1-2.

October 16-23

An MSC Spacecraft Technology Division Working Group reexamined Apollo mission requirements and suggested a number of ways to reduce spacecraft weight: eliminate the free-return trajectory; design for slower return times; use the Hohmann descent technique, rather than the equal period orbit method, yet size the tanks for the equal period mode; eliminate the CSM/LEM dual rendezvous capability; reduce the orbital contingency time for the LEM (the period of time during which the LEM could remain in orbit before rendezvousing with the CSM); reduce the LEM lifetime.

MSC, "ASPO Status Report for Period Ending October 23, 1963."

October 16-November 15

Because of an electrical equipment failure on Mercury MA-9, North American began a CM humidity study. The company found in the crew compartment major spacecraft systems which were not designed for operation in the presence of corrosive moisture. (The environmental control system did not guarantee complete humidity control.) Investigators also examined in minute detail all electrical electronic components. North American was considering design changes that would protect all components from moisture.

"Apollo Monthly Progress Report," SID 62-300-19, p. 25.

October 18

NASA and GD/C negotiated amendments totaling \$354,737 to Little Joe II contract. This sum covered study activity and several relatively small changes that came out of a Design Engineering Inspection on May 3. More ground support equipment was authorized, as was fabrication of an additional breadboard autopilot system for use at MSC. The dummy payload was deleted and the instrumentation was limited

to a control system on the vehicle to be used for Mission A-002 (BP-23).

Little Joe II Test Launch Vehicle, NASA Project Apollo: Final Report, Vol. I, p. 4-3.

October 18

NASA Headquarters announced the selection of five organizations for contract negotiations totaling \$60 million for the development, fabrication, and testing of LEM guidance and navigation equipment: (1) MIT, overall direction; (2) Raytheon, LEM guidance computer; (3) AC Spark Plug, inertial measurement unit, gyroscopes, navigation base, power and servo assembly, coupling display unit, and assembly and testing of the complete guidance and navigation system; (4) Kollsman Instrument Corporation, scanning telescope, sextant, and map and data viewer; and (5) Sperry Gyroscope Company, accelerometers. (All five had responsibility for similar equipment for the CSM as well. See Vol. I, August 9, 1961, and May 8, 1962.)

MSC News Release 63-175, October 18, 1963.

October 18

NASA announced the selection of 14 astronauts for Projects Gemini and Apollo, bringing to 30 the total number of American spacemen. They were Maj. Edwin E. Aldrin, Jr., Capt. William A. Anders, Capt. Charles A. Bassett II, Capt. Michael Collins, Capt. Donn F. Eisele, Capt. Theodore C. Freeman, and Capt. David R. Scott of the Air Force; Lt. Cdr. Richard F. Gordon, Jr., Lt. Alan L. Bean, Lt. Eugene A. Cernan, and Lt. Roger B. Chaffee of the Navy; Capt. Clifton C. Williams, Jr., of the Marine Corps; R. Walter Cunningham, research scientist for the Rand Corporation; and Russell L. Schweickart, research scientist for MIT.

MSC News Release 63-180, October 18, 1963; *Space News Roundup*, October 30, 1963.

October 20-November 16

MSC reported that preliminary testing had begun on the first prototype extravehicular suit telemetry and communications system and on the portable life support system of which it was an integral part. The hardware had recently been received from the prime contractor, Hamilton Standard.

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, October 20-November 16, 1963," p. 67.

October 21

The second prototype space suit was received by MSC's Crew Systems Division. (See August 15-

September 21.) Preliminary tests showed little improvement in mobility over the first suit. On October 24-25, a space suit mobility demonstration was held at North American. The results showed that the suit had less shoulder mobility than the earlier version, but more lower limb mobility. (See September 26-27.) Astronaut John W. Young, wearing the pressurized suit and a mockup portable life support system (PLSS), attempted an egress through the CM hatch but encountered considerable difficulty. At the same time, tests of the suit-couch- restraint system interfaces and control display layout were begun at the Navy's Aviation Medical Acceleration Laboratory centrifuge in Johnsville, Pa. Major problems were restriction of downward vision by the helmet, extension of the suit elbow arm beyond the couch, and awkward reach patterns to the lower part of the control panel. On October 30-November 1, lunar task studies with the suit were carried out at Wright-Patterson Air Force Base in a KC-135 aircraft at simulated lunar gravity. Mobility tests were made with the suit pressurized and a PLSS attached.

"Apollo Quarterly Status Report No. 6," p. 25; MSC, "Weekly Activity Report for the Office of the Director, Manned Space Flight, October 27-November 2, 1963," p. 6; MSC, "ASPO Status Report for Week Ending November 6, 1963;" "ASPO Status Report for Period Ending October 23, 1963;" "ASPO Status Report for Period October 16-November 12, 1963."

October 22

George E. Mueller, NASA Associate Administrator for Manned Space Flight, appointed Walter C. Williams Deputy Associate Administrator for Manned Space Flight in OMSF. Williams would direct operations at MSC, MSFC, and LOC for all manned space flight missions.

MSC News Release 63-179, October 22, 1963.

October 23

MSC Flight Operations Division defined systems and outlined ground rules for the lunar landing mission. System definitions were: (1) primary, most efficient or economic; (2) alternate, either redundant (identical to but independent of the primary) or backup (not identical but would perform the same function); (3) critical (failure would jeopardize crew safety); (4) repairable (for which tools and spares were carried and which the crew could service in flight); and (5) operational, which must be working to carry out a mission.

Mission rules established crew safety as the major consideration in all mission decisions and detailed actions to be taken in the event of a failure in any system or subsystem.

Memorandum, Eugene L. Duret, MSC, to Chief, Flight Operations Div., "Project Apollo, operational ground rules for the Lunar Landing Mission," October 23, 1963, with enclosure.

October 23-30

MSC Instrumentation and Electronic Systems Division awarded a \$50,000 contract to the Hughes Aircraft Company for a study of backup high gain directable antennas for the LEM lunar surface equipment.

MSC," ASPO Status Report for Week Ending October 30, 1963."

October 24

Because OMSF had requested OSSA to provide lunar surface microrelief and bearing strength data to support LEM landing site selection and to permit LEM landing-gear design validation, the Ad Hoc Working Group on Follow-On Surveyor Instrumentation met at NASA Headquarters. Attending were Chairman Verne C. Fryklund, Clark Goodman, Martin Swetnick, and Paul Brockman of the NASA Office of Space Sciences and Applications; Harry Hess and George Derbyshire of the National Academy of Sciences; Dennis James of Bellcomm (for OMSF); and Milton Beilock of the Jet Propulsion Laboratory (JPL). The group proposed "a fresh look at the problem of instrumenting payloads of Surveyor spacecraft that may follow the currently approved developmental and operational flights, so that these spacecraft will be able to determine that a particular lunar site is suitable for an Apollo landing." The study was assigned to JPL.

Summary Minutes," Ad Hoc Working Group on Follow-On Surveyor Instrumentation, October 24, 1963," October 28, 1963, pp. 1-2.

October 24

The NASA-Industry Apollo Executives Group, composed of top managers in OMSF and executives of the major Apollo contractors, met for the first time. The group met with George E. Mueller, NASA Associate Administrator for Manned Space Flight, for status briefings and problem discussions. In this manner, NASA sought to make executives personally aware of major problems in the program.

Tenth Semiannual Report to Congress of the National Aeronautics and Space Administration, July 1-December 31, 1963 (1964), p. 43.

October 25

MSC directed Grumman to schedule manned environmental control system (ECS) development tests, using a welded-shell cabin boilerplate and air lock. At about the same time, the company was also requested to quote cost and delivery schedule for a second boilerplate vessel, complete with prototype ECS. Although this vessel would be used by the MSC Crew Systems Division for in-house investigation and evaluation of ECS development problems, its major purpose was to serve as a tool for troubleshooting during the operational phase.

MSC, "Weekly Activity Report for the Office of the Director, Manned Space Flight, October 27-

November 2, 1963," p. 11; MSC," ASPO Status Report for Period October 16-November 12, 1963."

October 29

After a program review at an MSF Management Council meeting, George E. Mueller, head of OMSF, suggested several testing procedures. To meet schedules, "dead-end" testing, that is, "tests involving components or systems that [would] not fly operationally without major modification," should be minimized. Henceforth, Mueller said, NASA would concentrate on "all-up" testing. [In "all-up" testing, the complete spacecraft and launch vehicle configuration would be used on each flight. Previously, NASA plans had called for a gradual buildup of subsystems, systems stages, and modules in successive flight tests.] To simplify both testing and checkout at Cape Canaveral, complete systems should be delivered. An instrumentation task force with senior representatives from each Center, one outside member, and Walter C. Williams of OMSF should be set up immediately; a second task force, to study storable fuels and small motors, would include members from Lewis Research Center, MSC, MSFC, as well as representatives from outside the government.

Memorandum, Clyde Bothmer, MSF Management Council, for Distribution, "Management Council Meeting, October 29, 1963, in Washington, D.C.," October 31, 1963.

October 30

NASA canceled four manned earth orbital flights with the Saturn I launch vehicle. Six of a series of 10 unmanned Saturn I development flights were still scheduled. Development of the Saturn IB for manned flight would be accelerated and "all-up" testing would be started. (See November 1.) This action followed Bellcomm's recommendation of a number of changes in the Apollo spacecraft flight test program. The program should be transferred from Saturn I to Saturn IB launch vehicles; the Saturn I program should end with flight SA-10. All Saturn IB flights, beginning with SA-201, should carry operational spacecraft, including equipment for extensive testing of the spacecraft systems in earth orbit.

Associate Administrator for Manned Space Flight George E. Mueller had recommended the changeover from the Saturn I to the Saturn IB to NASA Administrator James E. Webb on October 26. Webb's concurrence came two days later.

Memoranda: Mueller to Robert F. Freitag, "Replacement of Scheduled Manned Flights on Saturn I," October 18, 1963; Mueller to Webb, "Reorientation of Apollo Plans," October 26, 1963, with handwritten notation signed by Webb, undated; OMSF, *Recommended Changes in the Use of Space Vehicles in the Apollo Test Program*, Technical Memorandum, MD(S) 3100.180 (October 29, 1963), pp. 1-4; NASA News Release 63-246, "NASA Announces Changes in Saturn Missions," October 30, 1963.

October 31

The Marquardt Corporation received a definitive \$9,353,200 contract from North American for

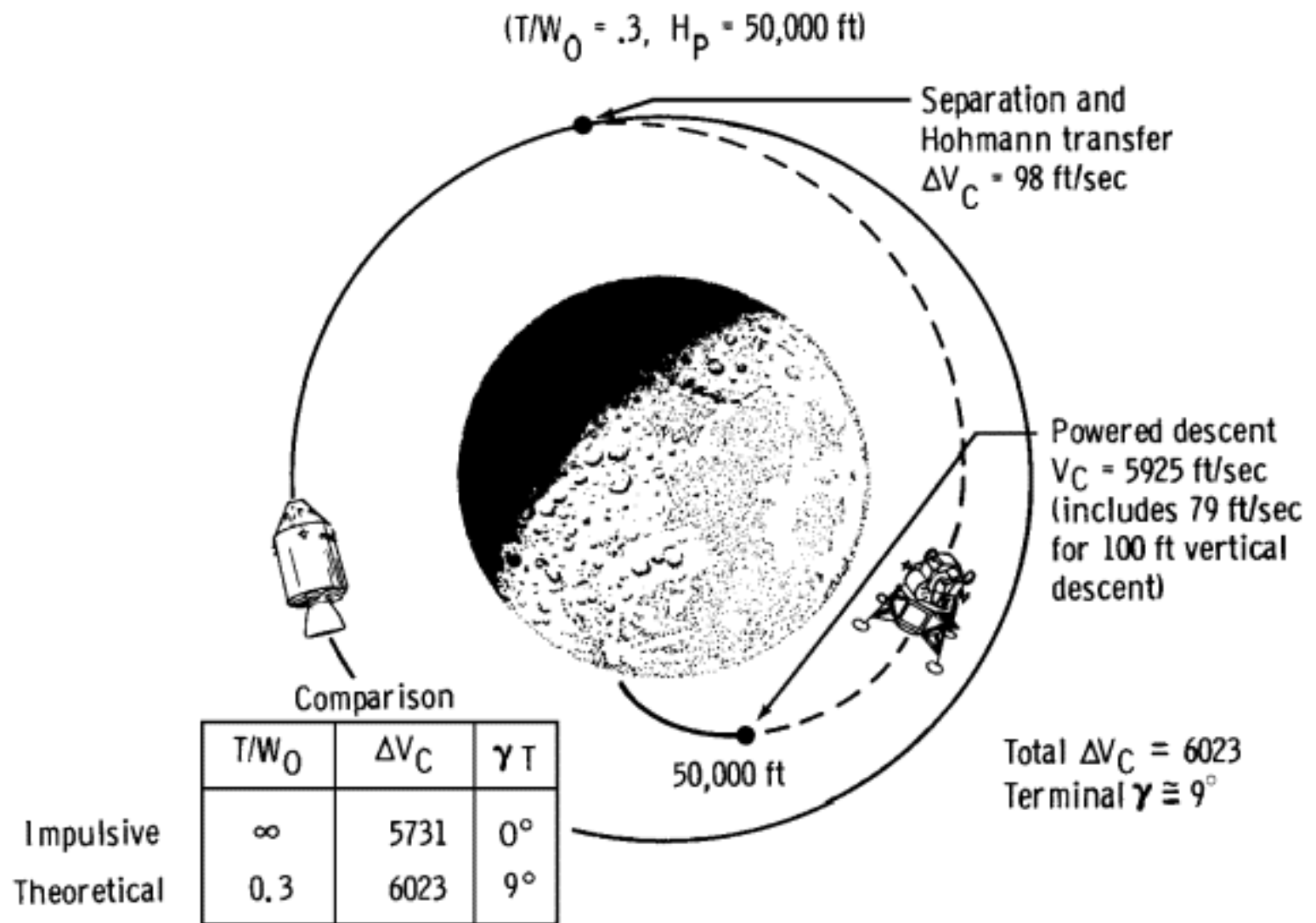
development and production of reaction control engines for the SM. Marquardt, working under a letter contract since April 1962, had delivered the first engine to North American that November.

MSC News Release 63-22, October 31, 1963; MSC, *Space News Roundup*, November 13, 1963, p. 8.

October 31

The first production F-1 engine was flown from Rocketdyne's Canoga Park, Calif., facility, where it was manufactured, to MSFC aboard Aero Spacelines' "Pregnant Guppy."

David S. Akens, A. Ruth Jarrell, and Leo L. Jones, *History of the George C. Marshall Space Flight Center From July 1 Through December 31, 1963* (MHM-8, July 1964), Vol. I, p. 129.



Theoretical optimum lunar module descent with thrust-to-weight ration (initial value in lunar orbit) at 0.3, height at perilune of the transfer orbit at 15,200 meters (50,000 feet), and using the Hohmann transfer technique. The diagram showed the velocity change (delta Vc, in feet per second) and approach

flight-path angle (gamma) close to that for an impulsive orbital change (an instantaneous change, without time value, taken as the ultimate though unachievable ideal for comparison). (NASA drawing)

During the Month

NASA tentatively approved Project Luster, a program designed to capture lunar dust deflected from the moon by meteorites and spun into orbit around the earth. An Aerobee 150 sounding rocket containing scientific equipment built by Electro-Optical Systems, Inc., was scheduled for launch in late 1964.

Missiles and Rockets, 13 (October 14, 1963), p. 9.

November 1

NASA Associate Administrator for Manned Space Flight George E. Mueller notified the Directors of MSC, MSFC, and LOC that he intended to plan a flight schedule which would have a good chance of being met or exceeded. To this end, he directed that "all-up" spacecraft and launch vehicle tests be started as soon as possible; all Saturn IB flights would carry CSM and CSM LEM configurations; and two successful unmanned flights would be flown before a manned mission on either the Saturn IB or Saturn V.

On November 18, Mueller further defined the flight schedule planning. Early Saturn IB flights might not be able to include the LEM, but every effort must be made to phase the LEM into the picture as early as possible. Launch vehicle payload capability must be reached as quickly as practicable. Subsystems for the early flights should be the same as those intended for lunar missions. To conserve funds, the first Saturn V vehicle would be used to obtain reentry data early in the Saturn test program.

By December 31 the official schedule showed:

Final Saturn I flight (SA-10):

June 1965

First Saturn IB flight (SA-201):

first quarter, 1966

First manned Saturn IB flight:

either SA-203, third quarter of 1966, or SA-207, third quarter of 1967

First Saturn V flight (SA-501):

first quarter, 1967

First manned Saturn V flight:

either SA-503, third quarter of 1967, or SA-507, second quarter of 1968.

TWX, Mueller to Dir., MSC, MSFC, and LOC, "Revised Manned Space Flight Schedule," November 1, 1963; memorandum, Mueller to Dir., MSC, MSFC, and LOC, "Manned Space Flight Schedule,"

November 18, 1963; "Apollo Quarterly Status Report No. 6," fig. 9, 10, 11.

November 1

MSC Flight Operations Division outlined the advantages inherent in the CSM's capability to use the HF transceiver during earth orbit. The HF transceiver would allow the CSM to communicate with any one tracking station at any time during earth orbit, even when the spacecraft had line-of-sight (LOS) contact with only one or two ground stations in some orbits. It would give the astronauts an additional communications circuit. Most important, this HF capability could alert the network about any trouble in the spacecraft and give the Flight Director more time to make a decision while the spacecraft was out of LOS communication with the ground stations.

Memorandum, Christopher C. Kraft, Jr., MSC, to Mgr., ASPO, "Apollo HF communications during earth orbit," November 1, 1963.

November 8

MSC Crew Systems Division, conducting flammability tests on the constant wear garment material in a 3.5 newtons per square centimeter (5 psi), 100 percent oxygen atmosphere, reported that no fires had been experienced thus far.

MSC, "Weekly Activity Report for the Office of the Director, Manned Space Flight, November 3-9, 1963," p. 7.

November 5

MSC Director Robert R. Gilruth announced a reorganization of MSC to strengthen the management of the Apollo and Gemini programs. Under Gilruth and Deputy Director James C. Elms, there were now four Assistant Directors, Managers for both the Gemini and Apollo programs, and a Manager for MSC's Florida Operations. Assigned to these positions were:

Maxime A. Faget, Assistant Director for Engineering and Development
Christopher C. Kraft, Jr., Assistant Director for Flight Operations
Donald K. Slayton, Assistant Director for Flight Crew Operations
Wesley L. Hjernevik, Assistant Director for Administration
Joseph F. Shea, Manager, Apollo Spacecraft Program Office
Charles W. Mathews, Manager, Gemini Program Office
G. Merritt Preston, Manager, MSC Florida Operations.

MSC News Release 63-277, November 5, 1963; *The Houston Post*, November 6, 1963.

November 5

MSC accepted the final items of a \$237,000 vibration test system from the LTV Electronics Division to

be used in testing spacecraft parts.

On this same day, MSC awarded a \$183,152 contract to Wyle Laboratories to construct a high-intensity acoustic facility, also for testing spacecraft parts. The facility would generate noise that might be encountered in space flight.

MSC News Release 63-224, November 5, 1963; MSC News Release 63-225, November 5, 1963.

November 5

North American presented to MSC the results of a three-month study on radiation instrumentation. Three general areas were covered: radio-frequency (RF) warning systems, directional instrumentation, and external environment instrumentation. The company concluded that, with the use of an RE system, astronauts would receive about two hours' notice of any impending solar proton event and could take appropriate action. Proper orientation of the spacecraft could reduce doses by 17 percent, but this could be accomplished only by using a directional detection instrument. There was a 70 percent chance that dosages would exceed safe limits unless such an instrument was used. Consequently North American recommended prompt development.

Despite the contractor's findings, MSC concluded that there was no need for an RE warning system aboard the spacecraft, believing that radiation warning could be handled more effectively by ground systems. But MSC did concur in the recommendation for a combined proton direction and external environment detection system and authorized North American to proceed with its design and development.

MSC, "ASPO Status Report for Period October 16-November 12, 1963"; memorandum, David M. Hammock and Lee N. McMillion, MSC, to E. E. Sack, NAA, "Contract NAS 9-150, Radiation Instrumentation for Apollo," November 27, 1963; "Apollo Monthly Progress Report," SID 62-300-20, pp. 12-13.

November 7

Apollo Pad Abort Mission I (PA-1), the first off-the-pad abort test of the launch escape system (LES), was conducted at WSMR. PA-1 used CM boilerplate 6 and an LES for this test.

All sequencing was normal. The tower-jettison motor sent the escape tower into a proper ballistic trajectory. The drogue parachute deployed as programmed, followed by the pilot parachute and main parachutes. The test lasted 165.1 seconds. The postflight investigation disclosed only one significant problem: exhaust impingement that resulted in soot deposits on the CM.

"Postlaunch Memorandum Report for Apollo Pad Abort I," November 13, 1963, pp. 1-1, 1-2, 3-1.

November 8

Grumman issued a go-ahead to RCA to develop the LEM radar. Negotiations on the \$23.461 million cost- plus-fixed-fee contract were completed on December 10. Areas yet to be negotiated between the two companies were LEM communications, inflight test, ground support, and parts of the stabilization and control systems. (See June 28.)

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, October 20-November 16, 1963," p. 57; *Wall Street Journal*, December 10, 1963.

November 8

MSFC directed Rocketdyne to develop an uprated H-1 engine to be used in the first stage of the Saturn IB. In August, Rocketdyne had proposed that the H-1 be uprated from 85,275 to 90,718 kilograms (188,000 to 200,000 pounds) of thrust. The uprated engine promised a 907-kilogram (2,000 pound) increase in the Saturn IB's orbital payload, yet required no major systems changes and only minor structural modifications.

Akens *et al.*, *History of Marshall . . . July 1-December 31, 1963*, Vol. I, pp. 65, 66.

November 8

At El Centro, Calif., a drop test was conducted to evaluate a dual drogue parachute arrangement for the CM. The two drogues functioned satisfactorily. The cargo parachute used for recovery, however, failed to fully inflate, and the vehicle was damaged at impact. This failure was unrelated to the test objectives.

MSC," ASPO Status Report for Period October 16-November 12, 1963."

November 12

A joint North American-MSFC meeting reviewed the tower flap versus canard concept for the earth landing system (ELS). (See January 18.) During a low-altitude abort, MSC thought, the ELS could be deployed apex forward with a very high probability of mission success by using the tower flap configuration. The parachute system proposed for this mode would be very reliable, even though this was not the most desirable position for deploying parachutes. Dynamic stability of the tower flap configuration during high- altitude aborts required further wind tunnel testing at Ames Research Center. Two basic unknowns in the canard system were deployment reliability, and the probability of the crew's being able to establish the flight direction and trim the CM within its stability limits for a safe reentry. Design areas to be resolved were a simple deployment scheme and a spacecraft system that would give the crew a direction reference.

MSC directed North American to proceed with the tower flap as its prime effort, and attempt to solve the

stability problem at the earliest possible date. MSC's Engineering and Development Directorate resumed its study of both configurations, with an in-depth analysis of the canard system, in case the stability problem on the tower flap could not be solved by the end of the year. (See February 7 and 25, 1964.)

Memorandum, David M. Hammock, MSC, to Asst. Dir. for Engineering and Development, "Analysis of the abort and earth landing systems if implemented by a tower flap versus a canard mode," November 18, 1963.

November 12

The Boeing Company and NASA signed a \$27.4 million supplemental agreement to the contract for development, fabrication, and test of the S-IC (first) stage of the Saturn V launch vehicle.

Aviation Week and Space Technology, 79 (November 25, 1963), p. 67; Akens *et al.*, *History of Marshall . . . July 1-December 31, 1963*, Vol. I, p. 97.

November 12

NASA awarded a \$19.2 million contract to Blount Brothers Corporation and M. M. Sundt Construction Company for the construction of Pad A, part of the Saturn V Launch Complex 39 at LOC.

Akens *et al.*, *History of Marshall . . . July 1-December 31, 1963*, Vol. I, p. 169.

November 12-15

North American representatives reviewed Farrand Optical Company's subcontract with Link for visual displays in the Apollo Mission Simulator. MSC officials attended the technical portion of the meeting, which was held at Link. Farrand and Link had established window fields of view and optical axis orientations. Designs were to be reviewed to verify accuracy and currency of window locations and crew eye position parameters.

MSC, "ASPO Status Report for Week Ending November 19, 1963."

November 12-19

ASPO reviewed Grumman's evaluation of series and parallel propellant feed systems for the LEM ascent stage. Because of the complications involved in minimizing propellant residuals in a parallel system, a series feed appeared preferable, despite an increase in LEM structural weight. Further study of the vehicle showed the feasibility of a two-tank configuration which would be lighter and have about the same propellant residual as the four-tank series-feed arrangement. (See December 17.)

"Monthly Progress Report No. 10," LPR-10-26, p. 16; MSC, "ASPO Status Report for Week Ending November 19, 1963"; "Apollo Quarterly Status Report No. 6," p. 33.

November 13-14

After careful study, Grumman proposed to MSC 15 possible means for reducing the weight of the LEM. These involved eliminating a number of hardware items in the spacecraft; two propellant tanks in the vehicle's ascent stage and consequent changes in the feed system; two rather than three fuel cells; and reducing reaction control system propellants and, consequently, velocity budgets for the spacecraft. If all these proposed changes were made, Grumman advised, the LEM could be lightened significantly, perhaps by as much as 454 kilograms (1000 pounds).

MSC, "ASPO Status Report for Week Ending November 19, 1963."

November 14

ASPO revised the normal and emergency impact limits (20 and 40 g, respectively) to be used as human tolerance criteria for spacecraft design. [These limits superseded those established in the August 14, 1963, North American contract and subsequent correspondence.]

Memorandum, David M. Hammock, MSC, to NAA, Attn: E. E. Sack, "Contract 9-150, Impact Acceleration Limits," November 14, 1963.

November 15

NASA and contractor studies showed that, in the event of an engine hard-over failure during maximum q, a manual abort was impractical for the Saturn I and IB, and must be carried out by automatic devices. Studies were continuing to determine whether, in a similar situation, a manual abort was possible from a Saturn V.

Memorandum, Maxime A. Faget, MSC, to ASPO, Attn: Calvin H. Perrine, "Apollo abort mode in event of maximum 'q' engine hard-over malfunction," November 15, 1963.

November 16-December 15

All production drawings for the CM environmental control system were released. - AiResearch Manufacturing Company reported the most critical pacing items were the suit heat exchanger, cyclic accumulator selector valve, and the potable and waste water tanks.

The Garrett Corporation, AiResearch Manufacturing Division, "Monthly Progress Report, Environmental Control System, NAA/S&ID, Project Apollo, 16 November 1963-15 December 1963," SS-1013-R(19) January 2, 1964, p. 4.

November 16-December 15

North American conducted an eight-day trial of the prototype Apollo diet. Three test subjects, who continued their normal activities rather than being confined, were given performance and oxygen consumption tests and lean body mass and body compartment water evaluations. The results showed insignificant changes in weight and physiology. "Apollo Monthly Progress Report," SID 62-300-20, p. 6.

November 17-December 21

As a result of an MSC Crew Systems Division-Hamilton Standard meeting on the space suit, MSC directed the company to develop a micrometeoroid protective garment to be worn over the suit. (See August 13-20, 1964.)

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, November 17-December 21, 1963," p. 54.

November 19-20

At a meeting of the Apollo Docking Interface Panel, North American recommended and Grumman concurred that the center probe and drogue docking concept be adopted. (See July 16.) MSC emphasized that docking systems must not compromise any other subsystem operations nor increase the complexity of emergency operations. In mid-December, MSC/ASPO notified Grumman and North American of its agreement. At the same time, ASPO laid down docking interface ground rules and performance criteria which must be incorporated into the spacecraft specifications.

There would be two ways for the astronauts to get from one spacecraft to the other. The primary mode involved docking and passage through the transfer tunnel. An emergency method entailed crew and payload transfer through free space. The CSM would take an active part in translunar docking, but both spacecraft must be able to take the primary role in the lunar orbit docking maneuver. A single crewman must be able to carry out the docking maneuver and crew transfer.

MSC, "ASPO Status Report for Week Ending December 4, 1963"; "ASPO Status Report for Week Ending December 17, 1963"; "Apollo Monthly Progress Report," SID 62-300-20, pp. 7, 8, 18; "Apollo Quarterly Status Report No. 6," pp. 3-4.

November 21

MSC approved Grumman's \$19,383,822 cost-plus-fixed-fee subcontract with Rocketdyne for the LEM descent engine development program. (See January 30, February 13, and May 1.)

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, November 17-December 21, 1963," p. 42.

November 22

MSC's Space Environment Division (SED) recommended (subject to reconnaissance verification) 10 lunar landing areas for the Apollo program:

1. 36 degrees 55' E. 1 degree 45' N.
2. 31 degrees E. 0 degrees N.
3. 28 degrees 22' E. 1 degree 10' N.
4. 24 degrees 10' E. 0 degrees 10' N.
5. 12 degrees 50' E. 0 degrees 20' N.
6. 1 degree 28'W. 0 degrees 30' S.
7. 13 degrees 15' W. 2 degrees 45' N.
8. 28 degrees 15' W. 2 degrees 45' N.
9. 31 degrees 30' W. 1 degree 05' S.
10. 41 degrees 30'W. 1 degree 10' S.

SED chose these sites on the basis of regional slopes, surface texture and strength, landmarks, isolated features, and the size, shape, and position of the various areas. The list included several sites that the Division had designated earlier in the year.

NASA Project Apollo Working Paper No. 1100, "Environmental Factors Involved in the Choice of Lunar Operational Dates and the Choice of Lunar Landing Sites" (November 22, 1963), pp. 30-33.

November 22

ASPO developed ground rules and guidelines for the Spacecraft Development Test Program being conducted by Grumman, North American, and MIT Instrumentation Laboratory. (See January 3, 1964.)

NAA, "Apollo Spacecraft Development Test Plan," Study Report, SID 64-66-1, February 3, 1964, Vol. I, pp. v, 26, 53-57.

November 27

At its Santa Susana facility, Rocketdyne conducted the first long-duration (508 seconds) test firing of a J-2 engine. In May 1962 the J-2's required firing time was increased from 250 to 500 seconds.

Akens *et al.*, *History of Marshall . . . July 1-December 31, 1963*, Vol. I, p. 242; *Missiles and Rockets*, 13 (December 9, 1963), p. 10; interview, telephone, Erika Fry, Rocketdyne, February 24, 1969.

November 27

ASPO Manager Joseph F. Shea asked NASA Headquarters to revise velocity budgets for the Apollo spacecraft. (Studies had indicated that those budgets could be reduced without degrading performance.) He proposed that the 10 percent safety margin applied to the original budget be eliminated in favor of specific allowances for each identifiable uncertainty and contingency; but, to provide for maneuvers which might be desired on later Apollo missions, the LEM's propellant tanks should be oversized. (See December 1963.)

The ASPO Manager's proposal resulted from experience that had arisen because of unfortunate terminology used to designate the extra fuel. Originally the fuel budget for various phases of the mission had been analyzed and a 10 percent allowance had been made to cover - at that time, unspecified - contingencies, dispersions, and uncertainties. Mistakenly this fuel addition became known as a "10% reserve"! John P. Mayer and his men in the Mission Planning and Analysis Division worried because engineers at North American, Grumman, and NASA had "been freely 'eating' off the so-called 'reserve'" before studies had been completed to define what some of the contingencies might be and to apportion some fuel for that specific situation. Mayer wanted the item labeled a "10% uncertainty."

Shea recommended also that the capacity of the LEM descent tanks be sufficient to achieve an equiperiod orbit, should this become desirable. However, the spacecraft should carry only enough propellant for a Hohmann transfer. This was believed adequate, because the ascent engine was available for abort maneuvers if the descent engine failed and because a low altitude pass over the landing site was no longer considered necessary. By restricting lunar landing sites to the area between ± 5 degrees latitude and by limiting the lunar stay time to less than 48 hours, a one-half-degree, rather than two-degree, plane change was sufficient.

In the meantime, Shea reported, his office was investigating how much weight could be saved by these propellant reductions.

Memorandum, Shea to NASA Headquarters, Attn: Mgr., Apollo Program Office, "Revised Apollo Spacecraft Delta-V Budget," November 27, 1963; memorandum, Christopher C. Kraft, Jr., MSC, to Mgr., ASPO, "Use of 10% 'reserve' delta-V in CSM and LEM delta-V Budgets," October 21, 1963.

November 28

In honor of the late President John F. Kennedy, who was assassinated six days earlier, President Lyndon B. Johnson announced that LOC and Station No. 1 of the Atlantic Missile Range would be designated the John F. Kennedy Space Center (KSC), ". . . to honor his memory, and the future of the works he started . . .," Johnson said. On the following day, he signed an executive order making this change official. With the concurrence of Florida Governor Farris Bryant, he also changed the name of Cape Canaveral to Cape Kennedy.

Angela C. Gresser, "Historical Aspects Concerning the Redesignation of Facilities at Cape Canaveral," KHN-1, April 1964, p. 15; *The New York Times*, November 29, 1963; *The Houston Chronicle*, November 30, 1963.

November 28-December 4

MSC reviewed a North American proposal for adding an active thermal control system to the SM to maintain satisfactory temperatures in the propulsion and reaction control engines. The company's scheme involved two water-glycol heat transport loops with appropriate nuclear heaters and radiators. During December, MSC directed North American to begin preliminary design of a system for earth orbit only. Approval for spacecraft intended for lunar missions was deferred pending a comprehensive review of requirements.

MSC, "ASPO Status Report for Week Ending December 4, 1963"; "Apollo Quarterly Status Report No. 6," p, 15.

November 29

After a meeting with Grumman officials on November 27, ASPO directed the contractor to begin a Grumman-directed Apollo mission plan development study. (See January 16, 1964.)

TWX, Owen E. Maynard, MSC, to GAEC, Attn: R. S. Mullaney, November 29, 1963.

During the Month

MSC directed Grumman to halt work on LEM test article 9, pending determination of its status as a tethered flight vehicle. (See August 1963.) As a result, the proposed flight demonstration of the tether coupler, using an S-64A Skycrane helicopter, was canceled.

"Monthly Progress Report No. 10," LPR-10-26, p. 37.

During the Month

Ames Research Center performed simulated meteoroid impact tests on the Avco Corporation heatshield structure. Four targets of ablator bonded to a stainless steel backup structure were tested. The ablator, in a Fiberglas honeycomb matrix, was 4.369 millimeters (0.172 inch) thick in two targets and 17.424 millimeters (0.686 inch) thick in the other two. Each ablator was tested at 116.48 K (-250 degrees F) and at room temperature, with no apparent difference in damage.

Penetration of the thicker targets was about 13.970 millimeters (0.55 inch). In the thinner targets, the ablator was pierced. Debris tore through the steel honeycomb and produced pinholes on the rear steel sheet. Damage to the ablator was confined to two or three honeycomb cells and there was no cracking or

spalling on the surface.

Tests at Ames of thermal performance of the ablation material under high shear stress yielded favorable preliminary results. MSC," ASPO Status Report for Week Ending December 4, 1963."

During the Month

Verne C. Fryklund of NASA's Manned Space Sciences Division advised Bellcomm of the procedure for determining Apollo landing sites on the moon. The Manned Space Sciences chief outlined an elimination for the site selection process. For the first step, extant selenographic material would be used to pick targets of interest for Lunar Orbiter spacecraft photography. After study of the Lunar Orbiter photography, a narrower choice of targets then became the object of Surveyor spacecraft lunar missions, with final choice of potential landing sites to be made after the Surveyor program. (See December 20.)

The selection criteria at all stages were determined by lunar surface requirements prepared by OMSF. Fryklund emphasized that a landing at the least hazardous spot, rather than in the area with the most scientific interest, was the chief aim of the site selection process.

Memorandum, Verne C. Fryklund, NASA Manned Space Sciences Division, to B. T. Howard, Bellcomm, "Your memorandum of October 31, 1963 about Apollo Landing Sites," November 4, 1963.

December 2

Grumman selected AiResearch Manufacturing Company to supply cryogenic storage tanks for the LEM electrical power system. Final negotiations on the cost-plus-incentive-fee contract were held in June 1964.

On this same date, Grumman concluded negotiations with Allison Division of General Motors Corporation for design and fabrication of the LEM descent engine propellant storage tanks (at a cost of \$5,479,560).

"Apollo Quarterly Status Report No. 6," pp. 30, 32; MSC, "Project Apollo Quarterly Status Report No.8 for Period Ending June 30, 1964," p.38; MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, November 17-December 21, 1963," p. 42.

December 3-5

A design review of the CSM part-task trainer was held at North American. Briefings included general design criteria and requirements, physical configuration, simulation models, and scheduling. The trainer was expected to be operational in December 1964.

"Apollo Monthly Progress Report," SID 62-300-20, pp. 20-21; MSC, "ASPO Status Report for Week Ending December 10, 1963."

December 5

Primarily to save weight, the length of the adapter was shortened to 853 centimeters (336 inches), as recommended by Grumman. (See October 2.)

Letter, Owen E. Maynard, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Line Items 1 and 6, Implementation of Actions Recommended in Apollo Program Systems Meetings," December 5, 1963; TWX, David M. Hammock and Maynard, MSC, to GAEC, Attn: Mullaney, and NAA, Attn: E. E. Sack, December 5, 1963.

December 9

ASPO requested that Grumman make a layout for transmittal to MSFC showing space required in the S-IVB instrument unit for 406.4- and 457-centimeter (160- and 180-inch) cantilevered gears and for 508-centimeter (200-inch)-radius lateral fold gears. (See October 2.)

Letter, Owen E. Maynard, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Implementation of Actions in MSC-MSFC Mechanical Integration Panel," December 9, 1963.

December 10-17

As a result of wind tunnel tests, Langley Research Center researchers found the LEM Little Joe II configuration to be aerodynamically unstable. To achieve stability, larger booster fins were needed. However, bigger fins caused more drag, shortening the length of the flight. MSC was investigating the possibility of using more powerful rocket engines to overcome this performance degradation. (See February 10, 1964.)

"Monthly Progress Report No. 11," LPR-10-27, p. 42; MSC, "ASPO Status Report for Week Ending December 17, 1963."

December 10-17

The MSC Operations Planning Division (OPD) reviewed the operational demands upon the CM from the time of CM-SM separation until splashdown. OPD concluded that the CM should be designed to operate for 45 minutes during this phase of the mission.

MSC," ASPO Status Report for Week Ending December 17, 1963."

December 11

NASA Headquarters approved a \$48,064,658 supplement to the Douglas Aircraft Company, Inc., contract for 10 additional S-IVB stages, four for the Saturn IB and six for the Saturn V missions.

Akens *et al.*, *History of Marshall . . . July 1-December 31, 1963*, Vol. I, p. 69.

December 13

NASA canceled five Ranger flights (numbers 10 through 14) designed to take high-resolution photographs of the lunar surface before impact. [Five Rangers had thus far been launched.] OSS Associate Administrator Homer E. Newell stated that NASA would depend on the remaining four Rangers, the Lunar Orbiters, and the Surveyors for information about the lunar surface. Cancellation of the flights promised to save \$90 million.

NASA News Release 63-276, "NASA Cancels Five Follow-On Rangers," December 13, 1963.

December 15

The Ad Hoc Working Group on Apollo Experiments submitted its final recommendations on what should be Apollo's principal scientific objectives:

1. Examination of the physical and geological properties of the moon in the area surrounding the spacecraft.
2. Geological mapping.
3. Investigations of the moon's interior.
4. Studies of the lunar atmosphere.
5. Radio astronomy from the surface.

This group, which had as its chairman Charles P. Sonett of NASA's Ames Research Center and thus was known as the Sonett Committee, had been formed wholly within NASA for just this purpose. Much of the Sonett Committee's report already was contained in the Office of Space Sciences' guidelines transmitted earlier to MSC (see October 8); their reception was not what one could call enthusiastic.

"Final Report of the Ad Hoc Working Group on Apollo Experiments and Training on the Scientific Aspects of the Apollo Program," December 15, 1963, p. 4; letter, Willis B. Foster, to Associate Administrator for Manned Space Flight, "Apollo Scientific Guidelines," December 19, 1963.

December 16

MSC and the U.S. Air Force Aerospace Medical Division completed a joint manned environmental experiment at Brooks Air Force Base, Tex. After spending a week in a sea-level atmospheric

environment, the test subjects breathed 100 percent oxygen at 3.5 newtons per square centimeter (5 psi) at a simulated altitude of 8,230 meters (27,000 feet) for 30 days. They then reentered the test capsule for observation in a sea-level environment for the next five days. This experiment demonstrated that men could live in a 100 percent oxygen environment under these conditions with no apparent ill effects.

MSC, "Consolidated Activity Report for the Office of the Director, Manned Space Flight, October 20-November 16, 1963," p. 63; *The Houston Chronicle*, November 4, 1963; *Missiles and Rockets*, 13 (November 11, 1963), p. 31; *The Evening Star*, Washington, December 17, 1963.

December 16

To ensure MSC's use of its manpower resources to the fullest extent possible, the Engineering and Development Directorate (EDD) assigned a subsystem manager to each of the major subsystems in the Apollo program. EDD provided such support as was needed for him to carry out his assignment effectively. These subsystem managers were responsible to ASPO for the development of systems within the cost and schedule constraints of the program. Primary duties were management of contractor efforts and testing.

MSC, "Apollo Subsystem Management Plan," December 16, 1963.

December 16

General Dynamics Corporation announced the receipt of a contract (worth about \$4 million) from the Philco Corporation for fabrication of the computer display equipment for the Integrated Mission Control Center at MSC.

Wall Street Journal, December 16, 1963.

December 16

ASPO concurred in Grumman's recommendation to delete the redundant gimbal actuation system in the LEM's descent engine. A nonredundant configuration would normally require mission abort in case of actuator failure. Consequently, in making this change, Grumman must ensure that mission abort and the associated staging operation would not compromise crew survival and mission reliability.

Letter, Owen E. Maynard, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Item 2, Descent Engine Gimbal Drive Actuator," December 16, 1963.

December 16-January 15

Phase I of the Apollo manned centrifuge program was completed at the U.S. Navy Aerospace Medical

Acceleration Laboratory, Philadelphia, Pa. The tests pointed up interface problems between couch, suit, and astronaut. For example, pressurizing the suit increased the difficulty of seeing the lower part of the instrument panel. The test fixture was disassembled and the couch, framework, and empty instrument panel were shipped to International Latex Corporation to serve as a mockup for further study.

"Apollo Monthly Progress Report," SID 62-300-21, p. 6.

December 16-January 15

North American completed a study to determine, for automatic modes of reentry, adequacy of the current CM reaction control system (RCS) and compatibility of the RCS with other reentry subsystems.

Ibid., p. 8.

December 16-January 15

MSC directed North American to redesign the CM environmental control system compressor to provide 0.283 cubic meters (10 cubic feet) of air per minute to each space suit at 1.8 newtons per square centimeter (3.5 psi), 16.78 kilograms (37 pounds) per hour total.

Ibid., p. 10.

December 17

Grumman proposed a two-tank ascent stage configuration for the LEM. (See November 12-19.) On January 17, 1964, ASPO formally concurred and authorized Grumman to go ahead with the design. The change was expected to reduce spacecraft weight by about 45 kilograms (100 pounds) and would make for a simpler, more reliable ascent propulsion system. ASPO also concurred in the selection of titanium for the two propellant tanks.

"Monthly Progress Report No. 11," LPR-10-27, p. 1; letter, William F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, LEM Program Review," January 17, 1964.

December 18-January 14

MSC directed North American to assign bioinstrumentation channels to the CM for early manned flights for monitoring the crew's pulse rate, blood pressure, respiration, and temperature. These readings could be obtained simultaneously on any one crew member and by switching from man to man for monitoring the entire crew.

MSC, "ASPO Status Report for Period December 18-January 14, 1964."

December 18-January 14

The System Engineering Division (SED) examined the feasibility of performing an unmanned earth orbital mission without the guidance and navigation system. SED concluded that the stabilization and control system could be used as an attitude reference for one to two orbits and would have accuracies at retrofire suitable for recovery. The number of orbits depended upon the number of maneuvers performed by the vehicle, since the gyros tended to drift.

Ibid.

December 19

Pratt and Whitney Aircraft delivered the first three prototype-A fuel cells to North American.

"Apollo Monthly Progress Report," SID 62-300-21, p. 11.

December 20

MSC announced that Grumman and Hamilton Standard had signed an \$8,371,465 definitive contract for the LEM environmental control system. A go-ahead had been issued to Hamilton Standard on July 23.

MSC News Release 63-257, December 20, 1963; *The Houston Post*, December 22, 1963

December 20

NASA selected The Boeing Company to build five Lunar Orbiter spacecraft. (See August 30.) Beginning in 1966, Lunar Orbiters would take close-range photographs of the moon and transmit them by telemetry back to earth. The spacecraft would also detect radiation and micrometeoroid density and supply tracking data on the gravitational field of the moon. Information derived from the project (managed by Langley Research Center) would aid in the selection of lunar landing sites. (See November 1963 and May 8, 1964.)

NASA News Release 63-280, "NASA to Negotiate with Boeing for Lunar Orbiter," December 20, 1963.

December 20-January 18

MSC awarded the U.S. Army Corps of Engineers contracts valued at \$4,211,377 (to be subcontracted to W. S. Bellows Construction Corporation and Peter Kiewit and Sons, Inc.) for the construction of the MSC Mission and Training Facility and for additions to several existing facilities at the Center.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space

Flight, December 22, 1963-January 18, 1964," p. 38; MSC News Release 64-46, March 5, 1964; *The Houston Post*, January 9, 1964.

December 21

MSC defined the LEM terminal rendezvous maneuvers. That phase of the mission would begin at a range of 9.3 kilometers (five nautical miles) from the CSM and terminate at a range of 152.4 meters (500 feet). Before rendezvous initiation, closing velocity should be reduced to 61 meters (200 feet) per second by use of the ascent engine. The reaction control system should be used exclusively thereafter.

Letter, Owen E. Maynard, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Definition of LEM Terminal Rendezvous Model," December 21, 1963.

December 23

Motorola, Inc., received a follow-on contract from the Jet Propulsion Laboratory for the manufacture and integration of at least three S-band receiving subsystems for NASA's Deep Space Network and Manned Space Flight Network ground stations. Within the unified S-band system adopted by NASA, receiving equipment of the two networks would be identical except for a slight difference in operating frequency. This enabled all communications between ground stations and spacecraft to be on a single frequency. It also allowed more efficient power transfer between the directive antennas and the spacecraft and would greatly reduce galactic noise encountered with UHF frequencies.

NASA News Release 63-284, "Motorola to Make S-Band Radio Receiving Equipment for NASA Ground Stations," December 23, 1963.

December 29-January 4

Based upon centrifuge test results, MSC directed Hamilton Standard to modify the space suit helmet. The vomitus port and other obstructions to the line of sight in the downward direction were deleted.

MSC, "Weekly Activity Report for the Office of the Director, Manned Space Flight, December 29, 1963-January 4, 1964," p. 4.

December 31

NASA announced the appointment of Air Force Brig. Gen. Samuel C. Phillips as Deputy Director of the NASA Headquarters Apollo Program Office. General Phillips assumed management of the manned lunar landing program, working under George E. Mueller, Associate Administrator of Manned Space Flight and Director of the Apollo Program Office.

NASA News Release 63-287, "NASA Appoints General Phillips to Assist in Apollo Program

Management," December 31, 1963.

During the Month

MSC decided to supply television cameras for the LEM as government-furnished items. Grumman was ordered to cease its effort on this component.

Resizing of the LEM propulsion tanks was completed by Grumman. The cylindrical section of the descent tank was extended 34.04 millimeters (1.34 inches), for a total of 36.27 centimeters (14.28 inches) between the spherical end bells. The ascent tanks (two-tank series) were 1240.54 centimeters (48.84 inches) in diameter.

"Monthly Progress Report No. 11," LPR-10-27, pp. 18, 30.

During the Month

RCA, contractor to Grumman for the LEM rendezvous and landing radars, chose Ryan Aeronautical Company as vendor for the landing radar. The contract was signed March 16, 1964.

"Apollo Quarterly Status Report No. 6," p. 34.

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January 3

North American, Grumman, and MIT Instrumentation Laboratory summarized results of a six-week study, conducted at ASPO's request, on requirements for a Spacecraft Development Program. Purpose of the study was to define joint contractor recommendations for an overall development test plan within resource constraints set down by NASA. ASPO required that the plan define individual ground test and mission objectives, mission descriptions, hardware requirements (including ground support equipment), test milestones, and individual subsystem test histories.

Intermediate objectives for the Apollo program were outlined: the qualification of a manned CSM capable of earth reentry at parabolic velocities after an extended space mission; qualification of a manned LEM both physically and functionally compatible with the CSM; and demonstration of manned operations in deep space, including lunar orbit. The most significant basic test plan objective formulated during the study was the need for flexibility to capitalize on unusual success or to compensate for unexpected difficulties with minimum impact on the program.

Only one major issue in the test plan remained unresolved - lunar descent radar performance and actual lunar touchdown. Two possible solutions were suggested:

1. Landing of an unmanned spacecraft. If this failed, however, there would be little or no gain, since there was not yet a satisfactory method for instrumenting the unmanned vehicle for necessary failure data. If the landing were successful, it would prove only that the LEM was capable of landing at that particular location.
2. Designing the LEM for a reasonably smooth surface. This would avoid placing too stringent a requirement on the landing criteria to accommodate all lunar surface unknowns. A block change to the LEM design could then be planned for about mid-1966. By that time, additional lunar data from Ranger, Surveyor, and Lunar Orbiter flights would be available. The group agreed the second solution was more desirable.

The contractors recommended:

1. ASPO concur with the proposed plan as a planning basis for implementation;
2. ASPO issue a Development Test Plan to all three contractors (preferably within 30 to 60-days);
3. each contractor analyze the effect of the plan upon spacecraft, facility, and equipment contracts; and
4. ASPO and the contractors conduct periodic reviews of the plan once it was formalized.

In addition, the test plan should be coordinated with the lunar landing mission study, as well as development testing and systems engineering for the complete Apollo program.

The complete findings of this joint study were contained in a five-volume report issued by North American and submitted to MSC early in February 1964. [This document became known informally as the "Project Christmas Present Report."]

"Apollo Spacecraft Development Test Plan," SID 64-66-1, Vol. I, pp. v, 1, 3-5, 195-197.

January 3

MSC forwarded a \$1.4 million contract to Control Data Corporation for two computer systems and peripheral equipment which would be supplied to GE as part of the preflight acceptance checkout equipment.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, December 22, 1963-January 18, 1964," p. 39.

January 7

ASPO directed Grumman to implement a number of recommendations on space suit oxygen umbilical hoses discussed at a joint Grumman/North American meeting and forwarded to ASPO on December 4, 1963:

1. adopt a design that would permit use of CM hose sets in the LEM after crew transfer;
2. place connectors on short hoses permanently attached to the suit, because suit vision and arm mobility did not permit use of on-suit connectors;
3. determine exact placement and hose angles to route the suit portable life support system umbilicals between the legs of the suit;
4. build the "buddy concept" into the umbilical design by ensuring that one of the LEM hoses had valve and safety provisions; and
5. design the CM and LEM oxygen hose umbilicals to be interchangeable. (MSC would select a contractor for the connectors.)

MSC "ASPO Status Report for Week Ending December 10, 1963"; TWX, William F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Space Suit Oxygen Umbilical Hoses," January 7, 1964.

January 8

MSC directed Grumman to integrate LEM translation and descent engine thrust controllers. The integrated controller would be lighter and easier to install; also it would permit simultaneous reaction control system translation and descent engine control. Grumman had predicted that such a capability might be required for touchdown.

MSC, "ASPO Status Report for Week Ending January 7, 1963."

January 10

The Flight Data Systems Branch of the Engineering and Development Directorate provided ASPO's Lunar Mission Planning Branch with information about the LEM extravehicular suit telemetry and communications system. No line of sight (LOS) communications were possible, and there would be no ground wave propagation and no atmospheric reflection. The link between astronaut and LEM would be limited to LOS of the two antennas, and surface activities by an extravehicular astronaut must be planned accordingly.

Memorandum, Ragan Edmiston, MSC, to Richard H. Kohrs, "Lunar transmission range for Astro/LEM communications link," January 10, 1964.

January 11

Three U. S. Air Force test pilots began a five-week training period at the Martin Company leading to their participation in a simulated seven-day lunar landing mission. This was part of Martin's year-long study of crew performance during simulated Apollo missions (under a \$771,000 contract from NASA).

The Houston Post, January 13, 1964; *The Houston Chronicle*, January 13, 1964.

January 14

Based on the LEM mockup review of September 16-18, 1963, MSC established criteria for redundancy of controls and displays in the LEM crew station. Within the framework of apportioned reliability requirements for mission success and crew safety, these guidelines applied:

1. the LEM must be provisioned so that hover to touchdown could be flown manually by the crew;
2. no single failure in the controls and displays should cause an abort; and
3. the unknowns associated with lighting conditions or dust caused by rocket exhaust impingement on the lunar surface might require a joint effort by the crew.

Although duplication of all equipment was not required, dual flight controls and windows, as well as gross attitude, attitude error, and vehicle rates information, were necessary. Other flight displays should be dual or be readable from either station.

Letter, William F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Requirements for Dual Flight Controls and Displays in the LEM," January 14, 1964.

January 14

At an MSC-North American meeting, spacecraft communications problems were reviewed. Testing had indicated that considerable redesign was essential to ensure equipment operation in a high-humidity environment. Also antenna designs had created several problem areas, such as the scimitar antenna's causing the CM to roll during reentry. The amount of propellant consumed in counteracting this roll exceeded reentry allowances. Further, because the CM could float upside down, the recovery antenna might be pointed at the ocean floor. In fact, many at this meeting doubted whether the overall communications concept was satisfactory "without having detailed ground receiver characteristics." The situation derived from "one of the primary problems in the area of communications system design . . . the lack of functional requirements specifications."

"Minutes of NASA-NAA Technical Management Meeting, January 14-15, 1964," p. 4.

January 15

MSC and Bellcomm agreed upon a plan for testing the Apollo heatshield under reentry conditions. Following Project Fire and Scout tests, the Saturn IB would be used to launch standard "all-up" spacecraft into an elliptical orbit; the SM engine would boost the spacecraft's velocity to 8,839 meters

(29,000 feet) per second. Two flights were scheduled, one a test of ablator performance and the other a long-range flight to achieve a high total heat load and assess the interaction of the ablator, its backup structure, and other related structural members. This degree of heat rate and loading would permit "demonstration" rather than "development" tests on the Saturn V.

Memorandum, Robert O. Piland, MSC, to Joseph F. Shea, "Apollo Reentry Testing," January 16, 1964.

January 15

The first fuel cell module delivered by Pratt and Whitney Aircraft to North American was started and put on load. The module operated normally and all test objectives were accomplished. Total operating time was four hours six minutes, with one hour at each of four loads-20, 30, 40, and 50 amperes. The fuel cell was shut down without incident and approximately 1,500 cubic centimeters (1.6 quarts) of water were collected.

"Apollo Monthly Progress Report," SID 62-300-21, p. 11.

January 15

Bendix Products Aerospace Division was awarded a 99973 contract by MSC to study crushable aluminum honeycomb, a lightweight, almost non-elastic, shock-absorbing material for LEM landing gears. Bendix would test the honeycomb structures in a simulated lunar environment.

MSC News Release 64-9, January 15, 1964.

January 15-23

MSC's Systems Engineering Division met with a number of astronauts to get their comments on the feasibility of the manual reorientation maneuver required by the canard abort system concept. (See November 12, 1963.) The astronauts affirmed that they could accomplish the maneuver and that manual control during high-altitude aborts was an acceptable part of a launch escape system design. They pointed out the need to eliminate any possibility of sooting of the windows during normal and abort flight. Although the current design did not preclude such sooting, a contemplated boost protective cover might satisfy this requirement.

MSC, "ASPO Status Report for Week Ending January 23, 1964."

January 15-23

ASPO asked the Flight Crew Operations Directorate to study whatever was necessary to ensure that the LEM crew could reorient their spacecraft manually in an abort 36,600 meters (120,000 feet) above the moon.

Ibid.

January 15-23

MSC's Center Medical Office was reevaluating recommendations for LEM bioinstrumentation. The original request was for three high-frequency channels (two electrocardiogram and one respiration) that could be switched to monitor all crew members. Grumman wanted to provide one channel for each astronaut with no switching.

Ibid.

January 15-23

ASPO and the Astronaut Office agreed to provide the crew with food that could be eaten in a liquid or semi-liquid form during emergency pressurized operation. This would permit considerable reduction in the diameter of the emergency feeding port in the helmet visor.

Ibid.

January 16

Representatives of Grumman, MSC's Instrumentation and Electronics Systems Division, ASPO, and Resident Apollo Spacecraft Program Office (RASPO) at Bethpage met at Grumman to plan the LEM's electrical power system. The current configuration was composed of three fuel cell generators with a maximum power output of 900 watts each, spiking stabilizing batteries, one primary general-purpose AC inverter, and a conventional bus arrangement. To establish general design criteria, the primary lunar mission of the LEM-10 vehicle was analyzed. This "critical" mission appeared to be the "worst case" for the electrical power system and established maximum power and usage rate requirements.

Those attending the meeting foresaw a number of problems:

- Grumman allowed only 10 percent margin for all contingencies and errors in energy requirements.
- Fuel cells and cryogenic fuels needed testing in a simulated space environment.
- Grumman depended upon its subcontractors to develop component testing procedures.
- Optimum power supply modes and motors for the environmental control system were still to be selected.
- "Essential loads" needed standardizing to allow the proper bus loading structure.
- Proper charging rates and equipment for the portable life support system extravehicular suit batteries needed to be selected.

Memorandum, Donald G. Wiseman, MSC, to Deputy Asst. Dir. for Engineering and Development, "Meetings attended by Instrumentation and Electronics Systems Division personnel at the Grumman Aircraft Engineering Corporation," January 24, 1964.

January 16

Grumman presented to MSC the first monthly progress report on the Lunar Mission Planning Study. (See November 29, 1963.) The planning group, designated the Apollo Mission Planning Task Force (AMPTF), established ground rules and constraints to serve as a base line around which mission flexibilities and contingency analyses could be built. Main topics of discussion at the meeting were the reference mission, study ground rules, task assignments, and future plans. The following week, MSC Flight Operations Directorate provided a reference trajectory for the AMPTF's use. Major constraints were daylight launch, translunar injection during the second earth parking orbit, free-return trajectory, daylight landing near the lunar equator, 24-hour lunar surface staytime, and a water landing on earth. (See May 4.)

MSC, "ASPO Status Report for Week Ending January 23, 1964"; "ASPO Status Report for Period December 18-January 14, 1964."

January 16-February 12

The first full-throttle firing of Space Technology Laboratories' LEM descent engine (being developed as a parallel effort to the Rocketdyne engine) was carried out. The test lasted 214 seconds, with chamber pressures from 66.2 to 6.9 newtons per square centimeter (96 to 10 psi). Engine performance was about five percent below the required level.

MSC, "Monthly ASPO Status Report for Period January 16-February 12, 1964."

January 16-February 15

Two astronauts took part in tests conducted by North American to evaluate equipment stowage locations in CM mockup 2. Working as a team, the astronauts simulated the removal and storage of docking mechanisms. Preliminary results indicated this equipment could be stowed in the sleeping station. When his suit was deflated, the subject in the left couch could reach, remove, and install the backup controllers if they were stowed in the bulkhead, couch side, or headrest areas. When his suit was pressurized, he had difficulty with the bulkhead and couch side locations. The subject in the center couch, whose suit was pressurized, was unable to be of assistance.

NAA, "Apollo Monthly Progress Report," SID 62-300-22, March 1, 1964, p. 6.

January 16-February 15

AiResearch Manufacturing Company reported that it had completed design effort on all components of the CM environmental control system. (See January 23-29.)

The Garrett Corporation, AiResearch Manufacturing Division, "Monthly Progress Report, Environmental Control System, NAA/S&ID, Project Apollo, 16 January 1964-15 February 1964," SS-1013-R(21), February 29, 1964.

January 17

Grumman was studying problems of transmitting data if the LEM missed rendezvous with the CSM after lunar launch. This meant that the LEM had to orbit the moon and a data transmission blackout would occur while the LEM was on the far side of the moon. There were two possible solutions, an onboard data recorder or dual transmission to the CSM and the earth. This redundancy had not previously been planned upon, however.

Memorandum, Donald G. Wiseman, MSC, to Deputy Asst. Dir. for Engineering and Development, "Meetings attended by Instrumentation and Electronics Systems Division personnel at the Grumman Aircraft Engineering Corporation," January 24, 1964,

January 17

A design review of the CM reaction control system (RCS) was held. Included was a discussion of possible exposure of the crew to hazardous fumes from propellants if the RCS ruptured at earth impact. For the time being, the RCS design would not be changed, but no manned flights would be conducted until the matter had been satisfactorily resolved. A detailed study would be made on whether to eliminate, reduce, or accept this crew safety hazard.

"Apollo Monthly Progress Report," SID 62-300-22, p. 22.

January 19

NASA assigned George M. Low to the position of Deputy Director of MSC. He would replace James C. Elms, who had resigned on January 17 to return to private industry. Although Low continued as Deputy Associate Administrator for Manned Space Flight at NASA Headquarters until May 1, he assumed his new duties at MSC the first part of February.

MSC News Release 64-13, January 17, 1964; NASA News Release 64-13, "NASA Names Low Deputy Director of Manned Spacecraft Center," January 19, 1964.

January 21

North American gave a presentation at MSC on the block change concept with emphasis on Block II CSM changes. These were defined as modifications necessary for compatibility with the LEM, structural changes to reduce weight or improve CSM center of gravity, and critical systems changes. [Block I spacecraft would carry no rendezvous and docking equipment and would be earth-orbital only. Block II

spacecraft would be flight-ready vehicles with the final design configuration for the lunar missions.] (See February 13-20 and April 16, 1964.)

"Apollo Monthly Progress Report," SID 62-300-22, pp. 1-2.

January 22

Representatives of MSC, North American, Collins Radio Company, and Motorola, Inc., met in Scottsdale, Ariz., to discuss a proposed redesign of the unified S-band to make it compatible with the Manned Space Flight Network. To ensure that there would be no schedule impact, North American proposed only a limited capability on the Block I vehicles. MSC deferred a decision on the redesign pending equipment compatibility tests at Motorola; spacecraft network compatibility tests by MSC, North American, and the Jet Propulsion Laboratory; and cost analyses.

MSC, "ASPO Status Report for Period January 23-29, 1964;" "ASPO Status Report for Period January 30- February 5, 1964;" "Apollo Monthly Progress Report," SID 62-300-22, p. 10.

January 23

NASA and North American discussed visibility requirements on the CM and came to the following conclusions: the contractor would provide four portholes in the protective shroud so the astronauts could see through both side and forward viewing windows, and ensure that all windows were clean after launch escape tower separation. North American proposed the addition to Block II CM of a collimated optical device for orientation and alignment during docking. MSC Flight Crew Operations Directorate recommended that mirrors be added to increase external and internal field of vision.

MSC, "Minutes, Project Apollo Window and Vision Requirements Meeting, January 23, 1964," January 24, 1964; MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, January 19-February 15, 1964," pp. 29-30; MSC, "ASPO Status Report for Period January 23-29, 1964."

January 23

MSC issued a \$9.2 million contract amendment to North American for the construction and modification of buildings at Downey, Calif., and for research and development work on the CM.

MSC News Release 64-17, January 23, 1964.

January 23-29

The AiResearch Manufacturing Company began qualification testing of the first group of components of the CM environmental control system.

MSC, "ASPO Status Report for Period January 30-February 5, 1964"; "Monthly Progress Report, Environmental Control System," SS-1013-R(21), p. 2.

January 24

The second phase of docking simulation studies ended at North American- Columbus (Ohio). Tests included 170 runs simulating transposition and lunar orbital docking with stable and unstable targets, and two extendible probe concepts: cable and rigid boom.

"Apollo Monthly Progress Report," SID 62-300-22, p. 2.

January 24

A design review of crew systems checkout for the CM waste management system was held at North American. As a result, MSC established specific requirements for leakage flow measurement and for checkout at North American and Cape Kennedy. The current capability of the checkout unit restricted it to measuring only gross leakage of segments of the system.

Further analysis of the management system was necessary to determine changes needed in the checkout unit.

Ibid., p. 22.

January 26-February 1

MSC authorized AiResearch Manufacturing Company and the Linde Company to manufacture high-pressure insulated tanks. This hardware, to be available about May 15, would be used in a study of the feasibility of a supercritical helium pressurization system for the LEM.

MSC, "Weekly Activity Report for the Office of the Associate Administrator, Manned Space Flight, January 26-February 1, 1964," p. 11.

January 27

ASPO asked Grumman to study whether attitude control of the docked vehicles was practicable using the LEM's stabilization and control system (RCS). Grumman also was to evaluate the RCS fuel requirements for a five-minute alignment period to permit two star sightings. ASPO further directed the contractor to determine RCS fuel requirements for a second alignment of the LEM's inertial measurement unit during descent coast. This second alignment was needed for the required landing accuracy from a Hohmann descent.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Request for Study of LEM Capability to Stabilize the Command and Service Modules in Lunar Orbit," January 27, 1964.

January 27

Studies on the LEM's capability to serve as the active vehicle for lunar orbit docking showed the forward docking tunnel to be the best means of accomplishing this. ASPO requested Grumman to investigate the possibility of this docking approach and the effect it might have on the spacecraft's configuration.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Effects of Docking Requirements on the LEM Configuration," January 27, 1964.

January 28

The United States and Spain agreed to the construction and operation of a \$1.5 million space tracking and data acquisition station about 48 kilometers (30 miles) west of Madrid, Spain. Spanish firms would construct the storage and other support structures, and Spanish technicians would participate in operating the station. Linked with the NASA Deep Space Instrumentation Facility, the station included a 26-meter (85-foot)-diameter parabolic antenna and equipment for transmitting, receiving, recording, data handling, and communications with the spacecraft. Later, unified S-band equipment was added to join the facility with the Manned Space Flight Network to support the Apollo program.

NASA News Release 64-22, "Spain Becomes Site of Major U.S. Space Tracking Station," January 28, 1964; U.S. Congress, *Eleventh Semiannual Report to Congress*, House Doc. No. 63, 98th Cong., 1st Sess. (January 26, 1965), p. 146.

January 29

SA-5, a vehicle development flight, was launched from Cape Kennedy Complex 37B at 11:25:01.41, e.s. t. This was the first flight of the Saturn I Block II configuration (i.e., lengthened fuel tanks in the S-1 and stabilizing tail fins), as well as the first flight of a live (powered) S-IV upper stage. The S-1, powered by eight H-1 engines, reached a full thrust of over 680,400 kilograms (1.5 million pounds) the first time in flight. The S-IV's 41,000 kilogram (90,000-pound-thrust cluster of six liquid-hydrogen RL-10 engines performed as expected. The Block II SA-5 was also the first flight test of the Saturn I guidance system.

MSFC, Results of the Fifth Saturn I Launch Vehicle Test Flight, SA-5 (MPR-SAT-FE-64-17, September 22, 1964), pp. 1-5, 8, 82, 85; Missiles and Rockets, 14 (February 3, 1964), pp. 17-18.

January 29

NASA announced the award of a \$1.356 million contract to the Blaw-Knox Company for design and construction of three parabolic antennas, each 26 meters (85 feet) in diameter, for the Manned Space Flight Network stations at Goldstone, Calif.; Canberra, Australia; and near Madrid, Spain.

Missiles and Rockets, 14 (February 10, 1964), p. 42; *Astronautics and Aeronautics, 1964* (NASA SP-4005, 1965), p. 33.

January 30

NASA launched Ranger VI from Cape Kennedy. (See December 19, 1962.) The probe, which sought to obtain television pictures of the lunar surface, landed in the moon's Sea of Tranquillity on February 2. Despite being the subject of an intensive quality and reliability testing program, Ranger VI was a failure - no pictures were obtained. The cause was believed to exist in the power system for the spacecraft's television cameras.

Astronautics and Aeronautics, 1964, pp. 34-35, 41; Henry L. Richter, Jr., (ed.), *Space Measurements Survey: Instruments and Spacecraft, October 1957-March 1965* (NASA SP-3028), p. 468.

January 30-February 5

MSC and North American representatives discussed preliminary analysis of the probabilities of mission success if the spacecraft were hit by meteoroids. The contractor believed that pressurized tankage in the SM must be penetrated before a failure was assumed. To MSC, this view appeared overly optimistic. MSC held that, as the failure criterion, no debris should result from meteoroid impact of the SM outer structure. [This change in criteria would cost several hundred pounds in meteoroid protection weight in the SM and LEM.] North American thought that penetration of one half the depth of the heatshield on the conical surface of the CM was a failure. Here, MSC thought the contractor too conservative; full penetration could probably be allowed.

MSC, "ASPO Status Report for Period January 30-February 5, 1964."

During the Month

Grumman began initial talks with Bell Aerosystems Company looking toward concentrating on the all-ablative concept for the LEM's ascent engine, thus abandoning the hope of using the lighter, radiatively cooled nozzle extension. (See September 19-October 16, 1963; also May 4-11.) These talks culminated in July, when Bell submitted to Grumman a revised development and test plan for the engine, now an all-ablative design.

GAEC, "Monthly Progress Report No. 12," LPR-10-28, February 10, 1964, p. 16; GAEC, "Monthly Progress Report No. 18," LPR-10-34, August 10, 1964, p. 5.

February 1

At an Apollo Program Review held at MSC, Maxime A. Faget reported that Crew Systems Division had learned that the metabolic rate of a man walking in an unpressurized suit was twice that of a man in everyday clothes. When the suit was pressurized to 1.8 newtons per square centimeter (3.5 psi), the rate was about four times as much. To counteract this, a watercooled undergarment developed by the British Ministry of Aviation's Royal Aircraft Establishment was being tested at Hamilton Standard. These "space-age long johns" had a network of small tubes through which water circulated and absorbed body heat. Advantages of the system were improved heat transfer, low circulating noise levels, and relatively moderate flow rates required. An MSC study on integration of the suit with the LEM environmental control system showed a possible weight savings of 9 kilograms (20 pounds).

NASA, "Apollo, Program Review Document, February 1, 1964," p. 109; MSC, "Monthly ASPO Status Report for Period January 16-February 12, 1964"; *Space Business Daily*, February 3, 1964; MSC, "ASPO Status Report for Period February 13-20, 1964"; *Aviation Week and Space Technology*, 80 (February 17, 1964), p. 29; MSC, "ASPO Status Report for Period Ending February 27-March 4, 1964"; TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, March 2, 1964.

February 3

Fourteen new astronauts, chosen in October 1963, reported at MSC for training for the Gemini and Apollo programs. (See October 18, 1963.)

MSC News Release 64-24, February 3, 1964.

February 4

MSC and MSFC officials discussed development flight tests for Apollo heatshield qualification. Engineers from the Houston group outlined desired mission profiles and the number of missions needed to qualify the component. MSFC needed this information to judge its launch vehicle development test requirements against those of MSC to qualify the heatshield. By the middle of the month, Richard D. Nelson of the Mission Planning and Analysis Division (MPAD) had summarized the profiles to be flown with the Saturn V that satisfied MSC's needs. Nelson compiled data for three trajectories that could provide reentry speeds of around 11,000 meters (36,000 feet) per second, simulating lunar return. As an example, "Trajectory 1" would use two of the booster's stages to fire into a suborbital ballistic path, and then use a third stage to accelerate to the desired reentry speed.

Flight profiles for Saturn IB missions for heatshield qualification purposes proved to be a little more difficult because "nobody would or could define the requirements or constraints, or test objectives." In other words, MSFC requirements for booster development test objectives and those of MSC for the spacecraft heatshield conflicted. So compromises had to be forged. Finally Ted H. Skopinski and other members of MPAD bundled up all of ASPO's correspondence on the subject generated from the various

pertinent sources: MSFC, MSC, and contractors. From this, the Skopinski group drafted "broad term test objectives and constraints" for the first two Saturn IB flights (missions 201 and 202). Generally, these were to man-rate the launch vehicle and the CSM and to "conduct entry tests at superorbital entry velocities" (8,500 to 8,800 meters per second) (28,000 to 29,000 feet per second). Skopinski also enumerated specific test objectives covering the whole spacecraft-launch vehicle development test program. These were first distributed on March 27, and adjustments were made several times later in the year.

MSC," ASPO Status Report for Period January 30-February 5, 1964"; memorandum, Carl R. Huss, MSC, to BE4/Historical Office, "Comments on Volume II of *The Apollo Spacecraft: A Chronology*," March 30, 1970; memorandum, Richard D. Nelson, MSC, to Chief, Mission Planning and Analysis Division, "Mission profiles for Saturn V superorbital heat shield qualification test," February 13, 1964; memorandum, Ted H. Skopinski, MSC, to Distr., "Summary of broad term test objectives and constraints for Saturn IB development missions 201 and 202," March 27, 1964; memorandum, E. D. Murrah and R. E. McAdams, MSC, to Distr., "Possible change in trajectory profile for Apollo mission SA-201," September 29, 1964; memorandum, McAdams, to Distr., "Revised preliminary trajectory profile for Apollo Mission SA-201," October 19, 1964; memorandum, McAdams, to Distr., "Preliminary Reference Trajectory for Apollo Mission SA-201," October 26, 1964.

February 6

Minneapolis-Honeywell Regulator Company reported it had developed an all-attitude display unit for the CM to monitor the guidance and navigation system and provide backup through the stabilization and control system. The Flight Director Attitude Indicator (or "eight-ball") would give enough information for all spacecraft attitude maneuvers during the entire mission to be executed manually, if necessary.

Honeywell News Release, "All-Attitude Display Produced By Honeywell For Apollo Spacecraft," February 6, 1964; *Space Business Daily*, February 24, 1964, p. 290.

February 7

Grumman received MSC's response to the "Project Christmas Present Report" (see January 3), and accordingly reevaluated its testing concept for the LEM. On February 19, the contractor proposed to ASPO Manager Joseph F. Shea a flight program schedule, which was tentatively approved. ASPO's forthcoming proposal was identical to Grumman's proposal. It called for 11 LEMs (which were now renumbered consecutively) and two flight test articles. All LEMs were to have full mission capability, but numbers one through three had to be capable of either manned or unmanned flight.

GAEC, "Monthly Progress Report No. 13," LPR-10-29, March 10, 1964, p. 35; "Monthly Progress Report No. 14," LPR-10-30, p. 36.

February 7

Engineers from ASPO and Engineering and Development Directorate (EDD) discussed the current status of the tower flap versus the canard launch escape vehicle (LEV) configurations. (See November 12, 1963.) Their aim was to select one of the two LEV configurations for Block I spacecraft. (See February 25.) ASPO and EDD concluded that the canard was aerodynamically superior; that arguments against the canard, based on sequencing, mechanical complexity, or schedule effect, were not sufficient to override this aerodynamic advantage; and that this configuration should be adopted for Block I spacecraft. However, further analysis was needed to choose the design for the Block II LEV.

Memorandum, Calvin H. Perrine, Jr., MSC, to Distribution, "Minutes of meeting on tower flap and canards, February 7, 1964," February 12, 1964.

February 7

During a meeting at MSC, North American and MSC Crew Systems Division agreed that there should be a central authority with total cognizance over Gemini and Apollo food and survival equipment, and that all this equipment should be government furnished.

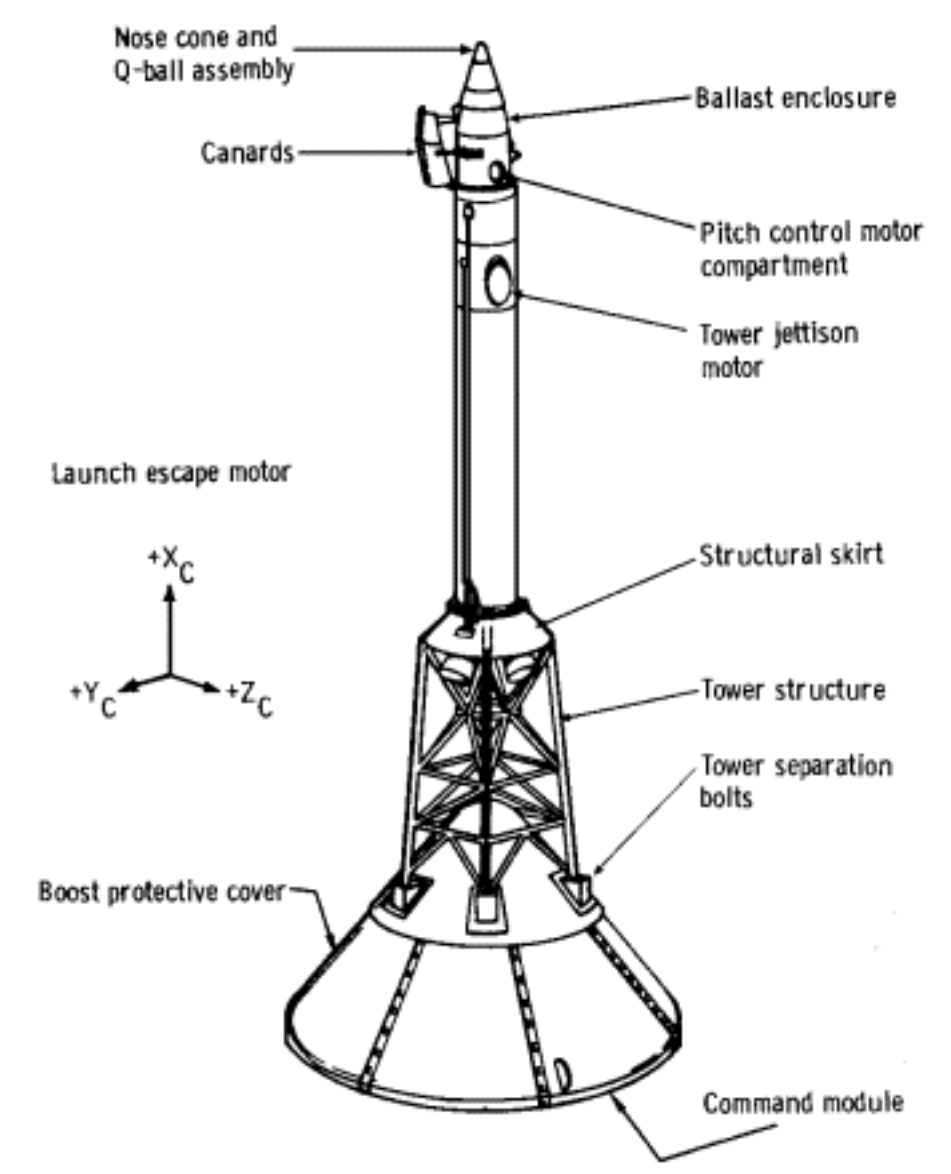
MSC, "Monthly ASPO Status Report for Period January 16-February 12, 1964."

February 10

MSC directed Grumman to stop all work on the LEM Little Joe II program. This action followed the ASPO Manager's decision against a testing program for the LEM comparable to that for the CSM. (See December 10-17, 1963.)

Ibid.; memorandum, Joseph F. Shea, MSC, to Distr., "Cancellation of LEM/LJ II Program," February 10, 1964.

February 11



Launch escape vehicle configuration.

ASPO directed Grumman to provide an abort guidance system (AGS) in the LEM using an inertial reference system attached to the structure of the vehicle. Should the spacecraft's navigation and guidance system fail, the crew could use the AGS to effect an abort. Such a device eliminated the need for redundancy in the primary guidance system (and proved to be a lighter and simpler arrangement).

Letter, Joseph F. Shea, MSC, to GAEC, Attn: R. S. Mullaney, "Abort Guidance System," February 11, 1964; interview, telephone, Enoch M. Jones, Houston, February 27, 1970.

February 12

NASA gave credit to two MSC engineers, George C. Franklin and Louie G. Richard, for designing a

harness system for the LEM that enabled the crew to fly the vehicle from a standing position. Eliminating the seats reduced the LEM's weight and gave the crew better visibility and closer observation of controls and instruments. (See September 16-18, 1963.)

MSC News Release 64-27, February 12, 1964.

February 13

MSC issued Requests for Proposals to more than 50 firms asking for studies and recommendations on how the lunar surface should be explored. Studies should show how lunar surveys could be performed and how points on the lunar surface might be located for future lunar navigation. Maximum use of equipment planned for the LEM and CM was expected. Part of the scientific apparatus aboard the LEM would be selenodetic equipment. The study would not include actual fabrication of hardware but might give estimates of cost and development times.

Space Business Daily, February 13, 1964, p. 238; *ibid.*, March 2, 1964, p. 329.

February 13-19

Boilerplate (BP) 13 spacecraft was flown from North American, Downey, Calif., to MSC's Florida Operations facility at Cape Kennedy, where the vehicle was inspected and checked out. On April 2, the spacecraft and launch escape system were moved to the pad and mated to the launch vehicle, SA-6. After exhaustive testing, a Flight Readiness Review on May 19 established that BP-13 was ready for launch. (See May 28.)

MSC, "Postlaunch Report for Apollo Mission A-101 (BP-13)," MSC-R-A-64-2 (June 18, 1964), pp. 6-1 through 6-4.

February 13-20

The Block II CSM configuration (see January 21) was based on three classes of changes: mandatory changes necessary to meet the

1. Functional requirements of the lunar mission.
2. Manufacturing or fabrication changes (identified only with improved fabrication techniques).
3. Technically desirable and weight reduction changes.

MSC, "ASPO Status Report for Period February 13-20, 1964."

February 14

MSC ordered North American to design the SM's reaction control system with the capability for emergency retrograde from earth orbit.

Letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. One-Hundred, Forty-Seven," February 14, 1964.

February 16-March 15

North American completed its initial phase of crew transfer tests using a mockup of the CM/LEM transfer tunnel. Subjects wearing pressure suits were suspended and counterbalanced in a special torso harness to simulate weightlessness; hatches and docking mechanisms were supported by counterweight devices. The entire tunnel mockup was mounted on an air-bearing, frictionless table. Preliminary results showed that the crew could remove and install the hatches and docking mechanisms fairly easily.

"Apollo Monthly Progress Report," SID 62-300-23, p. 5.

February 16-March 15

The potable water system was changed to meter both hot and cold water in one-ounce increments to provide accurate measurements for food rehydration. The previous water valve was a full-flow tap.

Ibid., p. 10.

February 16-March 21

MSC gave its formal consent to two of Grumman's subcontracts for engines for the LEM: (1) With Bell Aerosystems for the ascent engine (\$11,205,416 incentive-fee contract) (2) With Space Technology Laboratories for a descent engine to parallel that being developed by Rocketdyne (\$18,742,820 fixed-fee contract). (See May 1963.)

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, February 16-March 21, 1964," p. 45.

February 16-March 21

MSC completed and forwarded to NASA Headquarters a plan for changing the relationship of the navigation and guidance contractors. AC Spark Plug would become the principal contractor, with the Raytheon Company and Kollsman Instrument Corporation as subcontractors. MIT would still have primary responsibility for system design and analysis. (See June 20.)

Ibid.

February 17

MSC announced that, during a 14-day lunar mission, fuel cells in the Apollo CSM would produce about 16 liters (60 gallons) of potable water while furnishing power to operate the electronic equipment.

MSC News Release 64-32, February 17, 1964.

February 17

General Dynamics Convair delivered to White Sands Missile Range (WSMR) the second Little Joe II launch vehicle, the first Little Joe II scheduled to fly with a production Apollo spacecraft. (See May 13.)

MSC, "Postlaunch Report for Apollo Mission A-001 (BP-12)," MSC-R-A-64-1, May 28, 1964, p. 2-1.

February 17

Motorola, Inc., submitted a proposal to NASA for the Apollo Unified S-band Test Program, a series of tests on the unified S-band transponder and premodulation processor. Motorola had already begun test plans, analytical studies, and fabrication of special test equipment. (See December 23, 1963.)

MSC, "ASPO Status Report for Period February 20-26, 1964"; "ASPO Status Report for Period Ending February 27-March 4, 1964."

February 19-20

MSC officials conducted acceptance testing of the 024 prototype space suit at the International Latex Corporation. [Reviewers identified several faults, but they were minor and the suit was accepted.]

MSC, "ASPO Status Report for Period February 20-26, 1964."

February 20-26

Trajectory analyses by North American indicated that, with the tower flap configuration, it was highly probable that crew acceleration limits would be exceeded during high-altitude abort.

MSC, "ASPO Status Report for Period Ending February 27-March 4, 1964."

February 20-26

North American submitted to ASPO a proposal for dynamic testing of the docking subsystem, which called for a full-scale air-supported test vehicle. The contractor estimated the program cost at \$2.7

million for facilities, vehicle design, construction, and operation.

MSC, "ASPO Status Report for Period February 20-26, 1964."

February 20-26

ASPO decided upon transfer through free space as the backup mode for the crew's getting from the LEM back to the CM if the two spacecraft could not be pressurized. North American had not designed the CM for extravehicular activity nor for passage through the docking tunnel in a pressurized suit. Thus there was no way for the LEM crew to transfer to the CM unless docking was successfully accomplished. ASPO considered crew transfer in a pressurized suit both through the docking tunnel and through space to be a double redundancy that could not be afforded.

Ibid.

February 20-26

North American conducted three tests (4, 20, and 88 hours) on the CSM fuel cell. The third ended prematurely because of a sudden drop in output. (Specification life on the modules was 100 hours.)

During this same week, Pratt and Whitney Aircraft tested a LEM-type fuel cell for 400 hours without shutdown and reported no leaks.

Ibid.

February 20-26

Grumman completed negotiations with Bell Aerosystems Company for the LEM's reaction control system propellant tanks.

Ibid.

February 22

George E. Mueller, NASA Associate Administrator for Manned Space Flight, summarized recent studies of the dangers of meteoroids and radiation in the Apollo program. Data from the *Explorer XVI* satellite and ground observations indicated that meteoroids would not be a major hazard. Clouds of protons ejected by solar flares would present a risk to astronauts, but studies of the largest solar flares recorded since 1959 showed that maximum radiation dosages in the CM and the Apollo space suit would have been far below acceptable limits (set in July 1962 by the Space Science Board of the National Academy of Sciences). Cosmic rays would not be a hazard because of their rarity. Radiation in the Van Allen belts

was not dangerous because the spacecraft would fly through the belts at high speeds.

NASA News Release 64-43, "Radiation, Technical Problems Won't Bar Moon Landing in This Decade, Mueller Says," February 22, 1964.

February 24

RCA presented results of a weight and power tradeoff study on the LEM's radar systems, which were over Grumman's specification in varying amounts from 100 to 300 percent. RCA proposed that the accuracy requirements be relaxed to cope with this problem. MSC requested Grumman, on the basis of this report, to estimate a slippage in the schedule and the effects of additional weight and power. (See February 27-March 4.)

MSC, "ASPO Status Report for Period Ending February 27-March 4, 1964."

February 25

At a NASA-North American Technical Management Meeting at Downey, Calif., North American recommended that Apollo earth landings be primarily on water. On the basis of analytical studies and impact tests, the contractor had determined that "land impact problems are so severe that they require abandoning this mode as a primary landing mode." In these landings, North American had advised, it was highly probable that the spacecraft's impact limits would be surpassed. In fact, even in water landings "there may be impact damage which would result in leakage of the capsule." (See March 29-April 4.) ASPO Manager Joseph F. Shea, at this meeting, "stated that MSC concurs that land impact problems have not been solved, and that planning to utilize water impact is satisfactory." (See December 1962; February 1 and March 5, 1963.)

Three days later, Shea reported to the MSC Senior Staff that Apollo landings would be primarily on water. The only exceptions, he said, would be pad aborts and emergency landings. With this question of "wet" versus "dry" landing modes settled, Christopher C. Kraft, Jr., Assistant Director for Flight Operations, brought up the unpleasant problem of the CM's having two stable attitudes while afloat - and especially the apex-down one. This upside-down attitude, Kraft emphasized, submerged the vehicle's recovery antennas and posed a very real possibility of flooding in rough seas. Shea countered that these problems could be "put to bed" by using some type of inflatable device to upright the spacecraft. (See April 15 and August 16-September 15.)

"Minutes of NASA-NAA Technical Management Meeting, February 25, 1964," February 26, 1964, p. 3; MSC, "Minutes of Senior Staff Meeting, February 28, 1964," p. 4.

February 25

Grumman and RCA signed a contract on the LEM communications subsystem. (See June 28, 1963.)

MSC, "ASPO Status Report for Period March 12-18, 1964"; MSC, "Project Apollo Quarterly Status Report No. 7 for Period Ending March 31, 1964," p. 3.

February 25

At a NASA-North American technical management meeting, the tower flap versus canard configuration for the launch escape vehicle was settled. ASPO Manager Joseph F. Shea decided that canards should be the approach for Block I vehicles, with continued study on eliminating this device on Block II vehicles. (See January 18 and November 12, 1963, and February 7, 1964.)

"Minutes of NASA-NAA Technical Management Meeting, February 25, 1964"; "Apollo Monthly Progress Report," SID 62-300-23, p. 3.

February 25

MSC conducted a Design Engineering Inspection of the LEM timing equipment at the Elgin National Watch Company.

MSC, "ASPO Status Report for Period February 20-26, 1964."

February 27

MSC Crew Systems Division (CSD) received an improved version of the Apollo space suit (the A-3H-024 Phase B). In the course of the following week, CSD engineers examined the suit for weight, leakage, donning, and mobility.

MSC, "ASPO Status Report for Period Ending February 27-March 4, 1964."

February 27

Boilerplate (BP) 19 was drop tested at El Centro, Calif., simulating flight conditions and recovery of BP-12. (See May 13) A second BP-19 drop, on April 8, removed all constraints on the BP-12 configuration and earth landing system. Another aim, to obtain information on vehicle dynamics, was not accomplished because of the early firing of a backup drogue parachute.

"Apollo Quarterly Status Report No. 7," p. 5; "Apollo Monthly Progress Report," SID 62-300-23, p. 19; NAA, "Apollo Monthly Progress Report," SID 62-300-24, May 1, 1964, p. 28; MSC, "ASPO Management Report for Period April 9-16, 1964."

February 27-29

MSC and AC Spark Plug negotiated amendments to AC's contract for a research and development program for inertial reference integrating gyroscopes. The amendments covered cost overruns, an additional 30 pieces of hardware, and conversion of the contract to an incentive-fee type (target price, \$3.465 million; ceiling price, \$3.65 million).

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, February 16-March 21, 1964," p. 45; MSC, "ASPO Status Report for Period Ending February 27-March 4, 1964."

February 27-March 4

Representatives from MSC Crew Systems Division (CSD) visited Hamilton Standard to discuss space suit development. The prototype suit (024) was demonstrated and its features compared with the Gemini suit. Deficiencies in the Apollo helmet were noted and suggestions were made on how to improve the design. [At this time, CSD began looking into the possibility of using Gemini suits during Apollo earth orbital flights, and during the next several weeks began testing Gemini suits in Apollo environments. (See April 28-30.)]

MSC, "ASPO Status Report for Period Ending February 27-March 4, 1964;" MSC, "ASPO Management Report for Period April 2-9, 1964."

February 27-March 4

A joint Grumman, RCA, Ryan Aeronautical Company, ASPO, and Flight Crew Support Division (FCSD) meeting was held at Bethpage to review capability of the LEM landing radar to meet FCSD's requirements for ascent and for orbit circularization. A preliminary (unfunded) Ryan study (requested by ASPO earlier in the month) indicated some doubt that those accuracy requirements could be met. RCA advised that it would be possible to make these measurements with the rendezvous radar, if necessary. A large weight penalty, about 38 to 56 kilograms (84 to 124 pounds), would be incurred if the landing radar were moved from the descent to the ascent stage to become part of the abort guidance system. Adding this weight to the ascent stage would have to be justified either by improved abort performance or added crew safety. MSC authorized RCA and Ryan to study this problem at greater length. In the meantime, ASPO and FCSD would analyze weights, radar accuracies, and abort guidance performance capability. (See March 16 and May 22.)

MSC, "ASPO Status Report for Period Ending February 27-March 4, 1964"; "ASPO Status Report for Period March 19-26, 1964."

February 27-March 4

The MSC Primary Propulsion Branch (PPB) completed a study on the current LEM ascent engine and performance that might be gained if the chamber pressure and characteristic exhaust velocity efficiency

were increased. PPB also evaluated the use of hard versus soft chamber throats. A study by Bell Aerosystems Company had predicted a slightly lower performance than the MSC investigation (which estimated a drop of about six points below specification values if the current design were retained). PPB thought that specifications might be reached by increasing the chamber pressure to 82.7 newtons per square centimeter (120 psia) and the exhaust velocity efficiency to 97.3 percent, and by using a hard, rather than a soft, throat.

MSC, "ASPO Status Report for Period Ending February 27-March 4, 1964."

March 2-9

At North American, a mockup of the crew transfer tunnel was reviewed informally. The mockup was configured to the North American-proposed Block II design (in which the tunnel was larger in diameter and shorter in length than on the existing spacecraft). MSC asked the contractor to place an adapter in the tunnel to represent the physical constraints of the current design, which would permit the present design to be thoroughly investigated and to provide a comparison with the Block II proposal.

MSC, "ASPO Status Report for Period Ending March 5-11, 1964."

March 9

MSC received an additional \$1.035 million in Fiscal Year 1964 funds to cover development of equipment and operational techniques for scientific exploration of the moon:

- Power supplies for long-life equipment to be installed on the lunar surface during Apollo missions.
- Telemetry and Deep Space Instrumentation Facility requirements for this equipment.
- Tools and materials needed for examining, packaging, and transporting lunar samples.
- Cameras and film suitable for use on the moon by a space-suited astronaut.
- Methods of obtaining and returning lunar samples without contaminating or changing them.
- Techniques and instrumentation for geological mapping in the lunar environment.
- Processes for obtaining water, hydrogen, and oxygen from indigenous material on the moon.

Additionally, MSC would evaluate current techniques in seismology used to determine subsurface structural conditions.

Memorandum, Homer E. Newell, NASA, to Dir., MSC, through Assoc. Adm. for Manned Space Flight, "Funding for Development of Scientific Instruments for Apollo Lunar Missions," March 9, 1964.

March 10

Grumman completed negotiations with Yardney Electric Corporation for an auxiliary battery for the

LEM. A contract would be awarded when size requirements were determined by Grumman and MSC.

MSC, "ASPO Status Report for Period Ending March 5-11, 1964."

March 10

Grumman and North American began working out ways for common usage of ground support equipment (GSE). Through informal meetings and telephone discussions, the two prime contractors agreed to a formal procedure for the GSE's use, maintenance, and training procedures.

"Monthly Progress Report No. 14," LPR-10-30, p. 32.

March 12

Goddard Space Flight Center awarded a \$1.963 million contract to the Commonwealth of Australia's Department of Supply to construct and install a data acquisition facility, including an antenna 26 meters (85 feet) in diameter, at Canberra, Australia. The station would become part of the NASA Space Tracking and Data Acquisition Network to track unmanned satellites and part of the Deep Space Network to track lunar and planetary probes. Unified S-band equipment was later installed to support the Manned Space Flight Network during Apollo lunar missions.

The New York Times, March 12, 1964; NASA, *Twelfth Semiannual Report to Congress, July 1-December 31, 1964* (1965), pp. 129-130, 134; NASA, *Thirteenth Semiannual Report to Congress, January 1-June 30, 1965* (1966), p. 137; NASA, *Fourteenth Semiannual Report to Congress, July 1-December 31, 1965* (1966), p. 146.

March 12

North American was directed by NASA to study feasibility of using the LEM propulsion system as backup to the SM propulsion system. The most important item in the contractor's analysis was strength of the docking structure and its ability to withstand LEM main-engine and reaction control system thrusting.

Letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. 161," March 12, 1964.

March 12

NASA completed formal negotiations with Aerojet-General Corporation for 12 Algol 1-D solid rocket motors, to be used in the Little Joe II vehicles. The contract was a fixed-price-plus-incentive-fee type with a target price of about \$1.4 million. A maximum price of 20 percent more than the target cost was

allowed.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, February 16-March 21, 1964," p. 46.

March 12-18

Grumman completed negotiations with Kearfott Products Division, General Precision, Inc., for the LEM rate gyro assembly, and a contract was awarded later in the month.

MSC, "ASPO Status Report for Period March 12-18, 1964;" "Apollo Quarterly Status Report No. 7," p. 23.

March 12-18

Primarily as a weight-saving measure, the gas storage pressure in the LEM's descent stage helium tank was reduced from 3,103 to 2,413 newtons per square centimeter (4,500 to 3,500 psia). This allowed the thickness of the tank wall to be reduced.

MSC, "ASPO Status Report for Period March 12-18, 1964;" MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, February 16-March 21, 1964," p. 24.

March 13

ASPO notified Grumman that certain items were no longer to be considered in the weight saving program: guidance and navigation components, drinking water tankage, scientific equipment, pyrotechnic batteries, among others.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, weight reduction items," March 13, 1964.

March 16

Ryan Aeronautical Company signed a contract with RCA for the LEM lunar landing radar. Ryan was instructed to design for altitudes of 21,300 meters (70,000 feet) and accuracies of 0.5 percent. (See February 27-March 4, and May 22.)

MSC, "ASPO Status Report for Period March 19-26, 1964."

March 16-April 15

AiResearch Manufacturing Company completed testing on development components of the CM environmental control system. Specifications for components had been submitted to North American.

The Garrett Corporation, AiResearch Manufacturing Division, "Monthly Progress Report, Environmental Control System, NAA/S&ID, Project Apollo, 16 March 1964-15 April 1964," SS-1013-R (23), April 30, 1964, p. 7.

March 16-April 15

North American held a design review of the CM heatshield substructure. Use of titanium in place of stainless steel was being evaluated as part of a weight reduction study for the Block II spacecraft. Added reliability and a weight saving of several hundred pounds might be achieved thereby. Three factors would be considered: the brittleness of stainless steel at extremely cold temperatures, the higher cost of titanium, and the verification of diffusion bonding of titanium honeycomb.

"Apollo Monthly Progress Report," SID 62-300-24, p. 14.

March 16-April 15

The first prototype of the CM battery for use during reentry was delivered to North American by Eagle-Picher Industries, Inc.

"Apollo Quarterly Status Report No. 7," p. 7; "Apollo Monthly Progress Report," SID 62-300-24, p. 14.

March 17

Texas Instruments, Inc., presented a progress report on their lunar surface experiments study to the MSC Lunar Surface Experiments Panel. (See September 30, 1963.) Thus far, the company had been surveying and rating measurements to be made on the lunar surface. Areas covered included soil mechanics, mapping, geophysics, magnetism, electricity, and radiation. Equipment for gathering information, such as hand tools, sample return containers, dosimeters, particle spectrometers, data recording systems, seismometers, gravity meters, cameras, penetrometers, and mass spectrometers had been considered. The next phase of the study involved integrating and defining the measurements and instruments according to implementation problems, mission needs, lunar environment limitations, and relative importance to a particular mission. Texas Instruments would recommend a sequence for performing the experiments.

Memorandum, H. R. Largent, MSC, to Instrumentation and Electronics Systems Div. Files, "Lunar surface experiments study (NAS 9-2115)," March 17, 1964.

March 19

NASA instructed North American to fix the CM crew couches along all axes during normal and

emergency acceleration, except at impact. During nonacceleration mission phases, the couches would be adjustable for crew comfort.

Letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. 167," March 19, 1964.

March 19-20

Grumman reported to MSC the current load status and projected load growth for the LEM's electrical power system, requesting a mission profile of 121 kilowatt-hours total energy. (See January 28 and August 15, 1963.) The company also presented its latest recommendation for the LEM power generation subsystem configuration: two 900-watt fuel cells, a descent stage peaking battery, an ascent stage survival battery, and four cryogenic storage tanks. To compensate for voltage drops in the power distribution subsystem, Grumman recommended that two cells be added to the current fuel cell stack; however, on March 23 ASPO directed the contractor to continue development of the 900-watt, three-fuel-cell assembly and a five-tank cryogenic storage system. MSC's position derived from the belief that the load growth would make the two-cell arrangement inadequate. Also the three-cell configuration, through greater redundancy, afforded greater safety and chances of mission success: the mission could continue in spite of a failure in one of the cells; should two cells fail, the mission could be aborted on the final power source. The cryogenic tanks should be sized for a usable total energy of 121 kilowatt-hours to permit immediate tank procurement.

MSC, "ASPO Status Report for Period March 19-26, 1964"; letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Electrical Power Generation Section (PGS) Configuration," March 23, 1964; "Apollo Quarterly Status Report No. 7," p. 26; interview, telephone, William E. Rice, MSC, March 2, 1970.

March 19-26

After the decision to use canards instead of tower flaps (see February 25), North American returned to the concept of a hard boost protective cover. The tower jettison motor would remove the cover along with the tower. (See July 24.)

MSC, "ASPO Status Report for Period March 19-26, 1964."

March 19-26

MSC Crew Systems Division (CSD) evaluated a CM couch width of 58.4 centimeters (23 inches). CSD found that the couch hampered an astronaut's movement in an unpressurized suit and totally restricted him if his suit was pressurized.

Ibid.

March 20

NASA's Office of Space Science and Applications began organizing several groups of scientists to assist the agency in defining more specifically the scientific objectives of Project Apollo. (See October 8 and December 15, 1963.) In a number of letters to prominent American scientists, Associate Administrator for Space Science and Applications Homer E. Newell asked them to propose suitable experiments in such fields as geology, geophysics, geochemistry, biology, and atmospheric science. This broadly based set of proposals, Newell explained, is "for the purpose of assuring that the final Apollo science program is well balanced, as complete as possible, and that all potential investigators have been given an opportunity to propose experiments." The proposals would then be reviewed by subcommittees of NASA's Space Sciences Steering Committee.

Letter, Homer E. Newell, NASA, to Dr. S. P. Clark, Yale University, March 20, 1964. Twenty-eight nearly identical letters were sent to other members of the scientific and academic community.

March 20

Tests at North American demonstrated the possibility of using onboard tools to break the CM hatch windows for postlanding ventilation of the spacecraft.

"Apollo Monthly Progress Report," SID 62-300-24, p. 8.



Mission Control Center (Building 30) at MSC was physically completed, if not yet operationally ready, March 21, 1964.

March 23

Members of the Gemini Flights Experiments Review Panel discussed procedures for incorporating Apollo-type experiments into the Gemini program, experiments that directly supported the three-man space program. These experiments encompassed crew observations, photography, and photometry.

MSC, "ASPO Status Report for Period March 19-26, 1964."

March 23

OMSF outlined launch vehicle development, spacecraft development, and crew performance demonstration missions, using the Saturn IB and Saturn V:

1. Launch vehicle and unmanned CSM (at least two flights planned).
2. CSM long-duration.
3. CSM and LEM (two flights planned).
4. Launch vehicle and heatshield (at least two flights).
5. Lunar mission simulation.
6. Lunar exploration.

Missions (1) through (3) would use the Saturn IB and (4) through (6) the Saturn V. Additional launch vehicles and spacecraft would be provided for contingency or repeated flights. If necessary, repeat flights could provide additional crew training.

NASA OMSF, "Apollo Flight Mission Assignments," Program Directive M-DE 8000.005B, March 23, 1964.

March 24

To verify a narrower hatch configuration proposed for Block II spacecraft, North American evaluated the capability of an astronaut wearing a pressurized space suit and a portable life support system to pass through the main hatch of the CM for extravehicular activities. Subjects were able to enter and leave the mockup without undue difficulty despite the presence of gravity.

"Apollo Monthly Progress Report," SID 62-300-24, pp. 6-7.

March 24-26

The first formal inspection and review of the LEM test mockup TM-1 was held at Grumman. TM-1 allowed early assessment of crew mobility, ingress, and egress. It was a full-size representation of crew stations, support and restraint systems, cabin equipment arrangement, lighting, display panels and instrument locations, and hatches. The TM-1 evaluation became the basis for the final LEM mockup, TM-5, from which actual hardware fabrication would be made.

The TM-1 Review Board (comprising Chairman Owen E. Maynard, Maxime A. Faget, Donald K. Slayton, and William F. Rector III, all of MSC; and Tom J. Kelly and Robert M. Carbee of Grumman) approved 28 requests for change; 15 others were marked for further investigation.

NASA, "Lunar Excursion Module, Project Apollo, Board Report for NASA Inspection and Review of TM-1 Mockup, March 19-26, 1964," pp. 1, 3, 4.

March 25

The Boeing Company received NASA's go-ahead to develop the Lunar Orbiter spacecraft. (See

December 20, 1963.) Two significant changes were made in the original Statement of Work:

1. for the selenodetic part of the mission, the spacecraft lifetime was extended from 60 days to one year; and
2. to expand the area of photographic coverage, the film capacity was increased.

Lee R. Scherer, NASA, "Lunar Orbiter Program Status Report," March 26, 1964.

March 25

The General Electric (GE) Company submitted its cost quotations to NASA, starting the final phase of a program to provide Acceptance Checkout Equipment (ACE - formerly PACE [see February 1963]) ground stations for Apollo spacecraft. The overall "ACE" plan slated three ground stations for North American, two for Grumman, four for Cape Kennedy, and one for MSC. GE's contract called for spacecraft systems integration and checkout and for maintenance of the ACE stations. Much of the ACE equipment was government furnished and had been procured by NASA from several sources: Control Data Corporation - computer; Radiation, Inc. - "decommutators and pulse code modulation simulators." By May, GE had set up and commenced operating an experimental ACE station at Cape Kennedy. (See August 23-September 19.)

MSC, "ASPO Status Report for Period March 26-April 2, 1964;" "Apollo Quarterly Status Report No. 7," p. 61; "Apollo Quarterly Status Report No. 8," pp. 59-60; MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, February 16-March 21, 1964," pp. 9, 78; "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, April 19-May 16, 1964," p. 46; MSC, "Weekly Activity Report for the Office of the Associate Administrator, Manned Space Flight, May 17-23, 1964," p. 3; NASA News Release 63-286, "NASA to Extend Contract with Control Data Corporation," December 26, 1963; MSC News Release 64-108, June 8, 1964.

March 26-April 1

Because of the pure oxygen atmosphere specified for the spacecraft, North American reviewed its requirements for component testing. Recent evaluation of the CM circuit breakers had indicated a high probability that they would cause a fire. The company's reliability office recommended more flammability testing, not only on circuit breakers but on the control and display components as well. The reliability people recommended also that procurement specifications be amended to include such testing.

MSC, "ASPO Management Report for Period April 2-9, 1964."

March 29-April 4

Impact tests indicated that, because of oscillations and consequent high angles of attack, the CM might

not withstand water impact and could sink. North American planned a series of water impact tests using boilerplate 28 to study the problem.

MSC, "Weekly Activity Report for the Office of the Associate Administrator, Manned Space Flight, March 29-April 4, 1964," p. 5; MSC, "ASPO Status Report for Period March 26-April 2, 1964."

March 30

MSFC awarded Rocketdyne a definitive contract (valued at \$158.4 million) for the production of 76 F-1 engines for the first stage of the Saturn V launch vehicle and for delivery of ground support equipment.

David S. Akens, Leo L. Jones, and A. Ruth Jarrell, *History of the George C. Marshall Space Flight Center from January 1 through June 30, 1964* (MHM-9, May 1965), Vol. I, p. 139.

March 30

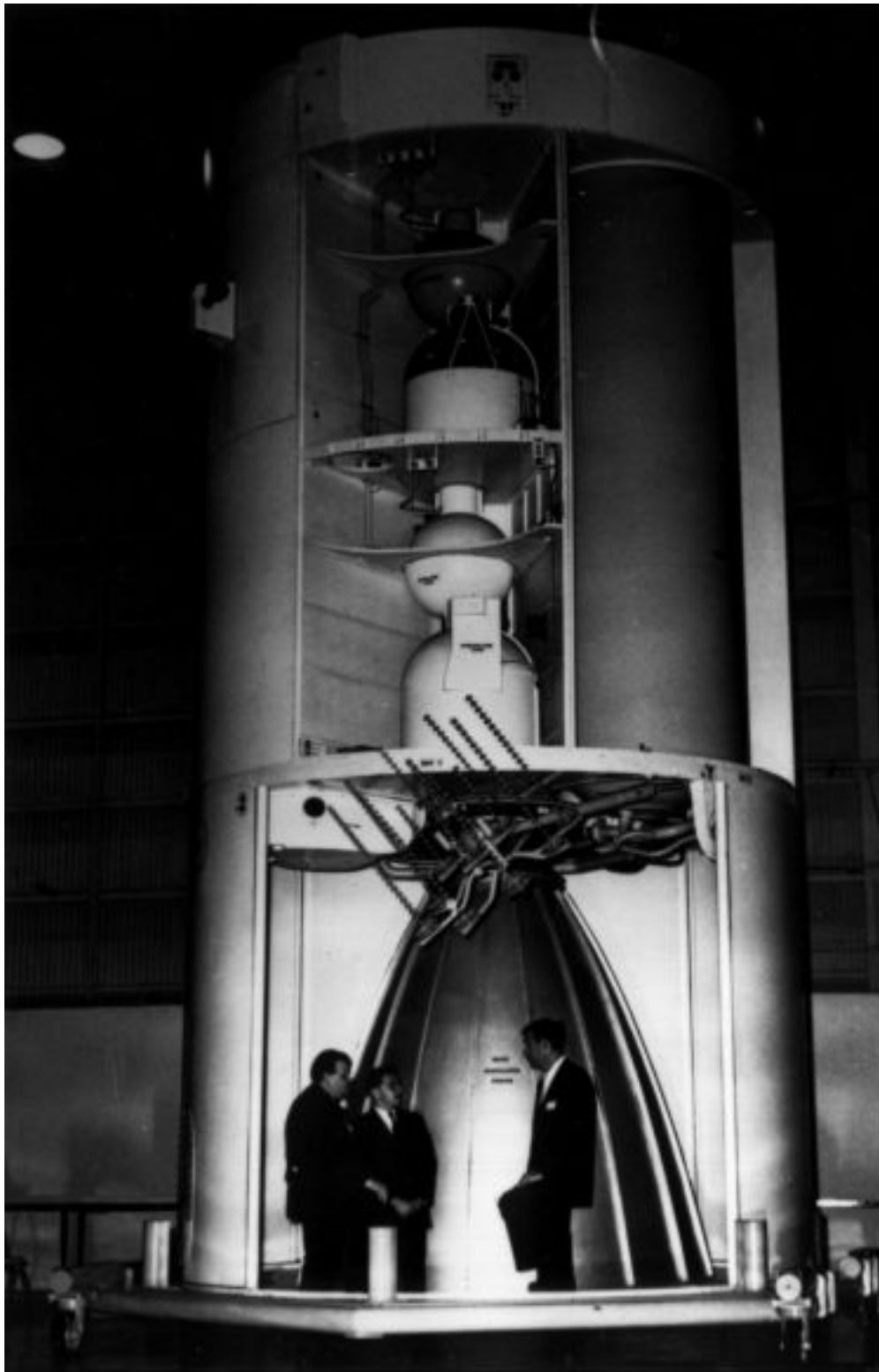
CSM boilerplate 12 (with launch escape system) was mated to its Little Joe II launch vehicle. (See May 13.)

MSC, "Postlaunch Report for Apollo Mission A-001 (BP-12)," MSC-R-A-64-1 (May 28, 1964), p. 5-2.

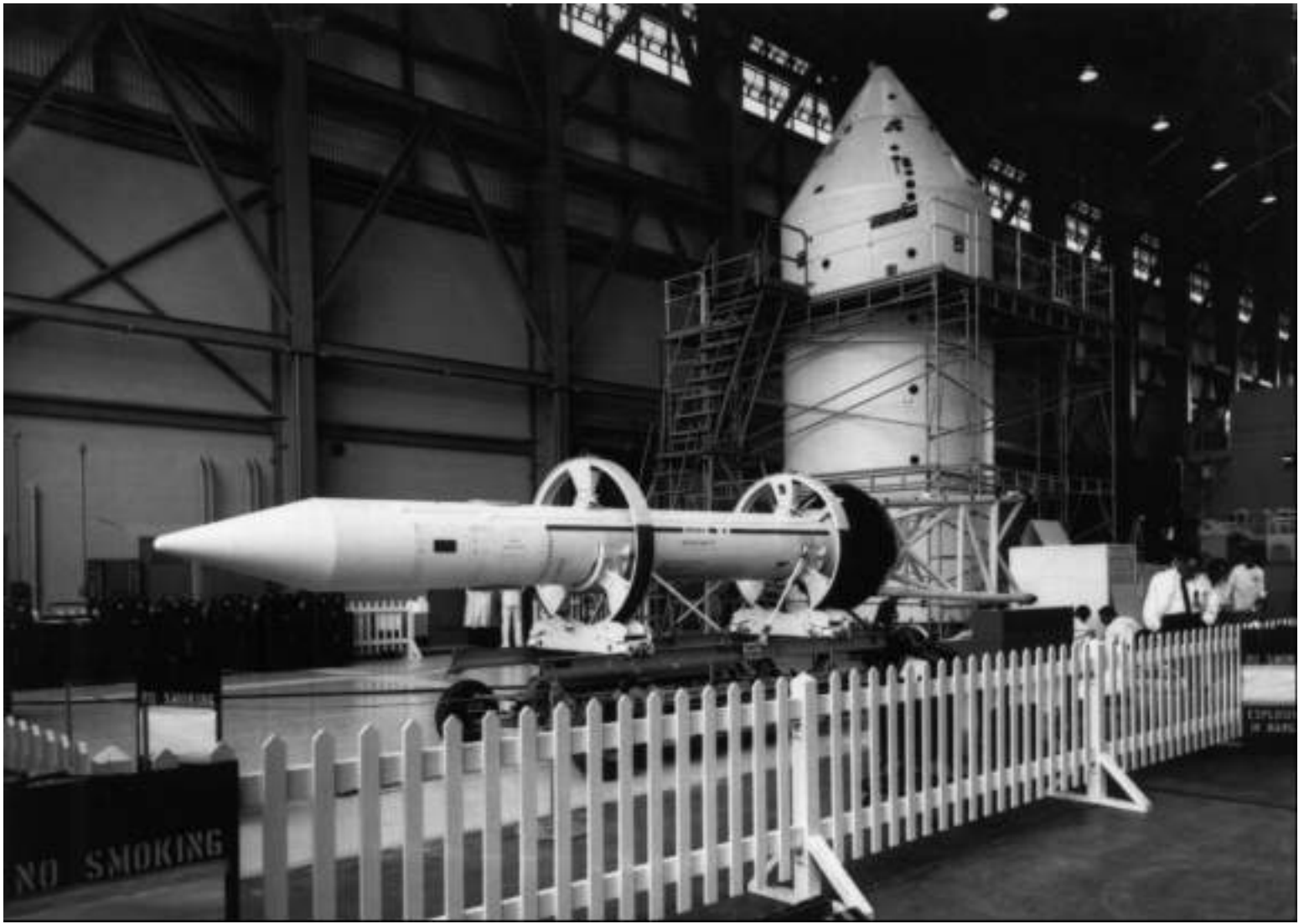
April 1

MSC negotiated a cost-plus-incentive-fee contract, valued at \$1.65 million, with Hamilton Standard for 27 prototype Apollo space suits and 12 pairs of gloves.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, March 22-April 18, 1964," p. 56.



An Apollo service module mockup showing the portion that contained the main rocket engine and propellant supply to be used for maneuvers to and from the moon. Produced by Aerojet-General Corporation under contract to NAA, the engine could provide more than 89,000 newtons (20,000 pounds) of thrust to keep Apollo on course and to perform other missions. Standing by the multiple-start engine's flaring skirt were NAA and Aerojet rocket engineers.



The first Apollo boilerplate to fly during the program was BP-13, shown here in Hanger AF at Cape Kennedy before being taken to the launch complex to be mated with the Saturn SA-6 launch vehicle. The Apollo escape rocket and tower are in the foreground.

April 2-9

Space Technology Laboratories (STL) began using its new San Juan Capistrano, Calif., test facility to static fire the firm's LEM descent engine. Hereafter, the bulk of STL's development firings were made at this site.

MSC, "ASPO Management Report for Period April 2-9, 1964"; MSC, "Weekly Activity Report for the Office of the Associate Administrator, Manned Space Flight, June 7-13, 1964," p. 2.

April 2-9

The MSC Operations Planning Division (OPD) reviewed recent revisions by OMSF to Apollo's communications requirements:

- Elimination of the requirement for continuous tracking of the spacecraft during translunar injection
- Sequential rather than simultaneous transmission of data from the ground to the two spacecraft (to be compatible with the Manned Space Flight Network)
- A five-kilometer (three-nautical-mile) communications range on the lunar surface (to be compatible with the design of the portable life support system)
- Elimination of the requirement for direct transmission to the CSM from an extravehicular astronaut; instead, such transmission would be relayed via the LEM.

Thus were resolved, OPD reported, a number of conflicting items (i.e., incompatibilities between OMSF's requirements and the capabilities of the two spacecraft). Two other items that OMSF made into firm requirements were already compatible with the design of the spacecraft:

1. A radar in the CSM capable of tracking the LEM (provided the LEM had a compatible transponder)
2. Three-way communications between an astronaut on the moon, his fellow crewman inside the LEM, and with mission control.

MSC, "ASPO Management Report for Period April 2-9, 1964."

April 6-13

Grumman issued a letter contract to AiResearch Manufacturing Company to start design of cryogenic tank assemblies for the LEM fuel cells. AiResearch received the formal contract on June 23.

MSC, "ASPO Management Report for Period April 9-16, 1964"; "ASPO Weekly Management Report, June 18-25, 1964"; "ASPO Weekly Management Report, July 23-30, 1964."

April 7

Bell Aerosystems Company completed the first of two lunar landing research vehicles, to be delivered to the NASA Flight Research Center for testing. (See January 18, 1963.)

MSC News Release 64-68, April 7, 1964.

April 7-8

At the April 7-8 NASA-North American Technical Management Meeting (the first of these meetings to

be held at MSC's new home, "NASA Clear Lake Site 1"), ASPO Manager Joseph F. Shea summarized his office's recent activities concerning the Block II spacecraft. He spelled out those areas that ASPO was investigating - which included virtually the whole vehicle between escape tower and service engine bell. Shea outlined procedures for "customer and contractor" to work out the definitive Block II design, aiming at a target date of mid-May 1965. These procedures included NASA's giving North American descriptions of its Block II work, estimates of weight reduction, and a set of ground rules for the Block II design (see April 16). And to ensure that both sides cooperated as closely as possible in this work, Shea named Owen E. Maynard, Chief of MSC's Systems Engineering Division, and his counterpart at Downey, Norman J. Ryker, Jr., to "honcho" the effort.

"Minutes of NASA-NAA Technical Management Meeting, April 7-8, 1964," pp. 3-5.

April 8

The first Gemini mission, *Gemini-Titan I*, was launched from Complex 19 at Cape Kennedy at 11:00 a. m., e.s.t. This was an unmanned flight, using the first production Gemini spacecraft and a modified Titan II Gemini launch vehicle (GLV). The mission's primary purpose was to verify the structural integrity of the GLV and spacecraft, as well as to demonstrate the GLV's ability to place the spacecraft into a prescribed earth orbit. Mission plans did not include separation of the spacecraft from the second stage of the vehicle, and both were inserted into orbit as a unit six minutes after launch. The planned mission encompassed only the first three orbits and ended about four hours and 50 minutes after liftoff. No recovery was planned. The flight qualified the GLV and the structure of the spacecraft.

James M. Grimwood and Barton C. Hacker, with Peter J. Vorzimmer, *Project Gemini Technology and Operations: A Chronology* (NASA SP-4002, 1969), p. 139.

April 13

ASPO gave Grumman specific instructions on insulating wiring in the LEM: Teflon-insulated wiring was mandatory in a pure oxygen atmosphere. If the standard-thickness Teflon insulation was too heavy, a thin-wall Teflon-insulated wiring with abrasion-resistant coating should be considered. Teflon-insulated wiring should also be used outside the pressurized cabin, wherever that wiring was exposed. Any approved spacecraft insulation could be used within subsystem modules which were hermetically sealed in an inert gas atmosphere or potted within the case.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Spacecraft Electrical Wiring Insulation," April 13, 1964.

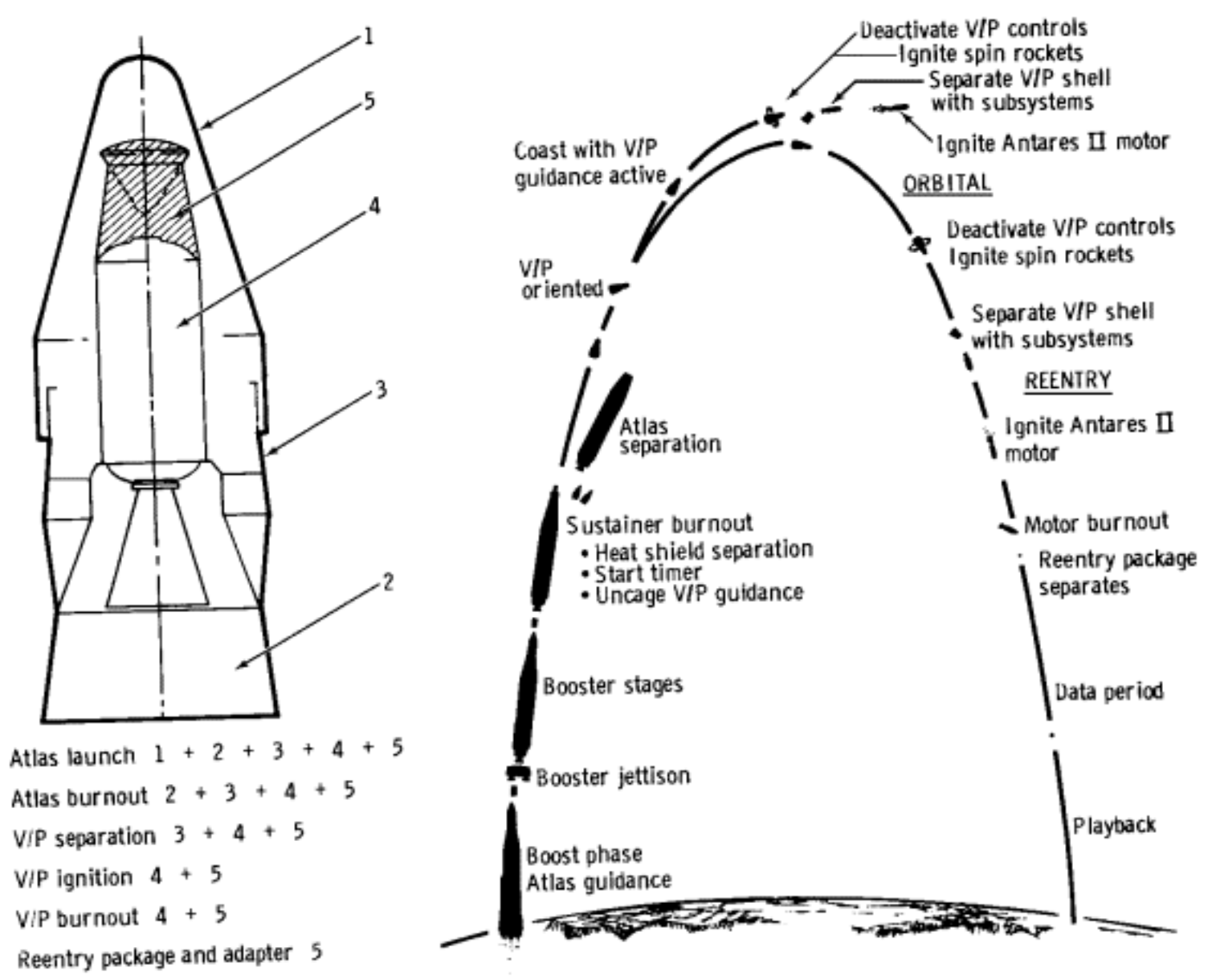
April 14

Firings at the Arnold Engineering Development Center (AEDC) and at Aerojet-General Corporation's Sacramento test site completed Phase I development tests of the SM propulsion engine. The last

simulated altitude test at AEDC was a sustained burn of 635 seconds, which demonstrated the engine's capability for long-duration firing. Preliminary data indicated that performance was about three percent below specification, but analysis was in progress to see if it could be improved.

NAA, "Apollo Monthly Progress Report," SID 62-300-25, June 1, 1964, p. 11; MSC, "ASPO Management Report for Period April 23-30, 1964"; "ASPO Management Report for Period April 30-May 7, 1964."

April 14



A typical Project Fire reentry or orbital mission. The weight sequence is at left. (LTV report)

An Atlas D launch vehicle lifted a Project Fire spacecraft (see November 27, 1962) from Cape Kennedy in the first test of the heat that would be encountered by a spacecraft reentering the atmosphere at lunar-return velocity. During the spacecraft's fall toward earth, a solid-fuel Antares II rocket behind the payload fired for 30 seconds, increasing the descent speed to 40,501 kilometers (25,166 miles) per hour. Instruments in the spacecraft radioed temperature data to the ground. The spacecraft exterior reached an estimated temperature of 11,400 K (20,000 degrees F). About 32 minutes after launch, the spacecraft impacted into the Atlantic Ocean. The mission, sponsored by Langley Research Center, provided reentry heating measurements needed to evaluate heatshield materials and information on the communications blackout during reentry.

NASA News Release 64-69, "NASA Schedules Project Fire Launch," April 1, 1964; *Astronautics and Aeronautics*, 1964, p. 135.

April 15

Dale D. Myers, North American's Space and Information Systems Division vice president, succeeded John W. Paup as the contractor's program manager for the CM.

Oakley, *Historical Summary, S&ID Apollo Program*, p. 10.

April 15

ASPO gave Grumman a go-ahead on procurement of the flight attitude indicator ("8-ball") and associated equipment for the LEM.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Lunar Excursion Module, Attitude Indicator," April 15, 1964.

April 15

ASPO asked North American to investigate the possibility of designing apex-upright, stable flotation attitude into Block I and Block II CM's.

MSC, "ASPO Management Report for Period April 9-16, 1964."

April 15

Grumman completed an environmental control system water management configuration study and concluded that a revised design would significantly improve the probability of mission success and crew safety. This design would combine water tanks for the water management functions into one easily accessible package.

MSC, "ASPO Weekly Management Report, May 21-28, 1964."

April 15-16

MSC Crew Systems Division representatives attended a demonstration at Grumman of Apollo Phase B and Gemini space suits using the LEM TM-1 mockup and a mockup portable life support system. Tests demonstrated ingress egress capability through the forward and top hatches, operation of controls and displays, and methods of getting out on the lunar surface and returning to the spacecraft. Generally, the Apollo suit proved sufficiently mobile for all these tasks, though there was no great difference between its performance and that of the Gemini suit during these trials.

MSC, "ASPO Management Report for the Period April 16-23, 1964"; GAEC, "Monthly Progress Report No. 15," LPR-10-31, May 10, 1964, p. 9.

April 16

NASA's Office of Space Science and Applications (OSSA) and the National Academy of Sciences (NAS) were planning a scientist-astronaut program. NAS people had met in Houston with MSC officials in February to help draft a formal plan to develop a "scientist astronaut program for NASA." This plan also placed the responsibility on NAS to define what scientific qualifications a person would need; MSC agreed to define "other qualifications."

OSSA Associate Administrator Homer E. Newell asked Harry H. Hess, Chairman of the Space Science Board, NAS, and his group to pursue this plan and be ready with a qualification list (both NAS and NASA requirements) by August for advertisement. Newell said the screening-for-selection process could be scheduled for February 1965. (See August 19.)

Letter, Newell, NASA, to Harry H. Hess, Chairman, Space Science Board, National Academy of Science, April 16, 1964.

April 16

Joseph F. Shea, ASPO Manager, in a letter to North American's Apollo Program Manager, summarized MSC's review of the weight status of the Block I and the design changes projected for Block II CSM's. (See April 7-8.)

The Block II design arose from the need to add docking and crew transfer capability to the CM. Reduction of the CM control weight (from 9,500 to 9,100 kilograms [21,000 to 20,000 pounds]) and deficiencies in several major subsystems added to the scope of the redesign.

Redesign of the CM would cause a number of changes above the deck, although ASPO believed that the

73.7-centimeter (29-inch)-diameter tunnel could be retained and tunnel access might be improved if the restrictions for seating the hatches were removed. Other changes not related to the docking and transfer requirement would be considered as long as they did not affect the structure below the deck.

Changes below the deck would be kept to a minimum on both the inner and the outer structure. Anything which might invalidate the applicability of the Block I lunar reentry tests to the Block II design would not be changed.

ASPO wanted to evaluate a preliminary design of the CM in which the only access to the LEM would be by extravehicular transfer. Although this approach was not currently considered operationally acceptable, any gains from such a design should be studied.

ASPO agreed that the CM thermal protection would be enhanced by addition of a boost protective cover for both Block I and Block II. A "soft" cover should be simple to design and operate, and a boost cover would permit coating the CM with a thermally efficient surface. This, with the help of attitude programming, should permit North American to reduce the initial ablator bond line temperature from 394 K (250 degrees F) to below 338 K (150 degrees F). ASPO also asked the contractor to consider raising the bond line temperature on the blunt face from 590 K (600 degrees F) to 700 K (800 degrees F). These changes would reduce ablator weight significantly.

To eliminate the humidity problem in the Block I subsystems, ASPO believed that electronic repackaging would be required. Such a redesign should take advantage of ASPO's decision to eliminate onboard maintenance as an acceptable means of achieving mission reliability. A more efficient mounting arrangement should be considered in conjunction with electronic system repackaging. Elimination of onboard maintenance would change requirements on the inflight test system; perhaps that system could be eliminated from the spacecraft.

The biggest uncertainty in weight requirements was meteoroid protection. The design approach to this problem should be incorporated with a redesign of the SM to reduce both the tank size and structure (but see August 6 statement of Robert O. Piland) consistent with a 16,800-kilogram (39,000-pound) consumable fuel load, rather than the current 20,400-kilogram (45,000-pound) capacity. The SM design concept should remain the same, but North American should use this opportunity to clean up several structural details.

The SM thermal control system should be passive. Spacecraft orientation, either on a semicontinuous or discrete attitude program, would be permissible to maintain necessary temperature limits. To reach acceptable thermal time constants, the reaction control system (RCS) might have to be modified. It might also be desirable to change the RCS fuel to monomethylhydrazine.

Because of the large amount of spacecraft wiring, North American was asked to study using smaller sizes and reduced insulation thicknesses.

Another consideration was reducing the lunar mission time from 14 days to the reference mission length of about 10 days. But the current tank sizes should be maintained and the spacecraft should be capable of 14- day earth orbital missions with three men. The velocity reserve in the RCS might be decreased if the attitude requirements for guidance and navigation were eased. Here, also, the current tank sizes should not be changed.

Other major changes (such as redesign of the fuel cell, incorporation of new heatshield material, cryogenic helium pressures, and adapter staging) could be considered in the redesign; they would, however, be approved only if the foregoing changes did not provide sufficient weight margin.

ASPO would require a complete preliminary design and impact assessment of the Block II spacecraft before its incorporation into the program would be authorized.

Letter, Joseph F. Shea, MSC, to John W. Paup, NAA, April 16, 1964.

April 16-22

North American conducted a preliminary study on removal of one of three fuel cells from the Block II CSM. The contractor predicted a total weight saving of about 168 kilograms (370 pounds), with potential indirect reductions in the cryogenic systems, but this change would require a significant increase in reliability.

MSC, "ASPO Management Report for Period April 23-30, 1964."

April 16-23

MSC, North American, and Grumman reviewed development problems in the LEM and SM reaction control thrust chambers. They agreed that a reassessment of the chambers' operational and thermal parameters was necessary.

MSC, "ASPO Management Report for Period April 16-23, 1964."

April 16-May 15

North American completed the first of a series of simulations to evaluate the astronauts' ability to perform attitude change maneuvers under varying rates and angles. Subjects were tested in a shirtsleeve environment and in vented and pressurized International Latex Corporation state-of-the-art pressure suits. The subjects had considerable difficulty making large, multi-axis attitude corrections because the pressurized suit restricted manipulation of the rotational hand controller.

"Apollo Monthly Progress Report," SID 62-300-25, p. 5.

April 17

Grumman conducted manned drop tests to determine the LEM crew's ability to land the spacecraft from a standing position. (See September 16-18, 1963.) All tests were run with the subject in an unpressurized suit in a "hands off" standing position with no restraint system or arm rests.

"Monthly Progress Report No. 15," LPR-10-31, p. 10.

April 20

NASA selected IBM, Federal Systems Division, to develop and build the instrument units (IU) for the Saturn IB and Saturn V launch vehicles. [IBM had been chosen by NASA in October 1963 to design and build the IU data adapters and digital guidance computers and to integrate and check out the IUs.] Under this new contract, expected to be worth over \$175 million, IBM would supply the structure and the environmental control system. NASA would furnish the telemetry system and the stabilized platform (ST-124M) of the guidance system. MSFC would manage the contract.

NASA News Release 64-89, "NASA Selects IBM as Lead Contractor for Saturn IB, V Instrument Unit," April 20, 1964.

April 21

ASPO directed Hamilton Standard to provide urine storage in the Apollo space suit for prelaunch and launch. The contractor was to investigate the suitability of a Mercury-Gemini type urinal for storage and subsequent disposal.

TWX, W. F. Rector III, MSC, to GAEC, Attn: Waste Management Program Manager, April 21, 1964.

April 21

Officials from ASPO, Flight Crew Operations Directorate, Crew Systems Division, and Hamilton Standard established the basic ground rules for Apollo space suit operation:

1. At least one crewman would wear his space suit at all times.
2. All three crewmen would wear their suits continuously during launch through translunar injection, lunar operations, and reentry.
3. The three crewmen could remain suited at all times, although they could remove the suits during translunar and transearth phases.
4. The crew would be able to return from any point in the mission in pressurized suits.
5. Two men in the CM would be able to don their suits within five minutes.

Operations Planning Division reported that these rules required no modifications to the suit and only minor changes to the environmental control system.

MSC, "ASPO Management Report for Period April 16-23, 1964"; "ASPO Management Report for Period April 23-30, 1964."

April 23

After completing estimates of the heating conditions for a series of MIT guided reentry trajectories, the MSC Engineering and Development Directorate recommended that the heatshield design philosophy be modified from the current "worst possible entry" to the "worst possible entry using either the primary or backup guidance mode." North American had drawn up the requirements early in 1962, with the intent of providing a heatshield that would not be a constraint on reentry. However, it was now deemed extremely unlikely that an entry, employing either the primary or backup guidance mode, would ever experience the heat loads that the contractor had designed for earlier. The ablator weight savings, using the MIT trajectories, could amount to several hundred pounds.

Memorandum, C. H. Perrine, MSC, to Mgr., ASPO, "Modification of the heat shield design philosophy," April 23, 1964.

April 23-30

Grumman redesigned the LEM environmental control system to incorporate a replaceable lithium hydroxide cartridge with a portable life support system cartridge in parallel for emergency backup. The LEM cartridge would be replaced once during a two-day mission.

Also MSC advised Grumman that estimates of the metabolic rates for astronauts on the lunar surface had been increased. The major effect of this change was an increase in the requirements for oxygen and water for the portable life support system.

MSC, "ASPO Management Report for Period April 23-30, 1964."

April 23-30

Rocketdyne conducted the first firing of the prototype thrust chamber assembly for its LEM descent engine.

Ibid.

April 24

Representatives from a number of elements within MSC (including systems and structural engineers, advanced systems and rendezvous experts, and two astronauts, Edward H. White II and Elliot M. See, Jr.) discussed the idea of deleting the LEM's front docking capability (an idea spawned by the recent TM-1 mockup review [see March 24-26]). Rather than nose-to-nose docking, the LEM crew might be able to perform the rendezvous and docking maneuver, docking at the spacecraft's upper (transfer) hatch, by using a window above the LEM commander's head to enable him to see his target. A good many factors pointed to the merit of this approach:

- A rectangular window 18 by 38 centimeters (seven by 15 inches) above the commander's head could readily be incorporated into the LEM's structure, with only minimal design changes. The weight penalty would be between 4.5 and 6.8 kilograms (10 and 15 pounds) (excluding possible effects on the vehicle's environmental control system). On the other hand, eliminating the front docking mechanism would save about 11 or 14 kilograms (25 or 30 pounds). A docking aid on the CM was essential, but the device "would pay for itself in increased reliability and decreased design load requirements and fuel requirements." Additionally, instead of two docking aids on the LEM (as currently envisioned), only the upper one would be needed.
- The top-only docking arrangement would simplify the docking operation per se. The crew would no longer have to transfer the drogue from the top to the front hatch prior to rejoining the CM. [The need for depressurizing the spacecraft to perform this task thus was obviated.] As an additional "fringe benefit," the front hatch could possibly be reconfigured to make it easier for the crewmen to get out of and back into their craft while on the moon.
- The overhead window would enable the LEM commander to see the moon during powered descent and ascent portions of the flight, and thus would afford the crew a visual attitude and attitude reference.

There existed, naturally, some offsetting factors: the pilot's limited view of his target (thought to be of "no major consequence"); and his being unable quickly to scan his instrument panel (which was not essential). Also, the maneuver called for the pilot to fly his vehicle, for a considerable period, in a rather strained physical position (i.e., with his head tossed backward). But because of the many inherent advantages, the group concluded, LEM-active docking at the upper hatch was acceptable as a backup method for docking. (CM-active docking still would be the normal procedure, because that vehicle could "perform the docking maneuver more easily and more reliably than can the LEM . . . Deletion of the front docking capability on [the] LEM will not alter this relationship, therefore the LEM should be required to dock only when the CSM or the crew member inside is incapacitated. If the CSM is incapacitated returning to it is of questionable importance.") They recommended that Grumman be directed to proceed with this concept for the LEM. (See May 7--14 and May 22.)

Letter, Joseph P. Loftus, Jr., to Assistant Chief, Systems Engineering Division, "Disposition of TM-1 mockup review chit no. A9-4," April 28, 1964, with enclosure, attendance list.

April 24

To train astronauts in various mission procedures, LTV had completed simulations of manual abort and, within a week, would be able to conduct simulated final maneuver phases of a rendezvous. (See May 6, September 17, and October 10, 1963; also see June 1963.)

"Monthly Progress Report No. 15," LPR-10-31, p. 1.

April 24

The NASA Manned Space Science Division was planning a scientific experiments program for manned and unmanned earth orbital flights. The manned program would be a direct outgrowth of the Gemini experiments program. (See March 23.)

Memorandum, Willis B. Foster, NASA, to Assoc. Adm. for Manned Space Flight, "Science program for SIB's and SV's," April 24, 1964.

April 24

NASA definitized the letter contract with the Philco Corporation Techrep Division for spacecraft flight control support. The definitive contract covered the period from September 16, 1963, through March 31, 1965, and the total cost-plus-fixed-fee was \$720,624.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, April 19-May 16, 1964," p. 46.

April 28-30

At Downey, Calif., MSC and North American officials conducted a mockup review on the Block I CSM. Major items reviewed were:

- Cabin interior (complete except for hatches, display panel lighting, survival equipment, umbilical connections, and zero-g restraints).
- CM exterior (complete except for hatches and boost protective cover).
- Earth landing system.
- Launch escape system.
- SM.

One hundred and eleven request for change forms were submitted to the mockup review board, composed of Robert O. Piland (Chairman), Christopher C. Kraft, Jr., Donald K. Slayton, Caldwell C. Johnson, Owen E. Maynard, and Clinton L. Taylor of MSC; and H. G. Osbon and Charles H. Feltz of North American.

For the first time, three representative Apollo space suits were used in the CM couches. Pressurized suit

demonstrations, with three suited astronauts lying side by side in the couches, showed that the prototype suit shoulders and elbows overlapped and prevented effective operation of the CM displays and controls. Previous tests, using only one suited subject, had indicated that suit mobility was adequate. Gemini suits, tested under the same conditions, proved much more usable. (See February 27-March 4.) Moreover, using Gemini suits for Apollo earth orbital missions promised a substantial financial saving. As a result of further tests conducted in May, the decision was made to use the Gemini suits for these missions. The existing Apollo space suit contract effort was redirected to concentrate on later Apollo flights. A redesign of the Apollo suit shoulders and elbows also was begun.

MSC, "Command and Service Modules, Project Apollo Board Report for NASA Inspection and Review of Block I Mock-Up, April 23-30, 1964," pp. 1-2; MSC, "ASPO Management Report for Period April 30-May 7, 1964"; MSC, "Weekly Activity Report for the Office of the Associate Administrator, Manned Space Flight, May 3-9, 1964," p. 5; "Apollo Quarterly Status Report No. 8," pp. 47-48; interview, telephone, Matthew I. Radnofsky, Houston, March 24, 1970.

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Part 3 (A)

Developing Software Ground Rules

April 29, 1964 through June 1964

[1964 April](#)

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1964

April 29

ASPO defined weight and volume allocations for scientific equipment. Exact location of this equipment could not be specified, but each module had to have the following capacities:

- CM and LEM ascent stage: 36 kilograms (80 pounds); 0.06 cubic meter (2 cubic feet)
- LEM descent stage: 95 kilograms (210 pounds); 0.27 cubic meter (9 cubic feet), minimum; 0.45 cubic meter (15 cubic feet), design objective.

Any additional space gained by jettisoning expendable equipment could also be used for storage. (See June 8.)

Requirements for thermal protection for the scientific equipment were not yet defined, nor was the packaging concept. Electrical outlets on the LEM, furnishing power to the equipment, would of course have to be within the reach of an astronaut while he was standing on the moon's surface outside the spacecraft.

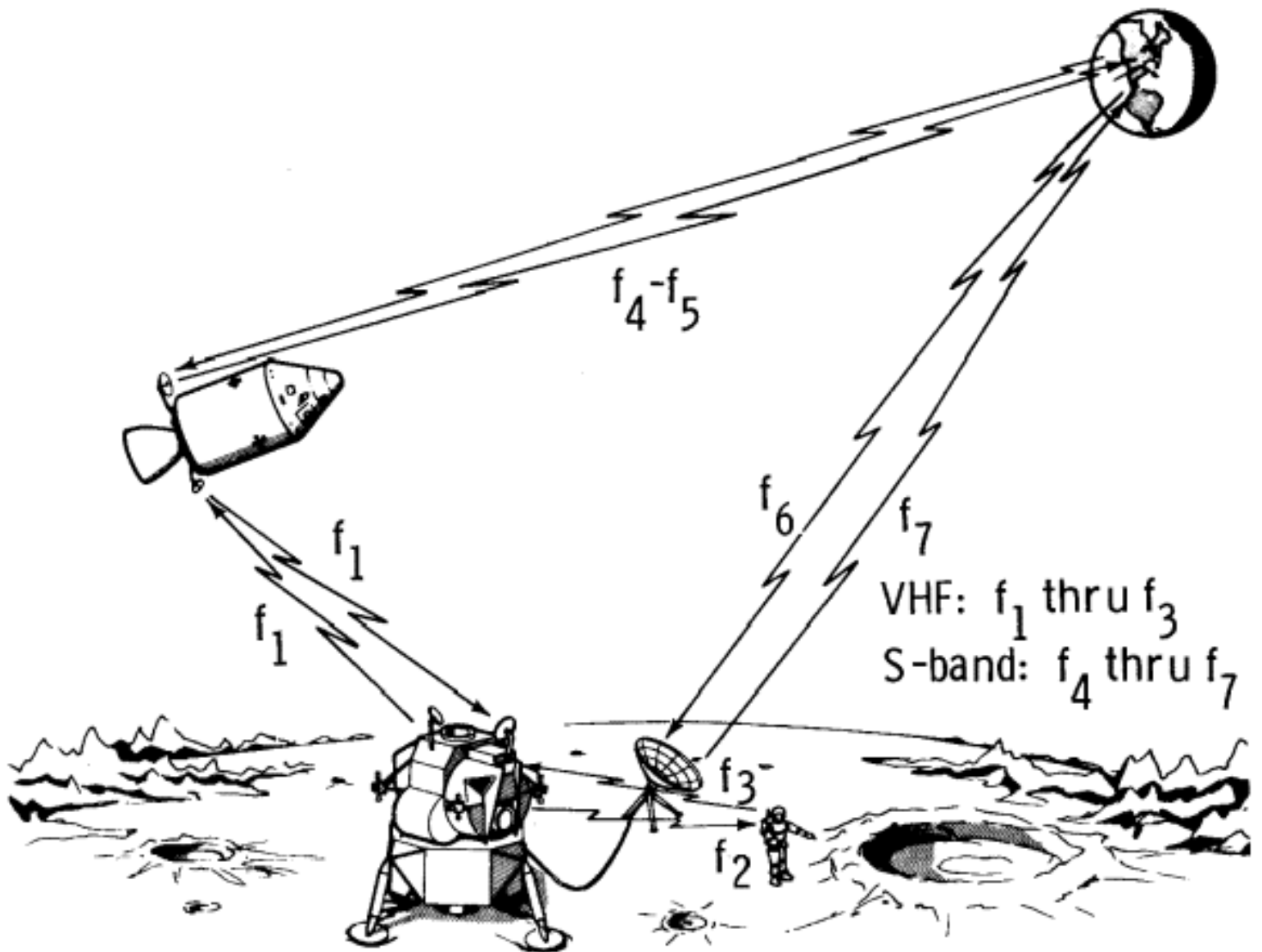
Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Scientific Equipment," April 29, 1964.

April 29

MSC established new LEM abort guidance ground rules, which defined the operation and reliability requirements of the stabilization and control system's abort guidance section. Grumman was to continue studies on the abort pitch programmer and on the capability of the LEM to perform rendezvous.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Abort Guidance Section of the Stabilization and Control Subsystem," April 29, 1964.

April 30



Communications links between CM, LEM, and earth stations.

MSC authorized major revisions in the CM communications system to provide better voice and data relay

between the CM, the LEM, and ground stations.

Letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. 201," April 30, 1964.

April 30

Following a series of 15 acceptance firings at Rocketdyne's Santa Susana test facility (conducted during March and April), the first hot-firing production J-2 engine was delivered to Douglas Aircraft Company (DAC). The engine then began "battleship" testing (i.e., fitted to a heavyweight stage of the vehicle built especially for static testing) at DAC's Sacramento test site.

Akens, *et al.*, *History of Marshall . . . January 1 through June 30, 1964*, Vol. I, pp. 148, 224.

During the Month

Grumman awarded Bell Aerosystems Company the contract for the LEM ascent stage reaction control system propellant tanks. The contract was worth about \$3.5 million.

Missiles and Rockets, 14 (April 27, 1964), p. 23.

During the Month

Grumman recommended using a self-stabilized trim gimbal system in the descent stage of the LEM, which would save about 34 kilograms (75 pounds) of reaction control system propellant.

"Monthly Progress Report No. 15," LPR-10-31, p. 24.

May 1

MSC Structures and Mechanics Division began vibration tests on SM boilerplate (BP) 22 to determine resonant frequencies, mode shapes, and structural damping characteristics. The results would be used in evaluation of data from the BP-22 flight test of the launch escape system at WSMR, scheduled for 1965.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, April 19-May 16, 1964," p. 56; MSC News Release 64-86, May 1, 1964.

May 1

ASPO Manager Joseph F. Shea reported to the Senior Staff that NASA was not imposing any requirement for the crew to get out of the CM quickly should some problem arise with the launch vehicle while on the pad. Given such an occurrence with the crewmen perched almost 122 meters (400 feet) high

- and atop a fueled Saturn V - it was believed more rational to make a standard abort (using the launch escape system) or to hold the countdown until the vehicle could be made safe.

MSC, "Minutes of Senior Staff Meeting, May 1, 1964," p. 3.

May 1

MSC Instrumentation and Electronic Systems Division personnel visited Jet Propulsion Laboratory to review the Surveyor landing radar test program and to investigate the use of either a reflector or a transponder on the Surveyor to help in the selection of landing sites for the LEM. At that time, the possibility did not appear promising because reflector usage seemed impractical and because power requirements were far above what was available. Additional study on the matter was planned.

MSC, "ASPO Management Report for Period April 23-30, 1964"; "ASPO Management Report for Period April 3-May 7, 1964."

May 1

Grumman completed negotiations with RCA for the attitude and translation control assembly (ATCA) for the LEM. The ATCA imposed thrust demands on the vehicle's stabilization and control system based upon information from the guidance equipment.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, April 19-May 16, 1964," p. 45.

May 4

The Apollo Mission Planning Task Force presented its Phase I progress report to ASPO. (See November 29, 1963, and January 16, 1964.) ASPO, in assigning this task, had defined its principal objectives: the determination of mission-related, functional requirements for spacecraft subsystems; the examination of current subsystem capabilities to meet these requirements; the evaluation of the capability of the spacecraft to fly missions which met the program objectives; the determination of flexibilities available within established control weights; and the provision of mission plans which would be the basis for other analyses and reporting.

The task force further refined program objectives:

1. to land two astronauts and scientific equipment on the near-earth-side of the moon and return them safely to earth; and
2. to perform experiments within the restrictions of 113 kilograms (250 pounds) and 0.3 cubic meter (10 cubic feet) of scientific payload, which would be landed on the lunar surface, and 36 kilograms (80 pounds) and 0.06 cubic meter (two cubic feet), which would be returned to earth.

Mission related spacecraft design rules were studied. Seventeen rules for spacecraft operations and seven for contingencies were selected. Although trajectory ground rules were considered more operational than design in nature, the group included 16 as necessary to define the performance capabilities of the spacecraft design. A reference trajectory, provided by MSC, assumed a launch date of May 8, 1968, and a 41,000-kilogram (90,000-pound) spacecraft injected into a 66.4-hour translunar-coast/free-return trajectory.

GAEC, "Apollo Mission Planning Task Force, Phase I Progress Report," LED-540-7, Vols. I, II, III, May 4, 1964.

May 4-11

MSC ordered Grumman to halt all work on a radiatively cooled nozzle for the LEM's ascent engine. (See January; also see September 19-October 16, 1963.) The Center took this action largely to avoid schedule slippage (because the work was drawing valuable people away from the "mainstream" effort, an ablative nozzle). Also involved in the cancellation were such factors as high risk and cost; the lack of previous experience with this type; and the minor saving in weight at best.

MSC, "ASPO Weekly Management Report, May 7-14, 1964."

May 5

MSC Operations Planning Division (OPD) reviewed power usage aboard the LEM if the fuel cell assembly (FCA) failed. OPD concluded that Grumman's requirements were too stringent (i.e., turning off all equipment not needed for lunar landing should one FCA fail and turning off everything not needed for crew safety following an abort should two FCA's fail). OPD planned to review all subsystems to determine their duty cycles after an FCA-dictated abort.

MSC, "ASPO Management Report for Period April 30-May 7, 1964."

May 6

NASA selected RCA for negotiation of a contract for C-band radar equipment to be used on tracking ships by NASA and the Department of Defense, under the U.S. Navy Instrumentation Ships Project Office, during lunar missions.

NASA News Release 64-107, "NASA Selects RCA Radar for Tracking Ships," May 6, 1964.

May 7

ASPO notified Grumman that a number of components must remain as common-use items, because they

were used in conjunction with government furnished equipment that was interchangeable between the two spacecraft: oxygen and water disconnects on the portable life support system and quick-disconnects for the suit umbilicals. ASPO added suit umbilicals and carbon dioxide sensors to the common-use list.

ASPO decided that the Gemini pressure suit would be used in Apollo Block I earth orbital flights and, on May 19, notified North American accordingly. This decision grew out of continuing mobility problems with Apollo prototype suit, especially restrictive inside the spacecraft. (See April 28-30.)

MSC, "Minutes of Senior Staff Meeting, May 8, 1964," p. 4; MSC, "ASPO Weekly Management Report, May 14-21, 1964."

May 7-14

At MSC's request, Grumman studied the use of the LEM stabilization and control system in aligning that vehicle's inertial measurement unit before spacecraft separation. The company found that the maneuver would consume 5.33 kilograms (11.74 pounds) of fuel from the vehicle's stabilization and control system (SCS), compared with 2.83 kilograms (6.24 pounds) for the same alignment with a free LEM. Grumman advised that the best procedure would be to use the CSM to position the LEM telescope field of view. The LEM could then begin the necessary drift for sighting, using less than 0.23 kilogram (0.5 pound) of SCS fuel.

Also, Grumman studied the feasibility of an overhead window at the command pilot's station in the LEM. The contractor was pursuing the question of the optimum window size and location and the type of reticle required. (See April 24 and May 22.)

MSC, "ASPO Weekly Management Report, May 7-14, 1964."

May 7-14

North American completed the environmental requirements for the CM television camera. The camera must be able to function under conditions of 100 percent humidity, including unhooking and reconnecting the cable. Also, because of the humidity requirement and the "outgassing" properties of commercial lenses (that is, the gases which they could possibly give off inside the spacecraft's cabin), North American decided that a special zoom lens would have to be developed, which would cost around \$110,000.

Ibid.

May 8

NASA and The Boeing Company signed a contract for five Lunar Orbiter spacecraft. Under the incentive provisions, Boeing could receive up to \$5.3 million more than the basic \$80 million cost if all Lunar Orbiter missions were successful. (See December 20, 1963.)

NASA News Release 64-109, "NASA Signs Contract with Boeing for Lunar Orbiter," May 8, 1964.

May 8

ASPO Manager Joseph F. Shea told the Center's Senior Staff that it was imperative to decide whether to use the gas-cooled space suit or the liquid-cooled undergarment. (See February 1.) Studies had shown that the current gas-cooled suit would not meet the heat load requirements and improvement would be difficult. Shea felt that parallel developments should not be carried out. A more conservative approach might be to adopt the liquid-cooled garment, which could readily handle the heat load, although it entailed some increase in weight and cost, if it could be developed and qualified within the next four years. On May 22, Robert O. Piland, Shea's Deputy, reported to the Staff that liquid-cooled undergarments had been selected for the Block II spacecraft. (See July.)

In line with selection of the liquid-cooled undergarment, Hamilton Standard was directed to stop work on the gas-cooled and begin work on a watercooled portable life support system (PLSS). On June 3, Grumman was officially notified that the PLSS was being redesigned to include a liquid transport loop for removal of heat from inside the space suit. This would be done by the liquid-cooled garment and incorporation of flexible tubing through which a coolant would be circulated. Current PLSS interfaces would be used to the greatest practical extent. It was expected that the new undergarments would first be used in manned flight about mid-1967.

MSC, "Minutes of Senior Staff Meeting, May 8, 1964," p. 4; "Minutes of Senior Staff Meeting, May 22, 1964," p. 4; MSC, "ASPO Weekly Management Report, May 14-21, 1964"; letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Portable life support system changes," June 3, 1964.

May 11-18

After a 444-second firing, Rocketdyne's first LEM descent engine prototype thrust chamber developed a hot gas leak at the injector flange. Studies were under way by the contractor to determine the cause of the leak.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, May 17-June 20, 1964," p. 24; MSC, "ASPO Weekly Management Report, May 14-21, 1964."

May 12

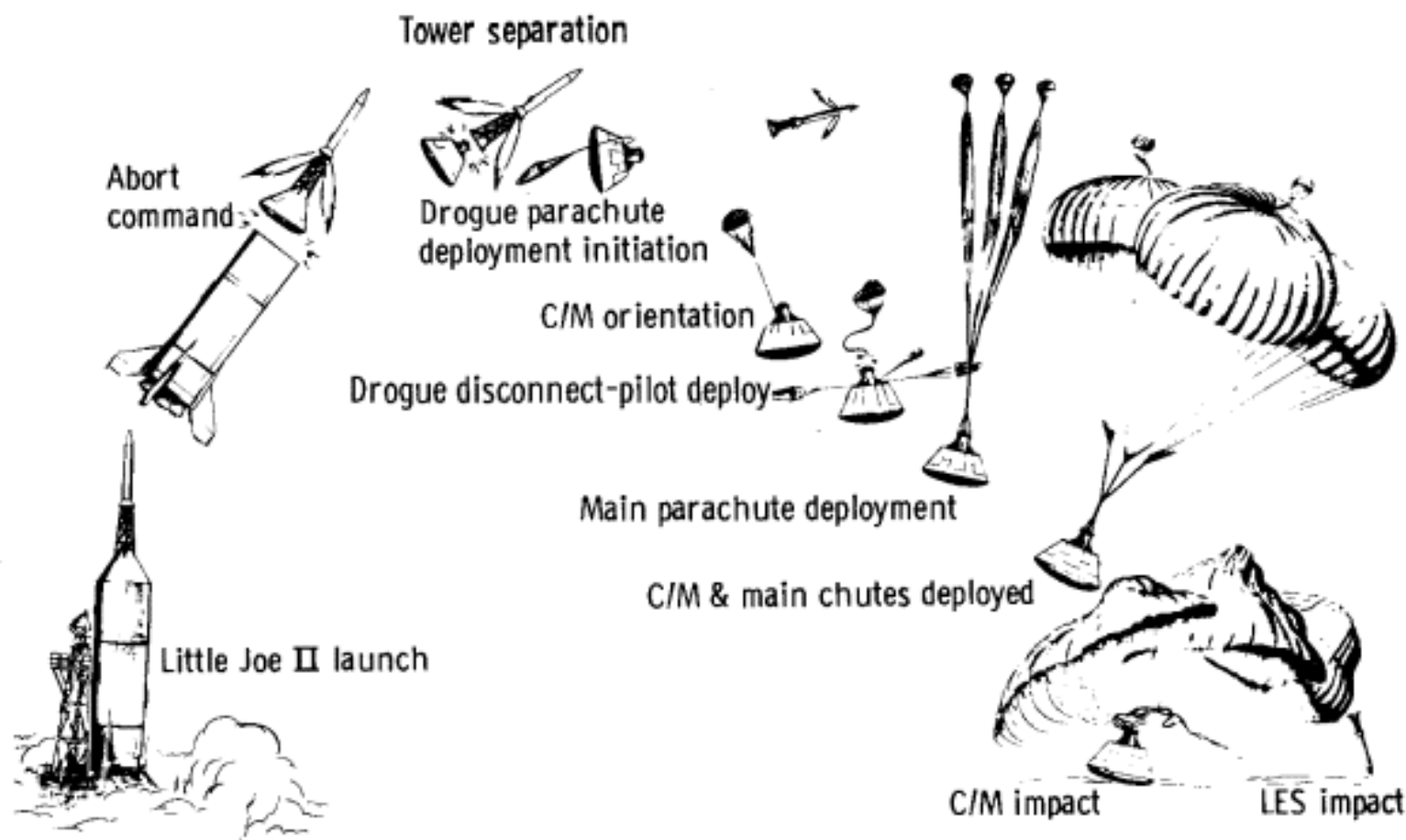
Verne C. Fryklund, Jr., Chief of the Lunar and Planetary Branch in NASA's Office of Space Science and Applications, reported that the Lunar Orbiter program was being coordinated with Apollo's requirements for moon maps. This agreement was reached through a series of meetings of Fryklund with William B. Taylor, of OMSF's Advanced Manned Missions Program Directorate; and Lee R. Scherer, Lunar Orbiter Program Manager. Fryklund set forth general requirements for maps for the Apollo program. Because

most Lunar Orbiter data were intended for Apollo's use, Fryklund said, these requirements must be borne in mind when Lunar Orbiter's information was analyzed and distributed. MSC was interested primarily in the equatorial area of the moon (10 degrees above and below the equator), and established rather stringent demands for accuracy around selected landmarks. These requirements were dictated by Apollo's need for selenodetic and topographic information, essential for lunar navigation and landing site selection and for scientific activities by the astronauts on the lunar surface. Although each mission might ultimately require special maps, Fryklund advised, major requirements could be met by a common series of charts and photomosaics.

Memorandum, Fryklund, NASA, to Distr., "The Lunar Orbiter Program and the lunar mapping requirements of Project Apollo," May 12, 1964.

May 13

Apollo's first flight test using the Little Joe II launch vehicle, Mission A-001, using CSM boilerplate (BP) 12, was launched from WSMR. The test was conducted to determine aerodynamic characteristics of the launch escape system (LES) and its capability to pull the spacecraft away from the launch vehicle during an abort at transonic speeds and high dynamic pressure. Thrust termination subjected the spacecraft to an environment more severe than expected, above the qualification test level of many of the CM's components.



he planned sequence of events for the BP-12 sub-orbital flight is shown above.

Except for a parachute failure, spacecraft and LES functioned flawlessly. All but one test objective was met: because of excessive spacecraft oscillation at the time the main parachutes were deployed, one riser was dragged across the spacecraft structure and severed. The shroud lines of the now-freed parachute burned a gore in one of the two remaining parachutes. Although the damaged gore failed, these two main parachutes deployed normally. BP-12 landed 3,530 meters (11,600 feet) downrange about five minutes and 50 seconds after liftoff. At impact, its rate of descent was 7.9 meters (26 feet) per second, 0.06 meters (two feet) per second faster than planned but still within human tolerances.

"Postlaunch Report for Apollo Mission A-001 (BP-12)," pp. 1-1, 2-1, 3-1, 6-1.

May 14-21

MSC decided to provide equipment in the LEM for recording the astronauts' voices, and was studying ways to achieve a capability for time correlation with a minimum increase in power and weight.

MSC, "ASPO Weekly Management Report, May 14-21, 1964."

May 18-25

The first test of a fully ablative thrust chamber for the LEM descent engine was held at Space Technology Laboratories. The chamber, with a wall thickness of 22.4 millimeters (0.88 inch), was fired for 488 seconds. Although some charring occurred, there was no streaking or gouging. Data showed good performance at low thrust.

MSC, "ASPO Weekly Management Report, May 21-28, 1964"; MSC, "Weekly Activity Report for the Office of the Associate Administrator, Manned Space Flight, May 24-30, 1964."

May 21

General Electric (GE) issued a report on postlanding tilt angles for the LEM (the result of a study ordered by ASPO). The Apollo Systems Specification, put out by OMSF, called for the LEM's ability to lift off from the moon from an angle of 30 degrees; MSC's LEM Technical Approach stated that "the Lunar Touchdown System [i.e., the landing gear] will be required to land the LEM in a near vertical position satisfactory for lunar launch and normal egress." GE's study was an attempt to reconcile this difference. There was some concern that, for a variety of reasons, a 30-degree tilt might be undesirable: the spacecraft could tip over; once stage separation occurred, the vehicle's ascent portion could shift slightly; and the crew's visibility and mobility - including their ability to get in and out of the craft - might be impaired. Added to this were possible constraints imposed by the performance of many of the LEM's

operational systems (e.g., communications, ascent propulsion, stabilization and control). In sum, GE reported that it had found no constraints that negated the 30-degree figure, and recommended that MSC's Technical Approach be revised to correspond with OMSF's specification.

General Electric Company, Apollo Support Department, "Study of the Postlanding Tilt Angle of the LEM," TIR 545-S64-03-006, May 21, 1964, *passim*, but especially pp. 1-4, 32-34; MSC, "ASPO Weekly Management Report, May 21-28, 1964"; interview, telephone, Richard H. Kohrs, Houston, March 9, 1970.

May 21

NASA completed negotiations with General Dynamics/Convair (GD/C) for two additional Little Joe II test vehicles and associated ground equipment. (See February 18, 1963.) The amendment (worth \$1,352,050) increased the contract's total estimated cost and fee to \$12,478,205, and brought to eight the total number of Little Joes (excluding the qualification vehicle) that NASA bought from GD/C.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, May 17-June 20, 1964," p. 42; *Little Joe II Test Launch Vehicle, NASA Project Apollo: Final Report*, Vol. I, pp. 1-7, 4-4.

May 21-28

North American completed zero-g egress tests, using the proposed small configuration CM side entry hatch with a crewman wearing a pressurized Gemini space suit and an operational portable life support system. Weightless tests were also conducted on the crew couch zero-g restraint harness. The subjects had considerable difficulty attaching the harness; additional development and testing were necessary.

NAA, "Apollo Monthly Progress Report," SID 62-300-26, July 1, 1964, p. 7; MSC, "ASPO Weekly Management Report, May 28-June 4, 1964."

May 22

ASPO directed Grumman to provide an overhead window in the LEM to permit the pilot to dock at the upper docking hatch. The forward access hatch was retained for lunar surface ingress and egress and on-the-pad access capabilities. The contractor would remove the forward docking interface and tunnel.

MSC, "ASPO Weekly Management Report, May 21-28, 1964"; MSC, "Minutes of Senior Staff Meeting, May 22, 1964," p. 4.

May 22

MSC received results of RCA and Ryan Aeronautical Company studies on modifying either the LEM

landing or rendezvous radar to achieve the high accuracies needed to circularize the LEM's lunar orbit. The contractors concluded that, as currently designed, radar performance would be marginal. Attempts to obtain this degree of accuracy could cause schedules to slip, because of the lack of knowledge of lunar reflectivity. As a means of reducing the effects of surface variations, RCA and Ryan recommended lessening the spectrum of the radar. (See February 27-March 4 and March 16.)

MSC, "ASPO Weekly Management Report, May 21-28, 1964"; MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, May 17-June 20, 1964," p. 58.

May 22

MSC informed Grumman of two major revisions to the ground rules for crew transfer between the two spacecraft:

1. Definite tasks were replaced with a general requirement that a "pressurized crew," should be able to prepare the docked spacecraft for translunar operations.
2. The requirement for a crewman to pressurize his space suit and, with the aid of a second crewman, move through the transfer tunnel without damage to the suit was changed: the crew must be able to transfer through the tunnel in a pressurized suit as a degraded mode of operation.

Transfer in an unpressurized suit continued to be the primary and extravehicular transfer the emergency mode. Crew transfer tests at North American indicated that no significant hardware changes were necessary to implement these revisions.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Revision of the Apollo-Docking Interface and Ground Rules," May 22, 1964.

May 26

At Hamilton Standard, MSC representatives reviewed status of the Apollo space suit (A3H-024). Tests showed that a suited astronaut could not put on the thermal coverall while wearing a portable life support system.

MSC, "ASPO Weekly Management Report, May 28-June 4, 1964."

May 26

ASPO notified Grumman that the carbon dioxide sensor was a crew safety item. Since failure of this component could cause loss of the crew, it must be designed to meet crew safety reliability. NASA's contract with The Perkin-Elmer Corporation, manufacturer of the; sensor, had been amended to include testing required for crew safety items.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, carbon dioxide (CO₂) sensor requirement," May 26, 1964.

May 26

ASPO directed North American to provide a station in the CM where the astronauts could put on and remove the portable life support systems.

MSC, "ASPO Weekly Management Report, May 21-28, 1964."

May 27

Meetings at Grumman (on May 21-22) had disclosed that the contractor had changed from an all-welded LEM cabin to one that was partially riveted. Although this change had not been coordinated with MSC, the Center nonetheless agreed to it, provided the structural integrity of a cabin thus fabricated could be demonstrated under all load, temperature, and vacuum conditions. MSC recommended that representatives from Grumman visit MSFC to review welding and sealant techniques developed for Saturn launch vehicles.

MSC, "ASPO Weekly Management Report, May 28-June 4, 1964."

May 28

Apollo Mission A-101, the first flight of an Apollo spacecraft with a Saturn launch vehicle, was launched from Cape Kennedy. The purpose of the flight was to demonstrate the compatibility of the spacecraft with the launch vehicle for earth orbital flights. A-101 also was the first Apollo flight test conducted at Cape Kennedy, and consisted of CSM boilerplate (BP) 13 and the Saturn SA-6 vehicle.

Launch azimuth was 105 degrees. S-I's first stage number eight engine shut down prematurely at T+1 16.9 seconds, delaying S-I cutoff and separation, which occurred at T+148.8 seconds (2.7 seconds late). The S-IV second stage ignited at T+150.9 seconds, and the LES was jettisoned 10.3 seconds later and was propelled safely from the flight path. S-IV cutoff took place at T+624.5 seconds (1.26 seconds earlier than predicted). Orbit insertion was completed at T+629.5 seconds, with a 31.78 degree equatorial plane. The payload weight at orbit insertion was 7,622 kilograms (17,023 pounds). Deviations from planned flight path angle and velocity were minus 0.05 degrees and plus 3.6 meters (11 feet) per second, respectively. Orbital parameters were 182 and 227 kilometers (98.4 and 122.5 nautical miles); the orbital period was 88.62 minutes.

Although there were a few cases of excessive delay in transmission, data coverage and availability were, in general, quite good. Electromagnetic interference was minor and did not degrade or invalidate the data. The instrumentation and communications systems performed satisfactorily; battery performances exceeded expectations. LES separation caused no detectable disturbance of the flight vehicle. The

sequencer system, explosive bolts, and tower jettison all functioned properly. Aerodynamic, thermodynamic, acoustic, and vibration data contained no surprises. As expected, stresses on the LES were considerably less than those imposed during abort; loads on other spacecraft structures all were within design limits.

BP-13 and the spent S-IV stage circled the earth 54 times before reentering the atmosphere east of Canton Island in the Pacific Ocean on June 1. No spacecraft recovery was planned.

NAA, "Project Apollo Flight-Test Report, Boilerplate 13," SID 63-1416-3, August 1964, pp. 2-1, 2-2; "Postlaunch Report for Apollo Mission A-101 (BP-13)," pp. 2-1, 3-2 through 3-5, 4-1 through 4-3, 7-1.

May 28

MSC issued a cost-plus-fixed-fee contract to Bissett-Berman Corporation of Santa Monica, Calif., for studies of Apollo mission planning, guidance and navigation system analysis, and related tasks. The contract was valued at \$915,357.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, May 17-June 20, 1964," p. 42.

May 28

MSC instructed North American to continue the Apollo food studies (being done under subcontract by the Stanford Research Center) on diet selection, nutritional value, packaging design and materials, and rehydration. North American was asked to furnish a final report documenting the project and to provide MSC Crew Systems Division with one set (i.e., food supply for three crewmen for a two-week Apollo mission) for evaluation of both the food itself and of packaging concepts. The contractor also was asked to report its findings on studies of snacks for the crewmen.

Letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. 174, Revision 1," May 28, 1964,

May 28-June 4

MSC reported that Grumman was studying how much restraint the LEM crew needed during lunar landing, and was conducting manned drop tests to help define requirements. The program was divided into two phases, one on vertical and the other on off-axis landing. In the first part, already completed, the subject had needed no restraints. The second phase, however, was much more severe, and it was believed that restraint would probably be essential.

MSC, "ASPO Weekly Management Report, May 28-June 4, 1964"; "Quarterly Status Report No. 8," p. 35.

During the Month

At the CSM mockup review at North American on April 28-30, MSC officials were concerned about the complexity of the couch restraint system. Because of the decision that primary landing would be on water (see February 28), the system was reviewed. Based upon load analyses, supplemented by manned tests at Holloman Air Force Base, a simpler system (principally a combination lap belt and shoulder harness) was found acceptable.

MSC, "ASPO Weekly Management Report, May 14-21, 1964"; "Quarterly Status Report No. 8," pp. 12-13.

June 1-5

MSC notified Grumman that primary LEM ingress and egress was through the forward hatch. To aid the LEM crew in getting down to the lunar surface and in climbing back into their vehicle, the Center said, a narrow platform must be provided from the hatch to the landing gear knuckle (which became the "front porch"), and a handrail and ladder down the strut to the foot pad.

MSC, "ASPO Weekly Management Report, June 4-11, 1964."

June 1-5

Technicians of MSC's Landing and Recovery Division began initial testing with a prototype flotation collar (similar to those used with both Mercury and Gemini spacecraft). Boilerplate 25 served as the test vehicle.

MSC, *Space News Roundup*, June 24, 1964, p. 3.

June 2

NASA signed a production contract worth \$1.82 million with Sperry Gyroscope for accelerometers for the CSM's navigation and guidance system. (See Volume I, May 8, 1962.) [Sperry Gyroscope had been chosen during the first half of 1962 to develop these devices, and a developmental contract had been signed on June 1 of that year.]

NASA Contract NAS 9-2847, June 2, 1964.

June 3

ASPO confirmed for Grumman that no conclusive requirement for a LEM emergency detection system (EDS) had been established. The LEM should be designed to preclude any potential failure which could

cause a time-critical emergency. Malfunctions which were not time-critical would be monitored by the caution and warning system while the LEM was manned. Equipment which operated during unmanned periods should be designed to present minimum hazard and to shut down or discharge in a safe condition in cases of malfunction.

ASPO therefore directed Grumman to take no further action on an EDS for the LEM; to analyze possible failures continuously to ensure that safety requirements were met; and to advise ASPO if, at any time, those analyses indicated increased criticality which might warrant reconsideration of an EDS.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Lunar Excursion Module Recommendation Concerning LEM Emergency Detection," June 3, 1964.

June 4

After studying several configurations for the probe and drogue docking concept, North American recommended one particular design: three radial attenuators attached to three pitch arms, a probe head, a sliding center probe, a stored gas retracting mechanism, and three probe-to-tunnel mounting arms. This configuration would be about 15 percent lighter than the single, center probe, attenuator configuration.

MSC, "ASPO Weekly Management Report, June 4-11, 1964."

June 4-11

North American assessed the ultraviolet energy emitted from the shock layer surrounding a spacecraft during reentry. The contractor sought to determine how much that energy added to the radiative heat load imposed on the vehicle, and what effect it would have on the amount of ablative material on the CM. North American's first estimates placed the figure at about 20 percent for lunar return velocities (a figure that thermodynamics experts at MSC called "very conservative"), which would cause about a 4.5-kilogram (10-pound) increase in ablator weight. Because ultraviolet emissions were insignificant at orbital speeds, MSC's Structures and Mechanics Division recommended that their effect be considered only for the design of the Block II CM's heatshield.

Ibid.

June 8

ASPO redefined the allowances for scientific equipment in the LEM ascent stage. Major changes were the increase of storage space from 0.06 to 0.09 cubic meter (two to three cubic feet) and of weight from 36 to 45 kilograms (80 to 100 pounds). (See April 29.)

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Scientific Equipment," June 8, 1964.

June 8

A test of the landing impact and stability test program was conducted at North American's drop facility. CM boilerplate 2 was tested with the centerline perpendicular to the water at a vertical speed of 10.4 meters (34 feet) per second. For the first time, a self-contained instrumentation package was installed in the dummy in the center couch. The other two dummies were not instrumented. Onboard cameras documented the general motions and responses during impact. No motion of the dummies in couches or restraint harnesses was observed, indicating that support and restraint were excellent. The simulated heatshield ruptured, as expected.

NAA, "Apollo Monthly Progress Report," SID 62-300-27, August 1, 1964, pp. 5-7, 17; MSC, "ASPO Weekly Management Report, June 4-11, 1964"; interview, telephone, Glenn W. Briggs, RASPO/NAA, January 12, 1970.

June 9

In response to a Grumman request, ASPO provided information on LEM crew provision requirements. Caloric requirements, management, packaging, and reconstitution of food supplies were spelled out in detail.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, LEM crew provisions," June 9, 1964.

June 9

MSC announced the letting of a \$67,261 contract to Geonautics, Inc., for a study of LEM navigation using lunar landmarks for reference. Geonautics would evaluate crew techniques and procedures for choosing safe landing sites, navigational devices and displays in the LEM, navigational data on the spacecraft's position and trajectory, errors to be expected using various methods of navigation, and the value of available lunar maps.

MSC News Release 64-109, June 9, 1964.

June 9

Micro Systems, a subsidiary of Electro-Optical Systems, received two North American contracts valued at \$1.85 million to provide temperature and pressure transducer instrumentation for the CM.

Space Business Daily, June 9, 1964, p. 212.

June 9

Intending to rely on redundant and backup systems to ensure the spacecraft's reliability, MSC ordered North American to discontinue all effort on the inflight test and maintenance concept for the CM, including spare parts.

Letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. 213," June 9, 1964.

June 9

MSC clarified design criteria for the launch escape vehicle (LEV). During initial portions of the first-stage flight, when range safety considerations precluded thrust termination (estimated to be 40 seconds), the LEV must be capable of aborting safely. Also, the LEV structure must be designed to withstand loads arising from tumbling or oscillating.

MSC, "ASPO Weekly Management Report, June 4-11, 1964."

Early June

MSC geologist Ted H. Foss described a simulated lunar surface (modeled after the Kepler crater in the Oceanus Procellarum) to be constructed at MSC. It would be used for geological training of astronauts and for studying their mobility in space suits. The 100-meter (328-foot)-diameter area would be covered mainly with slag. Plans for several craters about 15 meters (50 feet) in diameter and 4.6 meters (15 feet) deep were later altered to include a large crater 19.5 meters (64 feet) in diameter and 4.9 meters (16 feet) deep and a smaller crater 12.2 meters (40 feet) in diameter and 3 meters (10 feet) deep. There would be a major ridge, 102.4 meters (336 feet) long and 3.7 meters (12 feet) high, and about 75 small craters less than 1.2 meters (4 feet) in diameter. [The mock lunar surface was completed in December.]

MSC, *Space News Roundup*, June 10, 1964, p. 7; MSC News Release 64-194, December 21, 1964.

Early June

NASA notified Grumman, MIT, and North American that RCA would furnish the CSM rendezvous radar to be used with the radar equipment on the LEM. A purchase order for the additional units was issued.

"Apollo Quarterly Status Report No. 8," p. 46.

June 11

MSC directed North American to make a number of changes to the Block II CSM configuration, some of which were mandatory for Block I vehicles as well. This action followed reviews of the contractor's CSM Block II Technical Report at Houston and at NASA Headquarters (by Apollo Program Director Samuel C. Phillips and OMSF chief George E. Mueller) during May. (See April 16.)

Basically, these changes (including a number to the spacecraft's subsystems) were imposed by the requirements of a lunar mission. Most pertained to the CM per se: provisions for docking (including visual aids) and redesign of the transfer tunnel; capability for extravehicular transfer; and adding portable life support systems and scientific equipment. Micrometeoroid protection had to be added to the SM. (See September 30.)

Memorandum, Owen E. Maynard, MSC, to Addressees, "CSM Block II changes transmitted to NAA for implementation," June 19, 1964, with enclosure: letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., Attn: E. E. Sack, "Block II changes," June 11, 1964, with enclosures.

June 11-18

North American canceled its contract with Avien, Inc., for the CSM S-band high-gain antenna system. (See June 21-27, 1963.) Between July 16 and August 15, North American awarded 90-day study contracts to Hughes Aircraft Company and GE to determine the best approach for developing these antennas for Block II spacecraft. The studies were scheduled for completion in October.

MSC, "Apollo/E and D Technical Management Meeting No. 5," June 3, 1964, p. 1; MSC, "ASPO Weekly Management Report, June 11-18, 1964"; NAA, "Apollo Monthly Progress Report," SID 62-300-28, September 1, 1964, p. 8.

June 12

MSC and Space Technology Laboratories (STL) completed negotiations (begun May 12) on a \$4.6 million cost-plus-fixed-fee contract for a Mission Trajectory Control Program, a continuing project begun in September 1963 to analyze Gemini missions. STL would develop computer programs for flight control trajectories, orbital maneuvers, and analyses of guidance systems, range safety, and mission error. NASA Headquarters approved the contract on August 18 and announced the contract award on August 20.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, July 19-August 22, 1964," p. 42; "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, May 17-June 20, 1964," p. 43; NASA News Release 64-206, "STL to Compute Gemini, Apollo Missions Simulations," August 20, 1964.

June 12

MSC approved Grumman's subcontract (valued at \$9,411,144) with Pratt and Whitney Aircraft for the LEM fuel cell assembly.

On this same day, the Center awarded a letter contract with a total estimated cost and fee of \$3.315 million to AC Spark Plug for the LEM guidance and navigation and coupling display unit. (See October

18, 1963.)

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, June 21-July 18, 1964," p. 37.

June 15

Space Business Daily reported that MSC was developing a packaging system for bringing back uncontaminated lunar specimens for study. First, the Center would explore methods for collecting, storing, and shipping geological, chemical, and biological specimens in their original conditions to earth laboratories. MSC then would award a contract for production of the system.

Space Business Daily, June 15, 1964, p. 239.

June 16

ASPO notified Grumman that the use of reclaimed high explosives was undesirable, since this might reduce the reliability and quality of pyrotechnic systems. To trace any lot of reclaimed material to its point of origin was virtually impossible, nor could adulterants such as TNT, which might have been added for original military use, be easily removed. MSC therefore directed North American to use only virgin, newly manufactured high explosives in Apollo pyrotechnic devices and systems.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, High explosives in the Apollo Spacecraft," June 16, 1964.

June 16

A realignment of CSM guidance and navigation subsystems functions was mandatory for Block II spacecraft. MSC therefore directed North American and MIT to conduct a program definition study of these systems. MSC outlined Block II responsibilities, systems changes (both required and desired), and implementation requirements and assigned responsibilities in these areas to the appropriate contractors.

Letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. 216," June 16, 1964, with enclosure: "Notes for CSM Block II, Definition Discussions," June 4, 1964.

June 17

NASA selected Collins Radio Company for an estimated \$20 million fixed-price-plus-incentive-fee contract to fabricate, install, integrate, and test unified S-band tracking, data acquisition, and communications equipment for Manned Space Flight Network stations. Chosen from 14 competing firms, Collins would provide NASA with nine systems, each with a 9-meter (30-foot)-diameter parabolic

antenna. Six of these would be integrated into facilities being prepared for Gemini flights and three would be installed at new Apollo stations. About 30 partial systems would also be integrated into existing ground stations for tracking Apollo flights.

NASA News Release 64-116, "NASA Negotiating Apollo Communications Systems Contracts," May 14, 1964; NASA News Release 64-146, "NASA Selects Collins Radio to Provide Apollo Tracking Systems," June 17, 1964.

June 18-25

At MSC, tests were completed on the modified space suit with the new prototype helmet. Tests in the CM mockup indicated that the new helmet gave better visibility than previous helmets. The range of nodding provided by the neck joint, however, was not considered adequate. Both the suit and helmet were shipped back to Hamilton Standard for additional work.

MSC, "ASPO Weekly Management Report, June 11-18, 1964"; "ASPO Weekly Management Report, June 18-25, 1964."

June 18-25

Beech Aircraft Corporation completed qualification testing of the hydrogen pressure vessel for the CSM electrical power system cryogenic storage. All four vessels exceeded burst pressure specification requirements. Two Inconel oxygen tanks also were burst tested, with satisfactory results.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, June 21-July 18, 1964," p. 19; MSC, "ASPO Weekly Management Report, June 18-25, 1964."

June 18-25

MSC and Honeywell studied feasibility of the astronauts' exercising manual control of the spacecraft during SM propulsion engine firing to eject from earth orbit. Investigators found that, although the task became increasingly difficult as the maneuver progressed from attitude to position changes, manual control nonetheless was entirely feasible. North American had studied six possible methods of providing electronic redundancy in the stabilization and control system (SCS) to perform just this function, but in the end recommended manual rate command. Based upon this recommendation and the earlier study, on August 19 MSC decided to incorporate this manual rate control capability in Block I SCS systems.

MSC, "ASPO Weekly Management Report, June 18-25, 1964"; MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, July 19-August 22, 1964," pp. 20, 47; NAA, "Apollo Monthly Progress Report," SID 62-300-29, October I, 1964, p. 11; interview, telephone, Kenneth J. Cox, Houston, March 10, 1970.

June 19

Qualification testing on the launch escape motor began with a successful static firing by the Lockheed Propulsion Company. Twenty motors were tested during July and August; all performed satisfactorily. (See August 30.)

Lockheed Propulsion Company, "Apollo Launch Escape and Pitch Control Motors, Monthly Progress Report No. 28," LPC No. 588-P-28, September 30, 1964, p. 5; "Apollo Monthly Progress Report," SID 62-300-27, p. 15.

June 20

NASA announced a realignment of CSM guidance and navigation system contractors, effective July 25. (See February 16-March 21.) Two of the prime contractors, Kollsman Instrument Corporation (supplier of the scanning telescope, sextant, and map and data viewer) and Raytheon Company (manufacturer of the onboard computer), became subcontractors to AC Spark Plug, prime contractor for the inertial measuring unit and for assembly and test of the complete system. Under separate contracts, MIT continued to direct overall design, development, and integration of the system, while Sperry Gyroscope provided accelerometers. All contracts for the guidance and navigation system were managed by MSC.

NASA News Release 64-148, "AC Spark Plug Becomes Prime Contractor for Production of Apollo Guidance and Navigation System," June 20, 1964; MSC, "Weekly Activity Report for the Office of the Associate Administrator, Manned Space Flight, July 19-25, 1964," p. 3,

June 21-July 18

Two amendments to the LEM contract were forwarded to Grumman for signature. One, for \$1.257 million, was for additional flight engineering support at MSC; the other, for \$4.252 million, was for a data acquisition system to be installed in the Apollo Propulsion System Development Facility at WSMR.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, June 21-July 18, 1964," p.37; MSC News Release 64-151, September 11, 1964,

June 24



The hydrogen-fueled J-2 rocket engines for the upper stages of the Saturn IB and Saturn V launch vehicles were completed on the assembly line at the Canoga Park, Calif., plant of Rocketdyne Division of NAA. The J-2 developed a thrust of 1,000 kilonewtons (225,000 pounds) at altitude. It operated in a cluster of five engines in the S-II stage and singly in the S-IVB stage of the Apollo launch vehicle. (Rocketdyne photo)

NASA Headquarters approved the definitive contract with Rocketdyne for the production of 55 J-2 engines (used in the S-IVB stage of the Saturn IB and Saturn V launch vehicles). Negotiations had taken place from April 13 to May 15. Initial value of the contract was \$89.5 million.

Akens *et al.*, *History of Marshall . . . January 1 through June 30, 1964*, Vol. I, pp. 145, 226; David S. Akens, Leo L. Jones, and A. Ruth Jarrell, *History of the George C. Marshall Space Flight Center from July 1 through December 31, 1964* (MHM-10, undated), Vol. I, p. 132.

June 24

The Army Map Service reported the completion for NASA of the first complete topographic map of the visible face of the moon.

The San Diego Union, June 25, 1964.

June 24

North American conducted the first hot fire tests of the SM reaction control system, with steady and pulsed firings. Only one engine was fired. The only problem encountered was with the oxidizer shutoff valve, which would have to be completely redesigned.

MSC, "ASPO Weekly Management Report, June 25-July 2, 1964."

June 25

Grumman engineers, meeting with ASPO officials in Houston, outlined the contractor's philosophy about onboard checkout of the LEM and equipment required to do the job. Scheduled at times when the astronauts were not heavily pressed with other activities, company engineers said there should be three major checkouts of the LEM to come:

1. after lunar orbit injection,
2. immediately after lunar landing, and
3. just before lunar launch. Of course, the astronauts would monitor the various systems during activity with the LEM to manage and operate its subsystems.

The contractor did not visualize any need for "centralized onboard checkout equipment" - caution and warning lights, controls and displays, help from the ground network, among others, should satisfy the needs. Grumman asked MSC for authority to delete the requirement for centralized checkout equipment, and ASPO concurred with their recommendations on July 27.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, LEM on-board checkout equipment," July 14, 1964, with enclosure: "Minutes of Meeting At MSC Discussing LEM On-Board Checkout Equipment, June 25, 1964"; letter, Rector to Mullaney, "Contract NAS 9-1100, LEM On-Board Checkout Equipment," July 27, 1964.

June 25

LTV was awarded a \$1,125,040 contract for a dynamic crew procedures simulator to study task assignments in simulated space flight. The trainer was capable of yaw, pitch, and roll movements and duplicated vibrations and noise incurred during liftoff, powered flight, and reentry. Visual displays simulated views of starfields, earth or moon horizons, rendezvous target vehicles, and landscapes.

MSC News Release 64-122, July 1, 1964; MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, June 21-July 18, 1964," p. 38.

June 25-July 1

Zero g tests of the CM/LEM crew transfer tunnel were performed in KC-135 aircraft at Wright-Patterson Air Force Base, verifying data obtained during crew-transfer zero-g simulations conducted at North American in February and March. The task of controlling equipment proved difficult. For example, the docking probe was temporarily lost during removal.

MSC, "ASPO Weekly Management Report, July 2-9, 1964."

June 26

MSC awarded a letter contract (with a total cost and fee estimated at \$1.234 million) to Kollsman Instrument Corporation for optical components for the LEM guidance and navigation system. (See October 18, 1963.) Negotiations for a definitive contract began July 10.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, June 21-July 18, 1964," p. 37.

June 26

ASPO, Bellcomm, Inc., and MSC's Mission Planning and Analysis Division completed a study on reentry range requirements. Because of the deceleration limit of 10 g's, the minimum reentry range was 2,200 kilometers (1,200 nautical miles [n.m.]). A range flexibility of about 1,600 kilometers (1,000 n.m.) was essential to allow for weather conditions. An additional 1,600 kilometers (1,000 n.m.) was required by the emergency reentry monitoring system. Therefore, the heatshield must be designed to withstand reentry heating over a 5,920-kilometer (3,200-nm.) range.

During mid-July, ASPO learned from the Landing and Recovery Division that the minimum acceptable CM maneuverability during reentry was 1,600 kilometers (1,000 n.m.) for water landings. "This requirement was based on storm size, weather predictability, and reliability of storm location and direction of movement." Landing errors associated with reentry on backup guidance demanded that the spacecraft be capable of a 6,500-kilometer (3,500-n.m.) reentry.

Memorandum, Aaron Cohen, MSC, to Owen E, Maynard, "Reentry Range Requirement," June 26, 1964; MSC, "ASPO Weekly Management Report, July 16-23, 1964"; memorandum, Claude A. Graves, MSC, to Chief, Mission Planning and Analysis Div., "Operational entry range requirement," June 18, 1964; memorandum, Carl R. Huss, MSC, to BE4/Historical Office, "Comments on Volume II of *The Apollo Spacecraft: A Chronology*," March 30, 1970.

June 28-July 4

MSC authorized Grumman to procure a "voice only" tape recorder with time correlation for use in the LEM data storage electronic assembly. The unit would be voice operated and have a capacity of 10 hours recording time.

MSC, "Weekly Activity Report for the Office of the Associate Administrator, Manned Space Flight, June 28-July 4, 1964," p. 3.

June 30

After acceptance testing, AiResearch Manufacturing Company delivered the first production CM environmental control system to North American.

The Garrett Corporation, AiResearch Manufacturing Division, "Monthly Progress Report, Environmental Control System, NAA/S&ID, Project Apollo, 16 June 1964-15 July 1964," SS-1013-R(26), July 31, 1964, pp. 1, 15.

June 30

MSC directed North American to make whatever changes were necessary in the Block I design to make the spacecraft compatible with the Gemini space suit. (See May 7.)

MSC, "ASPO Weekly Management Report, June 25-July 2, 1964."

During the Month

MSC's Operations Planning Division requested OMSF to revise its spacecraft specifications to

1. delete the requirement for data storage in the LEM (this function would be performed by the CSM data recording equipment via an RE link); and
2. drop the requirement for one portable life support system (PLSS) for each crewman (a third PLSS would only allow the CM pilot to enter the LEM without benefit of a hard dock, and studies had shown that this situation probably would never arise).

Early in July, MSC requested OMSF to change two other requirements from tentative to firm:

1. LEM tilt angle at lunar liftoff should not exceed 30 degrees (MSC had accepted this value and Grumman had been asked to design systems to conform [see May 21]);
2. the service propulsion system should include a propellant control so that unused propellants (resulting from mixture ratio shift) would not exceed 0.5 percent of the initial propellant supply. (Studies showed that the North American design already met this requirement.)

"Apollo Quarterly Status Report No. 8," p. 63; MSC, "ASPO Weekly Management Report, July 2-9, 1964."

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July 1

ASPO spelled out operational procedures for the space suit emergency oxygen supply (EOS) units. [The primary function of the EOS was as a backup during extravehicular operations, if the portable life support system failed or if suit leakage was excessive. EOS could also be used to back up the spacecraft environmental control system during short-term emergencies such as crew transfer.] The two units, stowed in the CM, would be worn during crew transfer to the LEM, then stored there. After landing on the moon, the crewmen would wear the EOS during the entire lunar stay. Putting on or taking off the units unassisted would not be required. North American and Grumman were directed to provide suitable stowage areas in each spacecraft.

TWX, C. L. Taylor, MSC, to NAA, Attn: E. E. Sack, July 1, 1964; TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, July 14, 1964; memorandum, William C. Kincaide, MSC, to Chief, Crew Systems Div., "Apollo Emergency Oxygen Supply Subsystem (EOSS)," July 24, 1964.

July 2-9

MSC's Operations Planning Division (OPD) examined a 14-day lunar survey mission (a manned Apollo Lunar Orbiter-type of photographic mission). OPD found that the 578-kilowatt-hour capability of the CSM's electrical power system was adequate, provided there were no cryogenic tank failures. If such failures occurred, the maximum mission duration would be 11.8 days (four days in lunar orbit).

MSC, "ASPO Weekly Management Report, July 2-9, 1964;" interview, telephone, Richard H. Kohrs, Houston, March 11, 1970.

July 8

Donald K. Slayton, MSC Assistant Director for Flight Crew Operations, announced specific assignments for the astronauts. Alan B. Shepard, Jr., was named Chief of the Astronaut Office, Slayton's former job. This office was now divided into three branches, Apollo, Gemini, and Operations and Training: L. Gordon Cooper, Jr., was head of the Apollo branch, with James A. McDivitt, Charles Conrad, Jr., Frank Borman, and Edward H. White II assisting him; in the Gemini branch, headed by Virgil I. Grissom, were Walter M. Schirra, Jr., John W. Young, and Thomas P. Stafford; the Operations and Training branch was headed by Neil A. Armstrong, assisted by Elliot M. See, Jr., and James A. Lovell, Jr. (M. Scott Carpenter, currently on duty with the U.S. Navy's Project Sealab, was not given a specific MSC assignment.)

The 14 newest astronauts were given individual assignments within the Operations and Training branch: Edwin E. Aldrin, Jr., mission planning (including trajectory analysis and flight plans); William A. Anders, environmental control systems and radiation and thermal protection; Charles A. Bassett II, training and simulators; Alan L. Bean, recovery systems; Eugene A. Cernan, spacecraft propulsion and the Agena; Roger B. Chaffee, communications and the Deep Space Network; Michael Collins, pressure suits and extravehicular experiments; R. Walter Cunningham, electrical and sequential systems and monitoring of unmanned flight experiments in other programs which might relate to MSC programs; Donn F. Eisele, attitude and translation control systems; Theodore C. Freeman, boosters; Richard F. Gordon, Jr., cockpit integration; Russell L. Schweickart, future manned programs and inflight experiments in Gemini and Apollo; David R. Scott, guidance and navigation; and Clifton C. Williams, Jr., range operations and crew safety.

MSC News Release 64-125, July 9, 1964; MSC, *Space News Roundup*, July 8, 1964, pp. 1, 3.

July 8

Apollo Program Director Samuel C. Phillips called a meeting at NASA Headquarters to discuss disposing of the S-IVB stage and its instrument unit (IU) during lunar missions. Certain restrictions were considered:

1. the S-IVB/IU must not hit the spacecraft after separation;
2. it was preferable that the S-IVB/IU not impact either the earth or the moon, but in seeking to prevent this no changes would be made to the space vehicle that might result in weight, cost, or schedule penalties; and
3. no special provision would be made for tracking the S-IVB/IU after separation from the spacecraft.

"Minutes of Meeting to Review Disposition of the S-IVB/IU and Related Support Requirements During the Post Injection Phase of Lunar Missions," July 15, 1964.

July 8-9

MSC representatives attended the second Block I CSM mockup review at North American. (See April 28- 30.) Although the crew area was decidedly improved, further changes in the suit umbilicals and the restraint system - and significant ones - still were required.

MSC, "ASPO Weekly Management Report, July 9-16, 1964."

July 9

ASPO directed Grumman to delete 200 watts, currently appearing on the LEM's power allotment charts, for lighting during television transmission of lunar earthshine scenes. The LEM television camera, which was furnished by the government, would be able to televise all lunar scenes during sunshine or earthshine periods.

TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, July 9, 1964.

July 16

A NASA-North American Technical Management meeting set the CM control weight (based on an assumed 41,000-kilogram [90,000-pound]-payload capability of the Saturn V) at 5,000 kilograms (11,000 pounds). MSC then asked and North American agreed to design, test, and qualify the open ring-sail main parachutes for a CM weighing 5,200 kilograms (11,500 pounds).

"Minutes of NASA-NAA Technical Management Meeting, July 14, 1964"; MSC, "ASPO Weekly Management Report, July 30-August 6, 1964."

July 16

Once the decision was made to use Gemini space suits during Apollo earth-orbital flights, NASA took the next step. The space agency gave to the David Clark Company, manufacturer of the Gemini suit, a program for modifying and testing that suit for use in the Apollo program, and designated it the "Aponi" suit. Formal contract awards were scheduled for late in the year.

Memorandum, H. F. Battaglia, MSC, to Chief, MSC Crew Systems Div., "Trip report for visit to David Clark Company, Worcester, Massachusetts concerning Aponi Space Suit Program," July 16, 1964.

July 16-17

Representatives of North American, RCA, and MSC's Instrumentation and Electronic Systems Division held a meeting on the status of the CSM television subsystem. A design review covering all electrical, mechanical, and optical aspects of the configuration established that the design was complete, subject only to changes growing out of development and qualification tests.

MSC, "ASPO Weekly Management Report, July 16-23, 1964."

July 19-25

North American completed a CM-active docking simulation at its Columbus, Ohio, facility to study propellant consumption, engine duty cycles, and stabilization and control system characteristics and performance. Preliminary results showed that sighting aids mounted on the LEM were needed for a satisfactory docking. Furthermore, during transposition docking the S-IVB's roll rate must be no greater than 0.1 degree. North American would prepare a full-scale, three-dimensional study to evaluate differences in lighting and would design sighting aids (to be tested at Langley Research Center).

MSC, "Weekly Activity Report for the Office of the Associate Administrator, Manned Space Flight, July 19- 25, 1964," p. 4; "Apollo Monthly Progress Report," SID 62-300-28,

July 20-21

At Grumman, representatives from MSC's Structures and Mechanics and Systems Engineering Divisions reviewed the design criteria for the LEM's landing gear. The group agreed to study landing stability in various landing conditions. This investigation, and results of MSC Guidance and Control Division's landing simulations, would permit a realistic evaluation of the 406.4-centimeter (160-inch) cantilever gear. (See October 2, 1963.)

MSC, "ASPO Weekly Management Report, July 23-30, 1964."

July 21

MSC approved a configuration that Hamilton Standard had recommended for the power supply for the liquid-cooled portable life support system. This configuration embodied an 11-cell secondary battery and separate conversion devices for each electrical load. The total battery capacity required was 108.8 watt-hours.

TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, July 21, 1964.

July 21

Grumman held a portable life support system (PLSS) accessibility test in test mockup 1 for the MSC

Crew Systems Division. Subjects were able to put the PLSS on and take it off, unassisted, with the suits pressurized and unpressurized.

MSC, "ASPO Weekly Management Report, July 23-30, 1964."

July 21

MSC approved Grumman's subcontract with Allison Division of General Motors Corporation for the LEM descent engine tanks. The amount of the cost-plus-incentive-fee contract was \$5.48 million.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, July 19-August 22, 1964," p. 41.

July 21

NASA announced that its Office of Space Science and Applications was inviting scientists to participate in a scientific experiment program for manned and unmanned spacecraft. American and foreign scientists from universities, industry, and government were being asked to submit proposals. The earliest Apollo missions that could support this program were anticipated to be the fourth and fifth flights. About 0.06 cubic meter (two cubic feet) of space would be available for instruments and equipment weighing not more than 36 kilograms (80 pounds), but it was expected that additional space and weight would be available in the S-IVB stage during early flights.

NASA News Release 64-177, "NASA Invites World Scientists to Propose Space Experiments," July 21, 1964.

July 23-30

As currently conceived, the LEM's waste management system was designed for direct transfer from the space suit assembly and immediate dumping. If a storage system for the urine were not designed into the LEM, ASPO reported, the spacecraft could be lightened by more than 23 kilograms (50 pounds). MSC, "ASPO Weekly Management Report, July 23-30, 1964."

July 23-30

At its Reno, Nev., facility, Rocketdyne conducted the first checkout firing (five seconds) of their LEM descent engine at a simulated altitude of 39,600 meters (130,000 feet). A heavyweight, 20.3-millimeter (0.8-inch) thick nozzle extension skirt was used. During the following week, firings of the engine included one of 110 seconds.

MSC, "ASPO Weekly Management Report, July 23-30, 1964"; "ASPO Weekly Management Report, July 30-August 6, 1964."

July 23-30

Dalmo Victor Company was selected to supply the LEM S-band steerable antenna system to RCA, subcontractor for the LEM communication system. MSC, "ASPO Weekly Management Report, July 23-30, 1964."

July 24

After comparing capabilities of the space suit assembly with and without the emergency oxygen supply (EOS), the MSC Apollo Portable Life Support Systems Office recommended that the EOS system be retained for crew safety considerations. (See July 1.)

Memorandum, William C. Kinkaide, MSC, to Crew Systems Division, "Apollo Emergency Oxygen Supply Subsystem (EOSS)," July 24, 1964.

July 24

MSC authorized North American to provide a boost protective cover that would completely enclose the conical portion of the CM during launch. As an integral part of the launch escape system (LES), the cover would be jettisoned after atmospheric exit or during an atmospheric abort. Also the cover would satisfy the requirement for clean windows on the CM after LES separation and would protect the CM's thermal coating and docking mechanism from the launch environment. (See January 15-23 and March 19-26.)

Letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. 235," July 24, 1964.

July 27

ASPO notified Grumman that spacecraft attitude criteria had been changed to relax thermal design requirements. The former constraints ("worst case orientation") had imposed severe penalties on the design of subsystems and components. The new criteria relieved thermal design problems, but Grumman must ensure that these standards were compatible with other constraints and that they provided adequate operational flexibility.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Apollo spacecraft thermal design mission," July 27, 1964.

July 28

MSC awarded a \$335,791 contract to Lockheed-California Company for transient heat transfer and thermodynamic analyses of the service propulsion system (SPS). Phase I, an analytical study, and Phase II, testing a one-third-scale model of the SPS, were scheduled for completion in January and May. Tests would be run in the Hughes Aircraft Company altitude chamber in a thermal vacuum and under simulated solar radiation.

MSC, "ASPO Weekly Management Report, August 13-20, 1964."

July 28

Ranger VII was launched from Cape Kennedy. The 365.6-kilogram (806pound) spacecraft, carrying six television cameras to take close-up pictures of the moon, was boosted into an earth-parking orbit by an Atlas-Agena launch vehicle. The Agena engines then refired to place the spacecraft on a translunar trajectory. On July 31, *Ranger VII* crashlanded on the moon at 10.7 degrees S, 20.7 degrees W, in the Sea of Clouds. The spacecraft sent back 4,316 pictures, beginning at an altitude of about 800 kilometers (500 miles) and ending at impact.

During the next several weeks, MSC's Space Environment Division, ASPO, Grumman, and Bellcomm studied these photographs in great detail. On October 30, ASPO Manager Joseph F. Shea informed Samuel C. Phillips, Deputy Director of the OMSF Apollo Program, that the *Ranger VII* data had eliminated most of the major uncertainties about the lunar surface that could be resolved by photographic techniques.

The New York Times, July 29, 1964; memorandum, John M. Eggleston, MSC, to Shea, "Preliminary analysis of Ranger 7 photographs," August 13, 1964; memorandum, Shea, to NASA Headquarters, Attn: Phillips, "Apollo Mapping and Survey System," October 30, 1964.

July 30

MSC awarded a cost-plus-fixed-fee contract estimated at \$365,000 to the Astronautics Division of LTV for Apollo space suit evaluation and thermal development and qualification testing of Gemini space suits in the company's space environment simulator.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, July 19-August 22, 1964," p. 64; memorandum, Robert E. Smylie, MSC, to Chief, Systems Test Branch, "Technical Monitorship of the LTV Space Environment Simulator Contract," August 26, 1964.

July 30

NASA approved Grumman's proposal to use the spacecraft's VHF radios as an "intercom" between the docked LEM and the CM. Early planning had involved the use of a hardline/umbilical arrangement.

TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, July 30, 1964.

July 30-August 6

Technicians in MSC's Operations Planning Division (OPD) studied oxygen storage capacities in the two spacecraft to determine whether those supplies exceeded by 50 percent the levels of consumption anticipated during a normal mission (as required by OMSF specifications). On the basis of current design consumption, they found that mission requirements were exceeded by only 45 and 25 percent for the CSM and LEM, respectively. OPD therefore recommended that OMSF's specifications be revised, because oxygen for the fuel cells as well as for breathing was contained in the same tanks. Rather than the 50 percent reserve, OPD said, Headquarters should instead require the oxygen supplies in both spacecraft to be the maximum amount that would be used for environmental control and for generating power during a lunar mission. And, to allow for safe aborts, some alternate or redundant oxygen storage would be provided in each spacecraft.

MSC, "ASPO Weekly Management Report, July 30-August 6, 1964."

During the Month

Members of the National Academy of Sciences' Committee on Lunar Exploration, meeting in Houston, expressed fear about contamination of the lunar surface before Apollo astronauts could secure samples for analysis. Contaminants might come, they noted, from at least two possible sources:

1. air released when the LEM was depressurized, and
2. leakage from the space suits.

Elliott S. Harris, head of MSC's Microbiology, Biochemistry, and Hygiene Section, who was present at the meeting, informed Crew Systems Division of the scientists' concern and relayed their recommendations on ways of preventing or controlling such contamination (such as bacteria filters).

Memorandum, Elliott S. Harris, MSC, to Chief, Crew Systems Division, "Lunar contamination," July 31, 1964.

During the Month

At Hamilton Standard and at MSC, testing continued on early versions of the Hamilton Standard liquid-cooled garment as well as an in-house model developed by the Crew Systems Division. (See February 1 and May 8.) While sweating was not yet completely eliminated, these tests nonetheless confirmed the efficacy of using liquid- rather than gas-cooled garments.

MSC, Space News Roundup, June 24, 1964, p. 7; MSC News Release 64-121, July 8, 1964; MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, May

17- June 20, 1964," p. 53; memorandum, Gilbert M. Freedman and Francis J. DeVos, MSC, to Apollo Portable Life Support Systems Office, "Trip Report-Contract NAS 9-723," July 8, 1964; MSC, "ASPO Weekly- Management Report, July 2-9, 1964"; "ASPO Weekly Management Report, July 16-23, 1964."

August 3

At its new Magic Mountain, Calif., facility, the Marquardt Corporation began development firings on the LEM reaction control system. By using successively more advanced components, the testing program would gradually build toward a complete prototype. Early in September, MSC's Propulsion and Power Division (PPD) reported that Marquardt had suspended testing temporarily because of problems with monitoring equipment (which, the Division grumbled, could have been checked out before the testing started). Two weeks later, PPD reported that contamination of the thrust chamber had forced Marquardt to halt these developmental firings again. Finally, by mid-October, problems with manufacturing and acceptance checking of the thrust chambers at the company's manufacturing plant portended a twenty-week slippage in delivery of the chambers to the Magic Mountain site.

MSC, "ASPO Weekly Management Report, July 30-August 6, 1964"; "ASPO Weekly Management Report, August 27-September 3, 1964"; "ASPO Weekly Management Report, September 10-17, 1964"; "ASPO Weekly Management Report, October 8-15, 1964."

August 4

ASPO tentatively approved Grumman's recommendation to use electroluminescent lighting for controls and display panels inside the LEM's cabin (with backup floodlighting). "Definitive acceptance," of course, was "dependent upon resolution of actual production hardware capabilities." This action followed a July 16 presentation of the electroluminescent concept by Grumman and a review by MSC representatives (among whom were two astronauts, Richard F. Gordon, Jr., and Charles Conrad, Jr.). [Electroluminescence involved the use of a crystalline phosphor to give off light. Advantages of the concept, which was wholly new to manned spacecraft, were that it used less power and gave off less heat than conventional incandescent bulbs; and, even more significant in the eyes of the astronauts, it was much more even and had an "afterglow" of less than one second.]

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Lighting Mockup Review," with enclosure: "Abstract of Proceedings, LEM Crew Integration Meeting, GAEC, Bethpage, L. I., New York, Subject: LEM Interior Lighting Review," July 17, 1964.

August 4

At a meeting at MSC on July 23, MIT outlined aids and radar display requirements, as well as landing site selection procedures, for lunar landing. This included the reticular patterns on the LEM window that designated where the vehicle was coming down and which enabled the pilot to make touchdown corrections. There was a good deal of concern that, at some time during the final letdown phase, dust

might obscure the astronauts' vision and make the radar data unreliable. To overcome this, MSC ordered Grumman to use inertially derived data to monitor automatic touchdown or as a basis for switching to manual control of the descent.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, NASA Coordination Meeting L8A, Implementation of Decisions," August 4, 1964, with enclosure: "Minutes of NASA Coordination Meeting L8A, July 23, 1964."

August 6

ASPO Deputy Manager Robert O. Piland issued a memorandum concerning the Block II SM, as he put it, "to clear up any confusion which may have existed" - and obviously there was some. (See April 16.) On the basis of revised velocity budget requirements, and as a weight-saving scheme, Piland said, the service propulsion tanks in the Block II SM were being shortened. But he emphasized that the length of the spacecraft per se "*will not be* reduced," and would thus remain the same as the Block I vehicle.

Memorandum, Piland, MSC, to Addressees, "Block II Service Module Length," August 6, 1964.

August 6-13

To investigate problems that might be encountered during the LEM's "blast off" from the moon, Grumman conducted "fire in the hole" tests using a 1/10th-scale model of the spacecraft. (See February and March 11, 1963.) These tests showed that the initial shock of the ascent engine's ignition could increase the pressure in the engine nozzle by 2 newtons per square centimeter (3 psi), and that this pressure could vary from one side of the nozzle to the other by as much as 0.53 newtons per square centimeter (0.75 psi). This pressure differential would change the thrust vector and cause an overturning moment on the vehicle. Grumman planned additional testing before actual full-scale firings began at WSMR.

MSC, "ASPO Weekly Management Report, August 6-13, 1964."

August 7

At North American, engineers from MSC's Crew Systems Division (CSD) reviewed the revised CM couch restraint system. (See May.) CSD still considered the restraint harness unacceptable for use with the pressurized suit. Also the harness attachment gave inadequate restraint when the couch angles were changed and would have to be relocated. North American was asked to install a mirror in the CM to help the astronauts in securing the restraint harness.

Ibid.

August 7

ASPO's LEM Project Office authorized Grumman to proceed with its subcontractor effort for attitude indicators for the LEM. Until MSC concluded defining the LEM's guidance equipment (anticipated early in November), Grumman should pursue the analog concept (i.e., visual display instruments). (MSC was in the midst of "tradeoff" studies on digital versus analog indicators.) ASPO thus sought to ensure that the manufacturer did not delay procurement of the devices.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, LEM Attitude Indicator and Gimbal Angle Sequence Transformation Assembly (GASTA)," August 7, 1964.

August 7

At its Potrero, Calif., test facility, Lockheed Propulsion Company began qualification testing on the pitch control motors for the launch escape system. Early in September, when the program ended, about two dozen motors had been successfully fired for full duration. Test and reliability results showed that the motors met procurement specifications and had an average specific impulse three percent higher than required.

Lockheed Propulsion Company, "Qualification Test Report, Apollo Pitch Control Motor," 588-M-50, December 8, 1964, pp. 1-2, 2-1, 2-2, 2-11.

August 9-15

The modified ring-sail parachutes for the CM's earth landing system demonstrated their potential when Northrop Ventura conducted its first clustered drop using that type of chute.

MSC, "Weekly Activity Report for the Office of the Associate Administrator, Manned Space Flight, August 9-15, 1964," p. 2.

August 11

During late July and early August, MSC and its two spacecraft contractors worked out the dimensions of sample containers and other scientific equipment that would be stowed aboard the spacecraft during lunar missions: 48 by 20 by 29 centimeters (19 by 8 by 11.5 inches). MSC asked Grumman for cost and weight estimates for the containers.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Results of Meeting on Scientific Equipment Stowage Space," August 11, 1964, with enclosure: "Results of Meeting on Scientific Equipment Stowage Space, July 23, 1964."

August 12

In designing batteries for the LEM electrical power system, ASPO ordered Grumman to assume that, if a fuel cell failed, the mission would be aborted.

TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, August 12, 1964.

August 13-20

The U. S. Navy's Air Crew Equipment Laboratory agreed to conduct a series of tests on the water-cooled undergarment. Part I would determine the garment's suitability for the postlanding phase of the mission; Part II would investigate the CM range of temperature that could be tolerated wearing the garment, with and without a space suit.

MSC, "ASPO Weekly Management Report, August 13-20, 1964."

August 13-20

To save money on the Hamilton Standard contract in Fiscal Year 1965, MSC's Crew Systems Division (CSD) would take over preliminary development of the meteoroid protective garment. Since there was still too little knowledge about the need for meteoroid protection, CSD believed that a concentrated contractor effort was "unwarranted" at that time. (See November 17-December 21, 1963.)

Ibid.

August 13-September 3

MSC Crew Systems Division engineers evaluated the feasibility of transferring water from the CM to the LEM in lunar orbit. They found that hardware modifications would be needed - either lower water tank pressures in the LEM during transfer or a pump added to the water management system in the CM. Six weeks later, Grumman submitted a report confirming that continuous use of CM water from transposition to separation was more desirable than transferring water to the LEM.

MSC, "ASPO Weekly Management Report, August 13-20, 1964"; "ASPO Weekly Management Report, August 27-September 3, 1964"; "ASPO Weekly Management Report, October 1-8, 1964."

August 14

At Baylor University's College of Medicine, investigators presented some results of a joint MSC-Baylor study of human tolerance to low frequency noise (up to 12 cycles per second [cps]). [The study was undertaken because, as launch vehicles for manned spacecraft become larger - i.e., Saturn V and Apollo - they produce higher noise levels, but lower noise frequencies. The possibility of harmful effects upon the crew had to be known.] Audiometry indicated some temporary physiological effect: after three

minutes of exposure at levels of about 140 decibels (dB), about half of the twenty test subjects suffered some temporary impairment of their hearing. No serious vestibular effects were encountered during noise levels below 12 cps with a maximum of 144 db; heart and respiration rates of the subjects indicated no severe stresses. Based upon these findings, crew exposure to these noise levels (both - frequency and intensity) was considered acceptable.

MSC, "ASPO Weekly Management Report, August 13-20, 1964;" Burrell O. French *et al.*, *Effects of Low Frequency Pressure Fluctuations on Human Subjects*, NASA TN D-3323, March 1966, pp. 1-2, 7-9.

August 16-September 15

Studies at North American and at MSC disclosed that, during aborts above 9,100 meters (30,000 feet), simultaneous separation of the CM apex cover and the launch escape system (with boost protective cover attached) probably would damage the parachutes or escape hatch. One method of eliminating this hazard was to jettison the apex cover 0.4 second after ignition of the tower jettison motor and firing of the separation bolts. Also being studied were means of sequencing the firing of the jettison motor, the separation bolts, and the heatshield thrusters.

"Apollo Monthly Progress Report," SID 62-300-29, p. 3; MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, August 23-September 19, 1964," p. 63.

August 16-September 15

North American recommended an uprighting system for the CM composed of three 0.566-cubic-meter (20- cubic-foot) airbags and an inflation system with an electric pump. Using the bags and flooding the aft compartment would maintain a single-point flotation attitude for both Block I and Block II CMs. MSC Structures and Mechanics Division tests of a 1/5-scale model indicated that all three bags were needed to upright the CM. North American contended that any two bags would usually be sufficient, with the third bag providing a redundant capability. The contractor would conduct further tests with inflatable bags (rather than the rigid foam spheres used previously), while MSC would evaluate the use of an extendable boom with two flotation bags.

"Apollo Monthly Progress Report," SID 62-300-29, p. 8; MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, August 23-September 19, 1964," pp. 45-46.

August 18

From Wallops Island, Va., NASA launched another in its series of Scout reentry tests to evaluate the thermal performance of various ablative materials. The material (Avcoat 5026-39, which was being considered for use in the CM's heatshield - see June 10, 1963) was fabricated and bonded in much the same manner as on the actual heatshield. The multi- staged rocket's trajectory propelled the payload into a reentry path that simulated heating loads and shear forces of lunar returns. Though not coming through

completely unscathed, the material nonetheless survived.

Data on heating, telemetered from the vehicle, established design limits for the ablative material and, thus, were applied to the design of the CM's thermal protection.

James L. Raper (ed.), *Results of a Flight Test of the Apollo Heat-Shield Material at 28,000 Feet Per Second*, NASA TM X-1182, February 1966, pp. 1, 5, 11-12, 23; MSC, "ASPO Weekly Management Report, September 3-10, 1964"; NASA News Release 64-202, "Re-entry Heating Experiment to be Flown by Scout," August 11, 1964.

August 18

Thiokol Chemical Corporation began qualification testing on the tower jettison motor. The third motor to be fired in the series, on September 9, experienced a failure of the spot welding on the interstage structure. The motor, now freed, broke apart in the test bay. Analysis of the failure and repairs to the test stand followed, but Thiokol reported that testing could not be resumed until about mid-November - "at the earliest." This foreshadowed a probable delay of about two months in the qualification program.

Thiokol Chemical Corporation, Elkton Div., "Apollo Tower Jettison Program, Monthly Progress Report No. 26," A-226, October 14, 1964, pp. ii, 2-12, 32-34; "Apollo Monthly Progress Report," SID 62-300-29, p. 16.

August 19

Homer E. Newell, head of NASA's Office of Space Science and Applications, informed MSC Director Robert R. Gilruth that, as NASA had requested (see April 16), the Space Science Board of the National Academy of Sciences had defined the academic requirements for scientist-astronauts for the Apollo program. These requirements demanded graduate studies to the doctorate level, or equivalent.

Letter, Newell, NASA, to Gilruth, MSC, August 19, 1964.

August 20-27

MSC's Crew Systems Division (CSD) appraised crew tolerance to SM abort accelerations for Block I spacecraft. Normal mission limits of + 0.5 g, with total base durations of 50 seconds, were judged tolerable. Under these conditions, CSD estimated that dizziness or visual disturbance would occur in less than 10 percent of the cases. CSD set emergency limits as + 18 g, with base durations not exceeding 40 seconds.

MSC, "ASPO Weekly Management Report, August 20-27, 1964."

August 21

ASPO gave Grumman formal approval to proceed with their concept of a mission programmer for the LEM. The concept, which the contractor had presented in June, involved using the guidance computer as the main sequencing element, with the tape reader as a backup sequencer.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, LEM Mission Programmer," August 21, 1964; MSC, "ASPO Weekly Management Report, August 20-27, 1964."

August 23-29

A redesigned thrust chamber (called the "phase C") for the LEM ascent engine was tested in the altitude chamber at Arnold Engineering Development Center. [The "phase C" chamber differed from the "phase B" in that a compression-molded ablative throat section was used.] Firing runs of 60, 380, and five seconds produced only negligible throat erosion. Preliminary data indicated a 2.0-second specific impulse increase over the "phase B" chamber.

MSC, "Weekly Activity Report for the Office of the Associate Administrator, Manned Space Flight, August 23-29, 1964."p. 3.

August 23-September 19

MSC proposed a device affixed to the interior of the spacecraft, called a body-mounted attitude gyro (BMAG), as a backup to the inertial platform in the CM. Should the platform fail during reentry, the pilot could take control of the spacecraft and, using this secondary attitude indicator, fly a safe trajectory. Analog computer analysis indicated the BMAG's feasibility, provided the spacecraft did not maintain a constant roll rate during reentry.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, August 23-September 19, 1964," p. 49.

August 23-September 19

MSC-completed negotiations with General Electric Corporation (GE) Apollo Support Department for 10 ground stations for spacecraft checkout. (See March 25.) The figure finally agreed upon, \$62,244,657 with a \$4.1 million fee, was over \$20 million less than GE's March quotation.

Ibid., p. 41.

August 23-September 19

MSC's Technical Services Division (TSD) built a prototype lightweight Apollo couch and test fixture

and delivered them to the Crew Systems Division. TSD had designed this couch assembly, as a single unit, to replace previously planned individual couches in the CM, which would save 15.9 kilograms (35 pounds). During subsequent qualification testing, however, the couch did not stand up structurally, and was abandoned. But the concept itself was later useful to North American in the design of their couch arrangement.

Ibid., p. 35; interview, telephone, Ralph Drexel, Houston, March 12, 1970.

August 24-28

At North American, the service propulsion engine was gimballed during hot firing tests, the first time that the engine had been gimballed under these conditions. Gimbal operation was satisfactory.

MSC, "ASPO Weekly Management Report, September 3-10, 1964;" "Apollo Monthly Progress Report," SID 62-300-29, pp. 14-15.

August 24-29

MSC's Crew Systems Division (CSD) conducted mobility tests on lunar-like surfaces near Bend, Oreg. Three types of terrain were used: loose basaltic rubble, low-density pumice with crusty surface and low bearing load, and loose sand. Several CSD engineers and Astronaut Walter Cunningham wore pressurized Apollo prototype space suits and simulated portable life support systems. Climbing steep slopes covered by loose material proved difficult unless aided by ropes. Not surprisingly, how fast they could walk depended upon the terrain. Simple geophysical tasks at the level of the astronaut's feet were easily accomplished, but those requiring good visibility and dexterity were almost impossible and were better accomplished at a working level of between one and four feet above the ground. The only problems with the space suit were fogging of the visor, inadequate ventilation, and stiffness in the hips and ankles of the suits.

MSC, "ASPO Weekly Management Report, August 27-September 3, 1964"; "ASPO Weekly Management Report, September 3-10, 1964"; MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, August 23-September 19, 1964," p. 65; memorandum, Willis B. Foster, NASA, to Assoc. Adm., Manned Space Flight, "Apollo Field Simulations," September 8, 1964; MSC, *Space News Roundup*, September 2, 1964, p. 1.

August 25

At a Contractor Coordination Meeting on June 9-10, the point had been made that there existed a single-point failure that would preclude the crew's safe return - a disabled crewman in the CM during LEM operations. MSC demanded unequivocally that, even under these circumstances, the two crewmen in the LEM must be able to complete the mission. Therefore, the CSM must be designed for such a contingency; and to limit hardware impact, this must be done by using onboard equipment as much as

possible.

Accordingly William F. Rector III, the LEM Project Officer in ASPO, advised Grumman of two operational requirements:

1. The radar transponder in the CSM must be turned on before the LEM's ascent from the moon and must be pointed toward the LEM during ascent and rendezvous.
2. The CSM's attitude had to be stabilized during this phase of the mission.

The two prime contractors, Rector said, should decide on some means of controlling remotely the CSM's transponder and its stabilization and control system. The contractors should, however, use the simplest and most reliable arrangement. To initiate these two functions, the CSM would receive commands from the ground. Finally, Rector informed Grumman of a new ground rule on CSM communications: continuous communications, both telemetry and voice, must be maintained whenever the spacecraft was in view of the earth.

Letter, Rector, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Operations Groundrule for Disabled CSM Astronaut," August 25, 1964.

August 25

Apollo operational radiation protection was divided into two categories: personal dosimeters (attached to the space suit) and a portable, hand-held, radiation survey meter. Grumman was directed to provide a readily accessible stowage location aboard the LEM for the meter, which would weigh about 0.5 kilogram (one pound) and measure approximately 51 x 51 x 191 millimeters (2 x 2 x 7.5 inches).

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Space Allocation for LEM Radiation Instrumentation," August 25, 1964.

August 25

MSC's Crew Systems Division (CSD) concluded that, in terms of weight and complexity, the "buddy system" concept for supporting two crewmen on a single portable life support system (see July 28-August 3, 1963) was undesirable. An additional emergency oxygen system seemed more practical. The suit assembly already provided at least five minutes of emergency life support; this extra system would afford another five, at a cost of only 1.4 kilograms (three pounds). Consequently CSD redefined the rescue requirement to mean simply "the capability for the crewman remaining in the spacecraft to egress . . . and attend or retrieve the crewman in distress."

Memorandum, Richard S. Johnston, MSC, to Asst. Chief, Systems Engineering Div., "Portable Life Support System emergency operation," August 26, 1964.

August 30

North American reported that qualification testing had been completed on the launch escape motor. In all, 20 motors had been successfully static fired. (See June 19.)

MSC, "Project Apollo Quarterly Status Report No. 9 for Period Ending September 30, 1964," p. 17;
MSC, "ASPO Weekly Management Report, September 3-10, 1964."

August 30-September 5

MSC decided to use total mission elapsed time, instead of Greenwich mean time, as the time reference for mission operations. (See February 27, 1963.) North American and Grumman were directed to provide a common format for this display.

MSC, "Weekly Activity Report for the Office of the Associate Administrator, Manned Space Flight, August 30-September 5, 1964," p. 3.

August 31

Robert E. Smylie, of MSC's Crew Systems Division (CSD), advised that, as a consequence of MSC's canceling the requirement for inflight maintenance, there were no longer any provisions for tools or for a tool belt inside the spacecraft. Smylie reported that CSD was developing a belt for carrying tools and small equipment needed on the lunar surface, which would be stowed along with the scientific equipment in the LEM's descent stage.

Memorandum, Smylie, MSC, to Systems Engineering Div., Attn: Lee N. McMillion, "Extravehicular equipment belt," August 31, 1964.

August 31

Studies of future Gemini and Apollo missions showed that at least four flight directors would be needed. MSC Director Robert R. Gilruth named Christopher C. Kraft, Jr., John D. Hodge, Eugene F. Kranz, and Glynn S. Lunney to these positions. The flight directors would manage all flight operations from launch to recovery. Their responsibilities would include making operational decisions on spacecraft performance, implementing flight plans, and ensuring the safety of the astronauts.

MSC Announcement 64-120, "Designation of Flight Directors," August 31, 1964; MSC News Release 64-150, September 4, 1964.

During the Month

During zero g tests at Wright-Patterson Air Force Base, subjects wearing pressurized Gemini space suits got into the Apollo crew couch and attached the restraint harness. They entered through a Block II CM tunnel 73.6 centimeters (29 inches) in diameter. One subject made the transfer with a portable life support system (PLSS) strapped on his back and another with the PLSS carried in his hands. One subject also went through the tunnel with an 24.7-meter (81-foot) umbilical hose attached to his suit. These tests demonstrated the feasibility of moving the couch to the earth landing position without readjusting the restraint harness; also they pointed up the need for improving the lap belt.

MSC, "ASPO Weekly Management Report, September 3-10, 1964."

September 1

MSC Crew Systems Division reported that the present water capacity of the LEM (181 kilograms; 400 pounds) was sufficient for either a 35-hour lunar stay with a nine-hour orbital contingency or for a 44-hour lunar stay with no reserve. No excessive weight growths were needed to accomplish this mission flexibility.

Memorandum, Richard S. Johnston, MSC, to Asst. Chief, Systems Engineering Div., "LEM ECS Water Provisioning," September 1, 1964; MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, August 23-September 19, 1964," p. 19.

September 1

NASA and North American signed an amendment to the prime contractor's Apollo contract, extending that agreement to February 15, 1966. The amendment called for production of five additional CSM's (flight articles), three more boilerplate spacecraft, another full-scale mockup, and nine adapters which house the LEM. (See August 14, 1963.) The \$496 million amendment increased the estimated value of North American's contract (including cost and fee) to over \$1.436 billion. Also, the amendment forecast, beyond that February 1966 date, production of 20 more spacecraft.

Oakley, *Historical Summary, S&ID Apollo Program*, p. 25; MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, August 23-September 19, 1964," p. 40; NASA Note to Editors, "Correction on Release No: 64-277 Friday, Sept. 4, 1964," September 11, 1964.

September 2-9

The alternate mode of escape tower jettison called for firing the launch escape motors. Analyzing the structural integrity of a tower thus jettisoned, MSC Structures and Mechanics Division calculated that it would hold together for 3.5 seconds at least. By that time, it would be 610 meters (2,000 feet) away from the flight path of the spacecraft and launch vehicle. This second method for shedding the tower would be tested on the forthcoming AS-102 mission. (See September 18.)

MSC, "ASPO Weekly Management Report, September 3-10, 1964."

September 3

MSC awarded a \$2,296,249 contract to Westinghouse Electric Corporation for the LEM television camera. The first test model was scheduled for delivery to Houston in March 1965.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, August 23-September 19, 1964," pp. 42, 58.

September 3

MSC issued a definitive contract to Kollsman Instrument Corporation for the LEM optical subsystem. A statement of work had gone into effect on March 10 and had been implemented by technical directives from MIT to Kollsman. The definitive contract covered work until December 31. After that date, Kollsman would become a subcontractor to AC Spark Plug.

Ibid., p. 40; Kollsman Instrument Corporation, "LEM [Optics] Program Quarterly Technical Progress Report No. 1," September 30, 1964, pp. Kv, K1-1, K2-1.

September 3

To evaluate lunar surface light, Astronauts Edwin E. Aldrin, Jr., Elliot M. See, Jr., and David R. Scott (accompanied by engineer pilots) began simulated landing approaches over lava flats in southern Idaho. They wore dark glasses that had been modified to permit rapid change to progressively darker (or lighter) filters. Diving in T-33 aircraft from 4,600 meters (15,000 feet), they leveled off at 900 meters (3,000 feet). See, who had also participated in helicopter exercises earlier in California, believed that the reflected earth-shine would be insufficient to allow a LEM pilot to avoid deep surface cracks or large boulders. He also thought that earthshine would limit the crew's visibility to only a short distance. Aldrin, however, felt that this was a pessimistic view. He suggested that the LEM might be equipped with landing lights or flares.

The Houston Post, September 3, 1964; Jim Maloney, *The Houston Post*, September 12, 1964; interview, telephone, Dean F. Grimm, MSC, January 27, 1970.

September 3-10

Grumman and the Link Division signed a definitive cost-plus-incentive-fee contract (valued at \$7,083,022) for two LEM simulators.

MSC, "ASPO Weekly Management Report, September 3-10, 1964;" "ASPO Weekly Management Report, September 10-17, 1964."

September 3-10

North American gave Minneapolis-Honeywell an official go-ahead to begin design work on the Block II CSM stabilization and control system.

MSC, "ASPO Weekly Management Report, September 3-10, 1964."

September 4

Representatives of Geonautics, Inc., reported on the status of their study of selenodetic experiments for early lunar surface missions. (See June 9.) Results to date indicated that lunar survey measurements could rely heavily on photographic data acquired on the lunar surface.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, August 23-September 19, 1964," p. 65.

September 8-11

The resident Apollo office at Grumman reported that Pratt and Whitney had achieved reliable 100-hour operation of the LEM fuel cell through the use of new filling methods. This "apparently" had solved the problem of potassium hydroxide deposits stopping up the cell, the cause of early plugging failures (i.e., after only 10 hours of operation). Some cells, in fact, had run between 200 and 400 hours before failing, the office reported. On the other hand, carbonate plugging was still a problem.

MSC, "ASPO Weekly Management Report, September 10-17, 1964."

September 9

Robert E. Smylie, of MSC's Crew Systems Division, asked the Crew Performance Section of the Center's Space Medicine Branch to test the capability of men in space suits to roll over in 1/6 g. In a previous test, using a mockup portable life support system (PLSS), a subject lying on his back had been unable to turn over. Two different PLSS configurations and two kinds of thermal garments would be tested with the Apollo suit. Also an emergency oxygen system mockup would be attached to the helmet.

Memorandum, Smylie, MSC, to Chief, Space Medicine Branch, "Testing of Apollo SSA roll-over capability in 1/6 g," September 9, 1964.

September 9

NASA directed North American to add the electronics equipment needed to enable the crew to gimbal

the service propulsion engine by using the rotational hand controller.

Letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. 250," September 9, 1964.

September 11

MSC issued a definitive contract to AC Spark Plug for LEM guidance and navigation equipment. (See October 18, 1963, and June 12.) Estimated cost and fee of the contract was \$2.316 million.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, August 23-September 19, 1964," p. 40.

September 14

MSC issued three amendments (worth \$6,134,113) to Grumman's LEM contract. These amendments provided funds for data acquisition equipment that MSC formerly was to have furnished; for static test stands at WSMR; and for additional systems engineering studies by Grumman.

Ibid.

September 14

ASPO issued ground rules for Grumman and MIT to use when defining the LEM guidance and control system. MSC's concerns related to provision for lunar landing aborts and recognition of guidance and control equipment failures. An example of rules during an abort stated that the system should be able to provide information for the astronauts to fire the engines and gain orbital flight on the first effort after initiating an abort. If the first attempt failed, procedures had to specify how the crew could use the system to achieve orbit and then rendezvous and dock with the CM. The second matter concerned investigations to assure that failures in the guidance and control system could be detected and to define what responses the crew must make to those failures.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Ground Rules for LEM Guidance and Navigation Operation and Monitoring," September 14, 1964.

September 14

North American completed modifications to CM boilerplate (BP) 6, which had been used in Apollo mission PA-1 (see November 7, 1963). The spacecraft, now designated BP-6A, was then delivered to Northrop Ventura for use as a parachute test vehicle.

"Apollo Monthly Progress Report," SID 62-300-29, p. 1.

September 14

The first attitude-controlled Little Joe II (see May 1963) was shipped to WSMR. This vehicle would be used for Mission A-002, scheduled for December 1964.

Little Joe II Test Launch Vehicle, NASA Project Apollo, Final Report, p. 1-6,

September 15

William A. Lee of ASPO outlined minimum communications requirements for "near-lunar" operations. Those of a general nature included two-way voice communication between spacecraft and ground at any time when a line-of-sight existed with the tracking network. Also there should be provisions so that the crew could maneuver the spacecraft to control antenna position when needing to acquire or reacquire the communication link with the ground.

Requirements for specific phases of the mission - the trip from earth to moon, lunar orbit, and the flight to earth - were also covered:

- Translunar: must be able to transmit, track, and receive telemetry data, television, voice simultaneously at least 50 percent of the time (half-hour on and half-hour off) and, on occasions, as much as two hours at a time.
- Lunar Orbit:
 - continuous voice except when behind the moon and out of sight with the ground network;
 - continuous voice between the LEM and the spacecraft at all times when the LEM was flying - descending or ascending.
- Transearth: the same as translunar.

Memorandum, Lee, MSC, to Addressees, "CSM Lunar Mission Communications Requirements," September 15, 1964.

September 16

The Air Force released Launch Complex 16 of its Eastern Test Range to NASA for use as a service propulsion system test facility and static firing stand.

"Apollo Quarterly Status Report No. 9," p. 47.

September 17

The first production CM environmental control system was installed in boilerplate 14, and pressurization tests on the water-glycol system were begun. Contamination checks, servicing, and checkout were completed near the end of the month.

MSC, "ASPO Weekly Management Report, September 10-17, 1964"; "ASPO Weekly Management Report, September 24-October 1, 1964"; "Apollo Quarterly Status Report No. 9," p. 47.

September 17-24

MSC's Instrumentation and Electronic Systems Division (IESD) advised ASPO that it would probably recommend a second steerable S-band high gain antenna on the CSM. IESD based this assertion upon the operational requirements for communications, the need for reliability, and constraints imposed by the spacecraft's attitude. The division was giving Lockheed Electronics Company the job of analyzing the problems of acquisition and tracking with the high gain antennas on both spacecraft, and thus made the dual-antenna concept for the CSM a part of that study. Also included in Lockheed's study were: an RF (radio frequency) tracking system, comparing it with the current infrared concept; and an inertial reference system for acquisition.

MSC, "ASPO Weekly Management Report, September 17-24, 1964."

September 18

Apollo Mission A-102, the second flight of an Apollo spacecraft with a Saturn I (SA-7) launch vehicle, was launched from Complex 37B of the Eastern Test Range at 11:22:43 a.m., e.s.t. [The first such flight was Mission A-101, with boilerplate (BP) 13, launched on May 28.] A-102 used BP-15, essentially the same configuration as BP-13 except that one of the SM's simulated reaction control system quadrant assemblies was instrumented to measure launch temperatures and vibrations. The mission was intended to demonstrate

1. spacecraft launch vehicle compatibility,
2. launch and exit parameters to verify design, and
3. the alternate mode of escape-tower jettison (i.e., using the launch escape and pitch control motors).

The launch azimuth was again 105 degrees. The S-1 stage shut down at T+147.4 seconds, only 0.7 second later than planned. The S-1 and S-IV stages separated at T+148.2 seconds, and the S-IV stage ignited 1.7 seconds after that. The launch escape tower was jettisoned at T+160.2 seconds. S-IV cutoff took place at T+621.1 seconds, burning 1.3 seconds longer than anticipated. The spacecraft and S-IV were inserted into orbit at 631.1 seconds (2.0 seconds late), at a velocity of 7,810.05 meters (25,623.54 feet) per second. The spacecraft weight at insertion was 7,815.9 kilograms (17,231 pounds). Orbital parameters were 212.66 and 226.50 kilometers (114.85 and 122.37 nautical miles), and the period 88.64 minutes.

All spacecraft test objectives were met. Satisfactory engineering data verified the launch and exit design criteria. The launch escape and pitch control motors moved the launch escape system safely out of the path of the spacecraft. The Manned Space Flight Network obtained telemetry data into the fifth orbit, at which time the transponders stopped working, but several stations continued to track the vehicle until it reentered over the Indian Ocean on its 59th journey around the earth. As with BP-13, no recovery of the spacecraft was planned.

MSC, "Postlaunch Report for Apollo Mission A-102 (BP-15)," MSC-R-A-64-3 (October 10, 1964), pp. 1-1, 2-1, 3-4, 3-5, 3-6, 5-1, 6-1, 7-15.

September 18

ASPO asked Grumman to investigate automatic switching mechanisms for LEM VHF and S-band omnidirectional antennas. If such devices were used in manned flights, the crew would need to pay only minimum attention to antenna selection; on unmanned flights, it would improve communication operations and range. TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, September 18, 1964.

September 20-26

"Fire-in-the-hole" tests of the LEM's ascent engine (see February 1963) were completed at Arnold Engineering Development Center after 18 successful runs. Visual inspection showed no damage to the thrust chamber. Grumman confidently reported to MSC that these tests indicated that "the ascent engine can handle the shock" of ignition with its exhaust nozzle enclosed by the descent stage of the vehicle.

MSC, "Weekly Activity Report for the Office of the Associate Administrator, Manned Space Flight, September 20-26, 1964," p. 3; MSC, "ASPO Weekly Management Report,

September 17-24, 1964;" GAEC, "Monthly Progress Report No. 20," LPR-10-36, October 10, 1964, p. 20.

September 20-30

Joseph F. Shea directed that the LEM's television camera built by Westinghouse (see September 3) also be used in the Block II CM. (RCA was the contractor for the Block I's camera.) Engineers from North American and MSC met with Westinghouse representatives to work out the design details (such as mounting, since Westinghouse's camera was larger - and more versatile - than was RCA's).

"Apollo Quarterly Status Report No. 9," p. 2; MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, September 20-October 17, 1964," p.52; MSC, "ASPO Weekly Management Report, October 1-8, 1964"; interview, telephone, Milton G. Kingsley, Houston,

March 13, 1970.

September 20-26

Rocketdyne conducted its first firing of the prototype LEM descent engine using a new dome manifold injector, called the "Block II" engine (in comparison to the previously tested circumferential manifold type). Rocketdyne reported, in Grumman's words, "no noticeable change in the combustion chamber pattern thrust chamber erosion."

MSC, "Weekly Activity Report for the Office of the Associate Administrator, Manned Space Flight, September 20-26, 1964," p. 3; "Monthly Progress Report No. 20," LPR-1036, p. 20; interview, telephone, C. Harold Lambert, Jr., Houston, March 19, 1970.

September 21

NASA approved Grumman's subcontract with RCA for the LEM attitude and translation control assembly. (See May 1.) The cost-plus-incentive-fee subcontract was valued at \$9,038,875.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, September 20-October 17, 1964," p. 39.

September 21-24

North American, MIT, and NASA jointly conducted a series of tests at Wright-Patterson Air Force Base. The tests, in which four astronauts participated, evaluated suit mobility, manipulation of controls, and adjustment of couch and restraints.

NAA, "Apollo Monthly Progress Report," SID 62-300-30, November 1, 1964, pp. 7-8.

September 22

The first SM propulsion engine firing in the F-2 test fixture at WSMR was unsuccessful. Although analysis was incomplete, improper functioning of the engine's main propellant valve might have delayed full combustion until eight seconds after fire signal. In a second test on October 1, the engine was fired for 10 seconds. The engine performed satisfactorily this time, even though oxidizer inlet pressure was below normal.

MSC, "ASPO Weekly Management Report, September 17-24, 1964"; "Apollo Monthly Progress Report," SID 62-300-30, pp. 16, 32.

September 24-27

North American and MSC officials negotiated the specifications for the overall Block I CSM system, including special needs for some spacecraft to provide for specific mission objectives. The documents subsequently were incorporated into the North American contract. (See Volume I, July 28 and November 7, 1962; April 28-30, 1964.)

"Apollo Monthly Progress Report," SID 62-300-30, p. 27.

September 25

NASA approved a \$14,185,848 contract with North American for spare parts (for Apollo spacecraft and ground support equipment) to expedite repairing of the CSM at WSMR and Cape Kennedy. Spares would include complete electronic packages, hydraulic and mechanical components, reaction control engines, and equipment needed to service the spacecraft.

MSC News Release 64-159, September 25, 1964.

September 25

MSC Director Robert R. Gilruth approved a Structures and Mechanics Division proposal for three-dimensional dynamic testing of the Apollo docking system in a thermal-vacuum environment. Tests were scheduled for late 1965 in the Center's Space Environment Simulation Laboratory.

MSC, "ASPO Weekly Management Report, September 24-October 1, 1964"; "Apollo Quarterly Status Report No. 9," p. 8.

September 28

MSC's Crew Systems Division (CSD) advised against increasing the capacity of the portable life support system. CSD contended that the current design was capable of performing a variety of lunar missions (at the maximum design metabolic load of 1,600 BTUs per hour) and that the minimum 30 minutes of contingency time was sufficient.

Memorandum, Richard S. Johnston, MSC, to Systems Engineering Division, "Contingent operation of the Portable Life Support System," September 28, 1964.

September 29

Richard S. Johnston, Chief of Crew Systems Division, provided Hamilton Standard with some new guidelines and operating procedures formulated by MSC concerning crew transfer from CM to LEM. One major item related to suit umbilicals. A former requirement for end-to-end interchangeability (called the "buddy system") was deleted (see September 19-25, 1963), as was the requirement for quick

disconnects at the environmental control system (ECS) outlet. Under MSC's new rules, the crew would transfer with the two cabins unpressurized. Both CM and LEM umbilicals had to be long enough to enable the astronauts to reach the LEM's ECS controls.

TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, September 29, 1964; TWX, Richard S. Johnston, MSC, to Hamilton Standard, Attn: R. Breeding, October 8, 1964.

September 30

NASA conducted a formal inspection and review of the Block II CSM mockup. [The design resulted from a number of meetings earlier in the year (see April 16 and June 11), a three-month program definition study, and additional investigations requested by NASA.]

North American presented mockups of the CM interior, upper deck, lower equipment bay, and the SM with two bays exposed. Actual hardware was simulated. The couches from the Block I review in April were used, with revised harnesses. The Block I inner and outer hatches were displayed, while the CM exterior showed only changes from Block I.

North American explained that this mockup had been designed to depict only volume, space allocations, and arrangements of the CSM. New systems required for Block II were defined only as to maximum size. A detailed mockup, showing actual hardware configuration, of the Block II CSM interior and exterior would be available in February and April, respectively.

Letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. 254," October 1, 1964; MSC, "Command and Service Modules: Project Apollo, Board Report for NASA Inspection and Review of Block II Mockup, September 29-October 1, 1964," pp. 1-4.

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Appendix 1

Glossary of Abbreviations

ASPO - Apollo Spacecraft Program Office

BP - Boilerplate

CM - Command module

CSM - Command and service modules

EDD - Engineering and Development Directorate

GAEC - Grumman Aircraft Engineering Corporation

GE - General Electric Company

HF - High frequency

IBM - International Business Machines Corporation

ITT - International Telephone and Telegraph Company

KSC - Kennedy Space Center

LEM - Lunar excursion module

LES - Launch escape system

LEV - Launch escape vehicle

LOC - Launch Operations Center

LTV - Ling-Temco-Vought

MCC - Mission Control Center

MIT - Massachusetts Institute of Technology

MSC - Manned Spacecraft Center

MSF - Manned Space Flight

MSFC - Marshall Space Flight Center

NAA - North American Aviation, Inc.

NASA - National Aeronautics and Space Administration

OMSF - Office of Manned Space Flight

OSSA - Office of Space Sciences and Applications

RASPO - Resident Apollo Spacecraft Program Office

RCA - Radio Corporation of America

RF - Radio frequency

SM - Service module

STL - Space Technology Laboratories, Inc.

VHF - Very high frequency

WSMR - White Sands Missile Range

WSTF - White Sands Test Facility

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APPENDIX 2

Spacecraft weights by Quarter

December 1962

	Control Weight (kgs, lbs)	Target Weight (kgs, lbs)	Current Weight (kgs, lbs)
Command Module	4,309 (9,500)	3,856 (8,500)	4,246 (9,350)
Service Module	5,214 (11,500)	4,990 (11,000)	4,629 (10,205)
SM Useful Propellant	18,370 (40,500)	15,531 (34,240)	15,744 (34,710)
S-IVB Adapter	1,361 (3,000)	1,361 (3,000)	1,479 (3,260)
Lunar Exc. Module	11,567 (25,500)	11,113 (24,500)	9,752 (21,500)
Total Spacecraft Injected	40,823 (90,000)	35,471 (78,200)	35,745 (79,025)

March 1963

	Control Weight (kgs, lbs)	Target Weight (kgs, lbs)	Current Weight (kgs, lbs)
Command Module	4,309	3,856	4,067

	(9,500)	(8,500)	(8,990)
Service Module	4,763 (10,500)	4,309 (9,500)	4,336 (9,780)
SM Useful Propellant	17,921 (39,730)	16,381 (36,115)	16,860 (37,170)
S-IVB Adapter	1,542 (3,400)	1,361 (3,000)	1,411 (3,110)
Lunar Exc. Module	11,961 (26,370)	11,113 (24,500)	11,113 (24,500)
Total Spacecraft Injected	40,823 (90,000)	37,247 (82,115)	38,124 (84,050)

June 1963

	Control Weight (kgs, lbs)	Target Weight (kgs, lbs)	Current Weight (kgs, lbs)
Command Module	4,309 (9,500)	3,856 (8,500)	4,059 (9,170)
Service Module	4,763 (10,500)	4,309 (9,500)	4,264 (9,620)
SM Useful Propellant	17,921 (39,730)	11,381 (36,115)	17,060 (37,610)
S-IVB Adapter	1,542 (3,400)	1,361 (3,000)	1,411 (3,110)
Lunar Exc. Module	11,961 (26,370)	11,113 (24,500)	11,521 (25,400)
Total Spacecraft Injected	40,823 (90,000)	37,247 (82,115)	38,471 (85,410)

September 1963

	Control Weight (kgs, lbs)	Target Weight (kgs, lbs)	Current Weight (kgs, lbs)
Command Module	4,309 (9,500)	3,856 (8,500)	4,277 (9,650)
Service Module	4,763 (10,500)	4,309 (9,500)	4,291 (9,680)
SM Useful Propellant	17,988 (39,900)	16,488 (36,350)	17,958 (39,811)
S-IVB Adapter	1,542 (3,400)	1,361 (3,000)	1,542 (3,400)
Lunar Exc. Module	12,111 (26,700)	11,340 (25,000)	12,916 (28,476)
Total Spacecraft Injected	40,823 (90,000)	37,353 (82,350)	40,285 (91,017)

December 1963

	Control Weight (kgs, lbs)	Target Weight (kgs, lbs)	Current Weight (kgs, lbs)
Command Module	4,309 (9,500)	3,856 (8,500)	4,332 (9,770)
Service Module	4,763 (10,500)	4,309 (9,500)	4,408 (9,960)
SM Useful Propellant	22,524 (39,900)	16,488 (36,350)	18,727 (41,285)
S-IVB Adapter	1,542 (3,400)	1,361 (3,000)	1,542 (3,400)
Lunar Exc. Module	12,111 (26,700)	11,340 (25,000)	13,819 (30,465)

Total Spacecraft Injected	40,823 (90,000)	37,353 (82,350)	42,037 (94,880)
---------------------------	--------------------	--------------------	--------------------

March 1964

	Control Weight (kgs, lbs)	Target Weight (kgs, lbs)	Current Weight (kgs, lbs)
Command Module	4,309 (9,500)	3,856 (8,500)	4,554 (10,040)
Service Module	4,763 (10,500)	4,082 (9,000)	4,403 (9,950)
SM Useful Propellant	16,828 (37,100)	14,662 (32,325)	16,329 (36,000)
S-IVB Adapter	1,542 (3,400)	1,406 (3,100)	1,542 (3,400)
Lunar Exc. Module	13,281 (29,500)	11,567 (25,500)	12,314 (27,149)
Total Spacecraft Injected	40,823 (90,000)	35,573 (78,425)	39,253 (86,539)

June 1964

	Control Weight (kgs, lbs)	Target Weight (kgs, lbs)	Current Weight (kgs, lbs)
Command Module	4,309 (9,500)	3,856 (8,500)	4,553 (10,030)
Service Module	4,763 (10,500)	4,082 (9,000)	4,590 (10,120)
SM Useful Propellan	16,828 (37,100)	14,662 (32,325)	16,617 (36,635)

S-IVB Adapter	1,542 (3,400)	1,406 (3,100)	1,576 (3,475)
Lunar Exc. Module	13,281 (29,500)	11,567 (25,500)	12,748 (28,105)
Total Spacecraft Injected	40,823 (90,000)	35,573 (78,425)	40,082 (88,365)

September 1964

	Control Weight (kgs, lbs)	Target Weight (kgs, lbs)	Current Weight (kgs, lbs)
Command Module	4,990 (11,000)	No longer reported.	4,576 (10,090)
Service Module	4,627 (10,200)	No longer reported.	4,559 (10,050)
SM Useful Propellant	17,468 (38,510)	No longer reported.	16,894 (37,244)
S-IVB Adapter	1,724 (3,800)	No longer reported.	1,678 (3,700)
Lunar Exc. Module	13,281 (29,500)	No longer reported.	13,250 (29,431)
Total Spacecraft Injected	42,638 (94,000)	No longer reported.	40,057 (90,515)

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Service Module	4,763 (10,500)	4,309 (9,500)	4,336 (9,780)
SM Useful Propellant	17,921 (39,730)	16,381 (36,115)	16,860 (37,170)
S-IVB Adapter	1,542 (3,400)	1,361 (3,000)	1,411 (3,110)
Lunar Exc. Module	11,961 (26,370)	11,113 (24,500)	11,113 (24,500)
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Service Module	4,763 (10,500)	4,309 (9,500)	4,264 (9,620)
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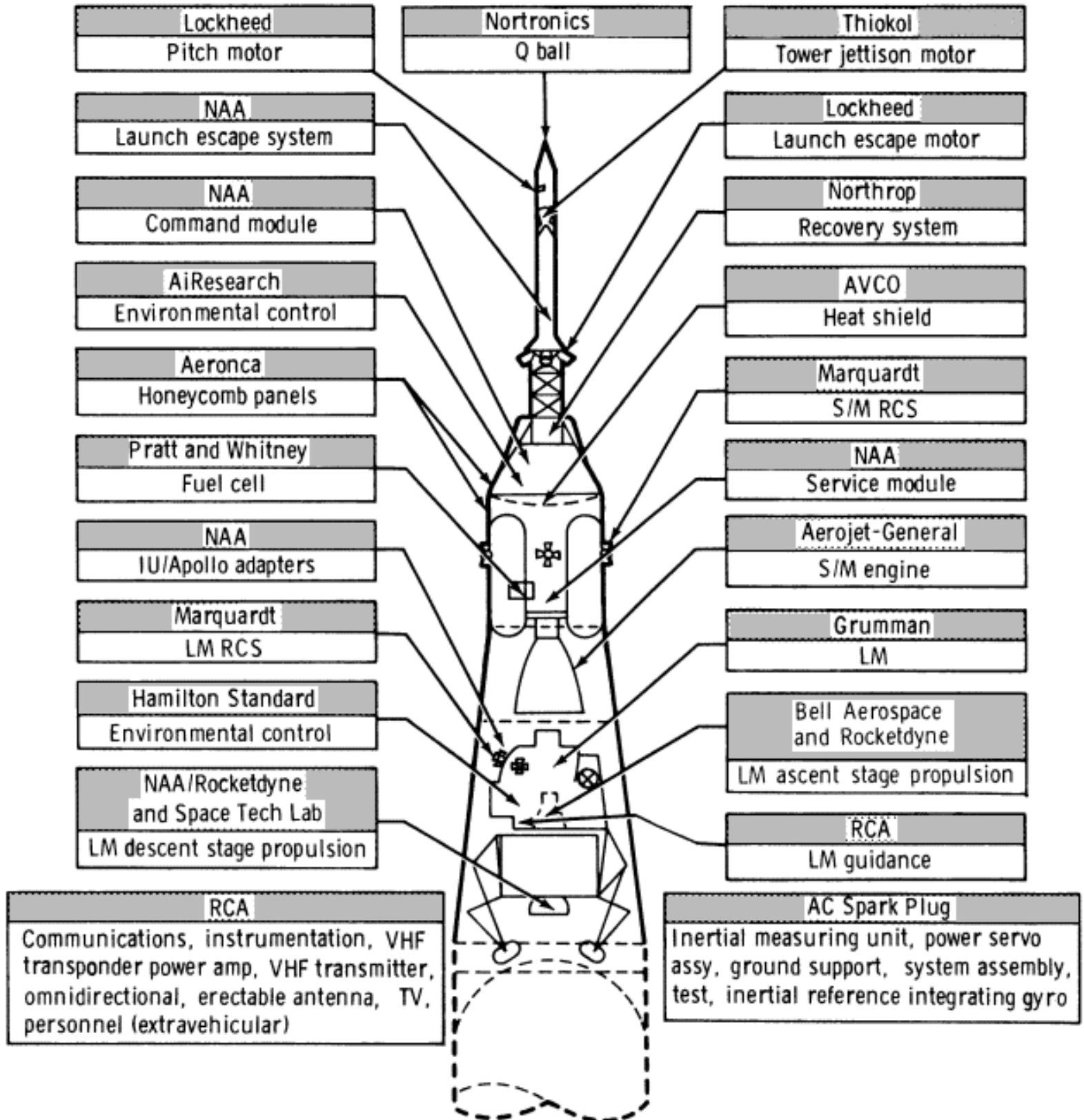
September 1963	Control Weight (kgs, lbs)	Target Weight (kgs, lbs)	Current Weight (kgs, lbs)
Command Module	4,309 (9,500)	3,856 (8,500)	4,277 (9,650)
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S-IVB Adapter	1,542 (3,400)	1,406 (3,100)	1,542 (3,400)
Lunar Exc. Module	13,281 (29,500)	11,567 (25,500)	12,314 (27,149)
Total Spacecraft Injected	40,823 (90,000)	35,573 (78,426)	39,253 (86,539)
June 1964	Control Weight (kgs, lbs)	Target Weight (kgs, lbs)	Current Weight (kgs, lbs)
Command Module	4,309 (9,500)	3,856 (8,500)	4,553 (10,030)
Service Module	4,763 (10,500)	4,082 (9,000)	4,590 (10,120)
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Total Spacecraft Injected	40,823 (90,000)	35,573 (78,425)	40,082 (88,365)

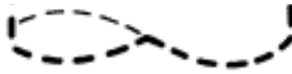
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Service Module	4,627 (10,200)	No longer reported	4,559 (10,050)
SM Useful Propellant	17,468 (38,510)	No longer reported	16,894 (37,244)
S-IVB Adapter	1,724 (3,800)	No longer reported	1,678 (3,700)
Lunar Exc. Module	13,281 (29,500)	No longer reported	13,250 (29,431)
Total Spacecraft Injected	42,638 (94,000)	No longer reported	40,057 (90,515)

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APPENDIX 3

Major Spacecraft Component Manufacturers





Honeywell Company	Collins Radio	Link	Beech Aircraft	Bell Aerosystems
Stabilization, control	Telecommunications	Spacecraft mission simulators	Supercritical gas storage	RCS positive expulsion fuel tanks
Allison and Airite Products	Radiation Inc.	Simmonds Precision Products	RCA	Westinghouse Electric
Fuel components	Telemetry data processing for Apollo S-II stage	Propellant mixture controls	TV cameras, main communications antenna	Static inverter
Elgin National Watch	RCA	MIT	Raytheon	Kollsman Instrument
Sequencer	Radar, engineering services	Associate prime-guidance, navigation	Computer	Optics

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APPENDIX 4

Flight Summary

[November 8, 1962, through September 30, 1964]

The launches described in this table include only those related to the exploration of the moon: unmanned lunar probes, unmanned tests of spacecraft designed for later manned missions, and manned spacecraft flights. The table is not intended as a comprehensive summary of all American and Soviet space flights.

AMR - Atlantic Missile Range

PMR - Pacific Missile Range

WSMR - White Sands Missile Range

WS - Wallops Station

F - Failure

S - Success

Mission Name	General Mission	Launch Vehicle	Performance Veh	Pay-load
Results	=====	(Site)	===== ===== =====	===== ===== =====

1962

November 16

Saturn (SA-3)	Launch vehicle development test ("Project Highwater")	Saturn C-1 (AMR)	S	S	S
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December 16

Explorer XVI (S-55b)	Scientific micrometeoroid satellite	Scout (WS)	S	S	S
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1963

March 28

Saturn (SA-4)	Launch vehicle development test ("engine out" capability test)	Saturn C-1 (AMR)	S	S	S
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April 2

Lunik IV	Lunar probe - reported attempt to soft-land instrument package	Unknown (U.S.S.R.)		Unknown	
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April 2

Explorer XVII	Measure atmospheric density, composition, pressure, and temperature at altitudes of 249 to 933 kilometers (155 to 580 miles)	Thor-Delta (AMR)	S	S	S
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May 15

Faith 7 (MA-9)	Project Mercury manned one-day mission - fourth US manned orbital flight	Atlas (AMR)	S	S	S
-------------------	--	----------------	---	---	---

June 14

Vostok V	Manned orbital space flight. First launch of second tandem flight	Unknown (U.S.S.R.)	S	S	S
-------------	---	-----------------------	---	---	---

June 16

Vostok VI	Manned orbital space flight. second launch of second tandem flight	Unknown (U.S.S.R.)	S	S	S
-----------	--	--------------------	---	---	---

July 20

--	Experimental heatshield reentry (29,934 kilometers per hour) (18,600mph) test	Scout (WS)	F	F	F
----	---	------------	---	---	---

August 28

--	Prove capability of Little Joe II as an Apollo spacecraft test vehicle	Little Joe II (WSMR)	S	S	S
----	--	----------------------	---	---	---

November 7

Pad Abort-1	Qualification test of Apollo launch escape system to effect a safe pad abort. (Spacecraft BP-6)	-- (WSMR)	-	S	S
-------------	---	-----------	---	---	---

November 26

Explorer XVIII	To measure interplanetary magnetic fields, solar wind, and cosmic radiation between earth and moon	Thor-Delta (AMR)	S	S	S
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November 27

Centaur II	In-space ignition of Centaur's liquid-hydrogen engines (second attempt, first success)	Atlas-Centaur (AMR)	S	S	S
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December 19

Explorer	To measure atmospheric	Scout	S	S	S
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XIX density fluctuations of (PMR)
earth's high latitudes

1964

January 29

Saturn (SA-5)	Test structure and performance of 2-stage Saturn; orbit second stage	Saturn I (AMR)	S	S	S
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January 30

Ranger VI	Television photographs of moon at close range	Atlas-Agena B (AMR)	S	F	F
--------------	---	------------------------	---	---	---

April 8

Gemini-Titan 1	Unmanned flight test of structural integrity of Gemini spacecraft and compatibility with launch vehicle	Titan II (AMR)	S	S	S
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April 14

Project Fire	Test of Apollo sample heatshield material at lunar reentry speeds	Atlas D (AMR)	S	S	S
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May 13

Apollo Mission A-001	Test capability of launch escape system to propel spacecraft from launch vehicle during abort at transonic speed (Spacecraft BP-12)	Little Joe II (WSMR)	S	S	S
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May 28

Apollo Mission A-101	First flight of an Apollo-configured spacecraft with a Saturn launch vehicle	Saturn I (AMR)	S	S	S
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(SA-6) (Spacecraft BP-13)

July 28

Ranger VII	Television photographs of the moon at close range	Atlas-Agena B (AMR)	S	S	S
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August 18

--	Experimental heatshield reentry test	Scout (WS)	S	S	S
----	--------------------------------------	------------	---	---	---

August 25

Explorer XX	Map irregularities in topside of earth's atmosphere; obtain electron densities and temperatures near satellite	Scout (PMR)	S	S	S
-------------	--	-------------	---	---	---

September 18

Apollo Mission A-102 (SA-7)	Demonstrate spacecraft-launch vehicle compatibility (Spacecraft BP-15)	Saturn I (AMR)	S	S	S
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APPENDIX 4

Flight Summary

November 8, 1962, through September 30, 1964

The launches described in this table include only those related to the exploration of the moon: unmanned lunar probes, unmanned tests of spacecraft designed for later manned missions, and manned spacecraft flights. The table is not intended as a comprehensive summary of all American and Soviet space flights.

AMR - Atlantic Missile Range

PMR - Pacific Missile Range

WSMR - White Sands Missile Range

WS - Wallops Station

F - Failure

S - Success

Name	General Mission	Launch Vehicle (Site)	Performance Veh	Performance Payload	Performance Mission Results
November 16, 1962					
Saturn (SA-3)	Launch vehicle development test ("Project Highwater")	Saturn C-1 (AMR)	S	S	S
December 16					

Explorer XVI (S-55b)	Scientific micrometeoroid satellite	Scout (WS)	S	S	S
March 28, 1963					
Saturn (SA-4)	Launch vehicle development test ("engine out" capability test)	Saturn C-1 (AMR)	S	S	S
April 2					
Lunik IV	Lunar probe-reported attempt to soft-land instrument package	Unknown (U.S.S.R)	Unknown	Unknown	Unknown
April 2					
Explorer XVII	Measure atmospheric density, composition, pressure, and temperature at altitudes of 249 to 933 kilometers (155 to 580 miles)	Thor-Delta (AMR)	S	S	S
May 15					
Faith 7 (MA-9)	Project Mercury manned one-day mission-fourth US manned orbital flight	Atlas (AMR)	S	S	S
June 14					
Vostok V	Manned orbital space flight. First launch of second tandem flight	Unknown (U.S.S.R.)	S	S	S
June 16					

Vostok VI	Manned orbital space flight. Second launch of second tandem flight	Unknown (U.S.S.R.)	S	S	S
July 20					
	Experimental heatshield reentry (29,934 kilometers per hour) (18,600mph) test	Scout (WS)	F	F	F
August 28					
	Prove capability of Little Joe II as an Apollo spacecraft test vehicle	Little Joe II (WSMR)	S	S	S
November 7					
Pad Abort-1	Qualification test of Apollo launch escape system to effect a safe pad abort. (Spacecraft BP-6)	(WSMR)	-	S	S
November 26					
Explorer XVIII	To measure interplanetary magnetic fields, solar wind, and cosmic radiation between earth and moon	Thor-Delta (AMR)	S	S	S
November 27					
Centaur II	In-space ignition of Centaur's liquid-hydrogen engines (second attempt, first success)	Atlas-centaur (AMR)	S	S	S
December 19					

Explorer XIX	To measure atmospheric density fluctuations of earth's high latitudes	Scout (PMR)	S	S	S
January 29, 1964					
Saturn (SA-5)	Test structure and performance of 2-stage Saturn; orbit second stage	Saturn I (AMR)	S	S	S
January 30					
Ranger VI	Television photographs of moon at close range	Atlas-Agena B (AMR)	S	F	F
April 8					
Gemini-Titan 1	Unmanned flight test of structural integrity of Gemini spacecraft and compatibility with launch vehicle	Titan II (AMR)	S	S	S
April 14					
Project Fire	Test of Apollo sample heatshield material at lunar reentry speeds	Atlas D (AMR)	S	S	S
May 13					
Apollo Mission A-001	Test capability of launch escape system to propel spacecraft from launch vehicle during abort at transonic speed (Spacecraft BP-12)	Little Joe II (WSMR)	S	S	S
May 28					

Apollo Mission A-101 (SA-6)	First flight of an Apollo-configured spacecraft with a Saturn launch vehicle (Spacecraft BP-13)	Saturn I (AMR)	S	S	S
July 28					
Ranger VII	Television photographs of the moon at close range	Atlas-Agena B (AMR)	S	S	S
August 18					
	Experimental heatshield reentry test	Scout (WS)	S	S	S
August 25					
Explorer XX	Map irregularities in topside of earth's atmosphere; obtain electron densities and temperatures near satellite	Scout (PMR)	S	S	S
September 18					
Apollo Mission A-102 (SA-7)	Demonstrate spacecraft-launch vehicle compatibility (Spacecraft BP-15)	Saturn I (AMR)	S	S	S

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APPENDIX 5

Apollo Program Flight Objectives

(Apollo spacecraft development flights only.)

Pad Abort 1 (November 7, 1963)

First Order Objectives:

1. **Determine aerodynamic stability characteristics of the Apollo escape configuration during a pad abort. (Achieved)**
2. **Demonstrate the capability of the escape system to propel a command module to a safe distance from a launch vehicle during a pad abort. (Achieved)**
3. **Demonstrate launch-escape timing sequence. (Achieved)**
4. **Demonstrate proper operation of the launch-escape tower release device. (Achieved)**
5. **Demonstrate proper operation of the tower-jettison and pitch-control motors. (Achieved)**
6. **Demonstrate earth-landing timing sequence and proper operation of the parachute subsystem of the earth-landing system. (Achieved)**

Second Order Objectives:

1. **Determine dynamics of command module during jettisoning of escape tower. (Achieved)**
2. **Demonstrate operation of research and development instrumentation and communications equipment to be used on subsequent flights. (Achieved)**
3. **Demonstrate compatibility of prototype handling ground support equipment. (Achieved)**
4. **Determine initial separation trajectory of the launch escape tower. (Achieved)**
5. **Determine escape-tower vibration during pad abort. (Achieved)**

Apollo Mission A-001 (May 13, 1964)

First Order Objectives:

1. **Demonstrate the structural integrity of the escape tower. (Achieved)**
2. **Demonstrate the capability of the escape subsystem to propel the command module to a predetermined distance from launch vehicle. (Achieved)**
3. **Determine aerodynamic stability characteristics of the escape configuration for this abort condition. (Achieved)**
4. **Demonstrate proper operation of the command module to service module separation subsystem. (Achieved)**

5. **Demonstrate satisfactory recovery timing sequence in the earth- landing subsystem. (Achieved)**

Second Order Objectives:

1. **Demonstrate Little Joe II-spacecraft compatibility. (Achieved)**
2. **Determine aerodynamic loads caused by fluctuating pressures on the command module and service module during a Little Joe II launch. (Achieved)**
3. **Demonstrate proper operation of the applicable components of the earth-landing subsystem. (Not achieved - a parachute riser chafed against a simulated reaction control subsystem motor. The riser broke after main parachute line stretch, and the command module descended safely on the two remaining main parachutes.)**

Apollo Mission A-101 (May 28, 1964)

First Order Objectives:

1. **Demonstrate physical compatibility of the spacecraft with the launch vehicle under preflight and flight conditions. (Achieved)**
2. **Obtain data to verify design criteria for the launch environment. (Achieved)**
3. **Demonstrate the primary mode of the launch escape tower jettison using the escape tower jettison motor. (Achieved)**

Second Order Objectives:

1. **Demonstrate the structural integrity of the launch escape subsystem under flight-loading conditions. (Achieved)**
2. **Demonstrate the compatibility of the BP-13 communications and instrumentation subsystem with the launch vehicle system. (Achieved)**
3. **Demonstrate the adequacy of ground support handling equipment and procedures. (Achieved)**

Apollo Mission A-102 (September 18, 1964)

First Order Objectives:

None - since Apollo Mission A-101 was successful and the launch and exit environments for the spacecraft were measured satisfactorily.

Second Order Objectives:

1. **Determine the launch and exit environmental parameters to verify design criteria. (Achieved)**
2. **Demonstrate the alternate mode of spacecraft launch escape system jettison utilizing the launch-escape motor and pitch-control motor. (Achieved)**

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APPENDIX 6

Hardware Manufacture and Acceptance

Excerpted from material compiled by North American Rockwell's Space Division Public Relation Office.

Section A - Boilerplates

No.	Unit	Acceptance Date (m-d-y)	Use	Location
===	====	=====	===	=====
BP-1	CM	11-14-62	Land and water impact tests	MSC
BP-2	CM	12-11-62	Land and water impact tests	MSC
BP-3	CM	4-15-63	Parachute recovery	
BP-6	CM	7-01-63	Pad abort	
	LES	7-01-63	Pad abort	
BP-9	CM	3-11-63	Dynamic test	
	SM	3-11-63		
	LES	3-11-63		
	Adapter	3-11-63		
BP-12	CM	2-16-64	Transonic abort	
	SM	2-25-64	Transonic abort	
	LES	2-22-64	Transonic abort	
BP-13	CM	2-17-64	Booster and launch	
	SM	2-15-64	environment compatibility	
	LES	2-15-64		
	Adapter	2-14-64		

BP-15	CM	6-14-64	Booster and launch	
	SM	6-05-64	environment compatibility	
	LES	6-14-64		
	Adapter	6-05-64		
BP-16	CM	8-17-64	Booster, flight compatibility	
	LES	8-17-64		
	Adapter	8-17-64		
BP-19	CM	2-19-63	Parachute recovery	
BP-23	CM	9-17-64	High-Q abort	
	SM	9-14-64	High-Q abort	High-Q abort
	LES	9-19-64		
BP-25	CM	10-02-62	Water recovery and handling equipment tests	MSC
BP-26	CM	8-10-64	Micrometeoroid flight	
	SM	8-18-64		
	LES	8-18-64		
	Adapter	8-18-64		
BP-27	CM	9-25-64	Dynamic tests	MSFC
	SM	9-28-64	Dynamic tests	MSFC
	LES	9-25-64	Dynamic tests	MSFC

Section B - Mockups, Trainers, Simulators

M-2	CM	9-29-62	Interior arrangement	KSC
M-3	CM	9-10-62	Interior arrangement	KSC
M-4	SM	11-14-62	Interface studies	
	(partial) Adapter	11-14-62		
	(partial)			
M-5 Storage	CM	10-12-62	Exterior arrangement	NAA
M-7	SM	11-04-62	Design studies	MSC

M-9	CM	1-04-63	Handling and transportation studies	Tulsa KSC
	SM	1-04-63		
	LES	1-04-63		
	Adapter	1-04-63		
M-11	CM	1-04-63	Handling and transportation studies	KSC Tulsa KSC
	SM	1-04-63		
	LES	1-04-63		
	Adapter	1-04-63		
M-12	CM (partial)	10-12-62	Crew support studies	
M-22	CM	3-18-64	Interior and exterior arrangement	
M-23	CM (partial)	12-01-64	Umbilical tests	MSFC
	SM (partial)	12-01-64		MSFC
	LES (partial)	12-01-64		MSFC

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APPENDIX 6

Hardware Manufacture and Acceptance

Excerpted from material compiled by North American Rockwell's Space Division Public Relation Office.

Section A - Boilerplates

No.	Unit	Acceptance Date (month, date, year)	Use	Location
BP-1	CM	11-14-62	Land and water impact tests	MSC
BP-2	CM	12-11-62	Land and water impact tests	MSC
BP-3	CM	4-15-63	Parachute recovery	
BP-6	CM	7-01-63	Pad abort	
	LES	7-01-63	Pad abort	
BP-9	CM	3-11-63	Dynamic test	
	SM	3-11-63		
	LES	3-11-63		
	Adapter	3-11-63		
BP-12	CM	2-16-64	Transonic abort	
	SM	2-25-64	Transonic abort	
BP-13	CM	2-17-64	Booster and launch environment compatibility	
	SM	2-15-64		
	LES	2-15-64		
	Adapter	2-14-64		
BP-15	CM	6-14-64	Booster and launch environment compatibility	

	SM	6-05-64		
	LES	6-14-64		
	Adapter	6-05-64		
BP-16	CM	8-17-64	Booster, flight compatibility	
	LES	8-17-64		
	Adapter	8-17-64		
BP-19	CM	2-19-63	Parachute recovery	
BP-23	CM	9-17-64	High-Q abort	
	SM	9-14-64	High-Q abort	High-Q abort
	LES	9-19-64		
BP-25	CM	10-02-62	Water recovery and handling equipment tests	MSC
BP-26	CM	8-10-64	micrometeoroid flight	
	SM	8-18-64		
	LES	8-18-64		
	Adapter	8-18-64		
BP-27	CM	9-25-64	Dynamic tests	MSFC
	SM	9-28-64	Dynamic tests	MSFC
	LES	9-25-64	Dynamic tests	MSFC
Section B- Mockups, Trainers, Simulators				
M-2	CM	9-29-62	Interior arrangement	KSC
M-3	CM	9-10-62	Interior arrangement	KSC
M-4	SM (Partial)	11-14-62	Interface studies	
	Adapter (Partial)	11-14-62		
M-5	CM	10-12-62	Exterior arrangement	NAA Storage
M-7	SM	11-04-62	Design studies	MSC
M-9	CM	1-04-63	Handling and transportation	Tulsa
	SM	1-04-63	KSC	
	LRS	1-04-63		

	Adapter	1-04-63		
M-11	CM	1-04-63	Handling and transportation studies	KSC
	SM	1-04-63	Tulsa	
	LES	1-04-63	KSC	
	Adapter	1-04-63		
M-12	CM (Partial)	10-12-62	Crew support studies	
M-22	CM	3-18-64	Interior and exterior arrangement	
M-23	CM (Partial)	12-01-64	Umbilical tests	MSFC
	SM (Partial)	12-01-64	MSFC	
	LES	12-01-64	MSFC	

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APPENDIX 7

Funding

Compiled by F. P. Hopson, Program Control and Contracts Directorate

1964

Original budget request including Fiscal Year 1963 supplemental

NASA: \$3,926,000,000

Apollo: \$2,243,900,000

Fiscal budget appropriation with Fiscal Year 1963 supplemental

NASA: \$3,974,979,000

Apollo: \$2,272,952,000

- Command and service modules: \$545,874,000
- Lunar excursion module: \$135,000,000
- Guidance and navigation: \$91,499,000
- Integration, reliability, and checkout: \$60,699,000
- Spacecraft support: \$43,503,000
- Saturn I: \$187,077,000
- Saturn IB: \$146,817,000
- Saturn V: \$763,382,000
- Engine development: \$166,000,000
- Apollo mission support: \$133,101,000

1965

Original budget request including Fiscal Year 1964 supplemental

NASA: \$4,523,000,000

Apollo: \$2,818,500,000

Fiscal budget appropriation with Fiscal Year 1964 supplemental

NASA: \$4,270,695,000

Apollo: \$2,614,619,000

- Command and service modules: \$577,834,000
- Lunar excursion module: \$242,600,000
- Guidance and navigation: \$81,038,000
- Integration, reliability, and checkout: \$24,763,000
- Spacecraft support: \$83,663,000
- Saturn I: \$40,265,000
- Saturn IB: \$262,696,000
- Saturn V: \$964,924,000
- Engine development: \$166,300,000
- Apollo mission support: \$170,542,000

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APPENDIX 8

Organization Charts

Readers should note that the web pages below contain large charts

- [National Aeronautics and Space Administration, April 26, 1963](#)
- [National Aeronautics and Space Administration, November 1, 1963](#)
- [National Aeronautics and Space Administration, April, 1964](#)
- [Office of Manned Space Flight, March 7, 1963](#)
- [Office of Manned Space Flight, July 18, 1963](#)
- [Office of Manned Space Flight, January 31, 1964](#)
- [Office of Manned Space Flight, July 1, 1964](#)
- [Manned Spacecraft Center, April 29, 1963](#)
- [Manned Spacecraft Center, November 1, 1963](#)
- [Manned Spacecraft Center, August 13, 1964](#)
- [Apollo Spacecraft Project Office, May 1, 1963](#)
- [Apollo Spacecraft Project Office, August 26, 1963](#)
- [Apollo Spacecraft Project Office, August 11, 1964](#)
- [MSC Florida Operations, December 5, 1963](#)
- [MSC Florida Operations, July 2, 1964](#)
- [MSC WSMR Operations, September 16, 1964](#)
- [Little Joe II and Apollo Pad Abort Test Operations, June 13, 1963](#)

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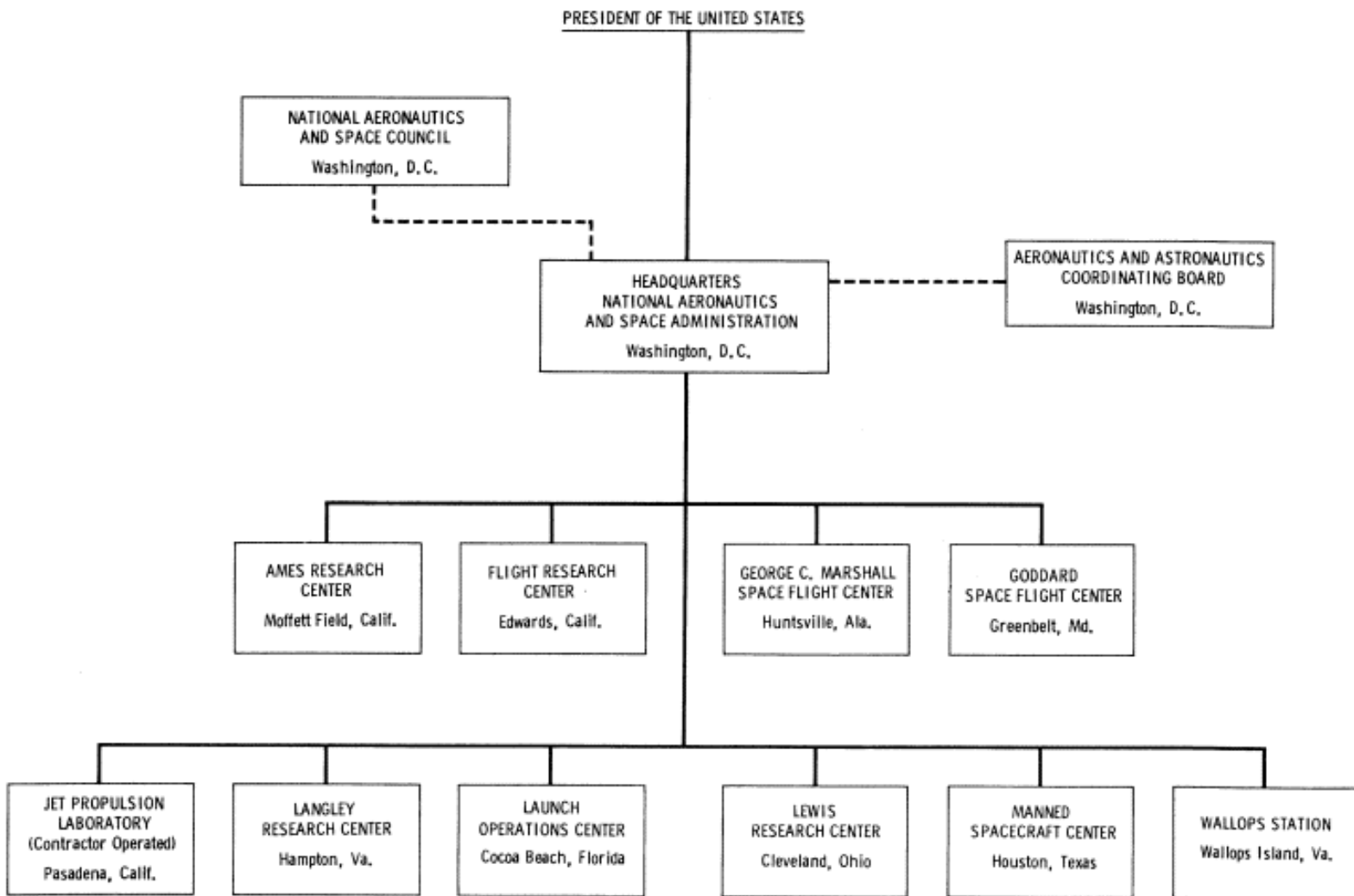
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Appendix 8a

National Aeronautics and Space Administration

April 26, 1963



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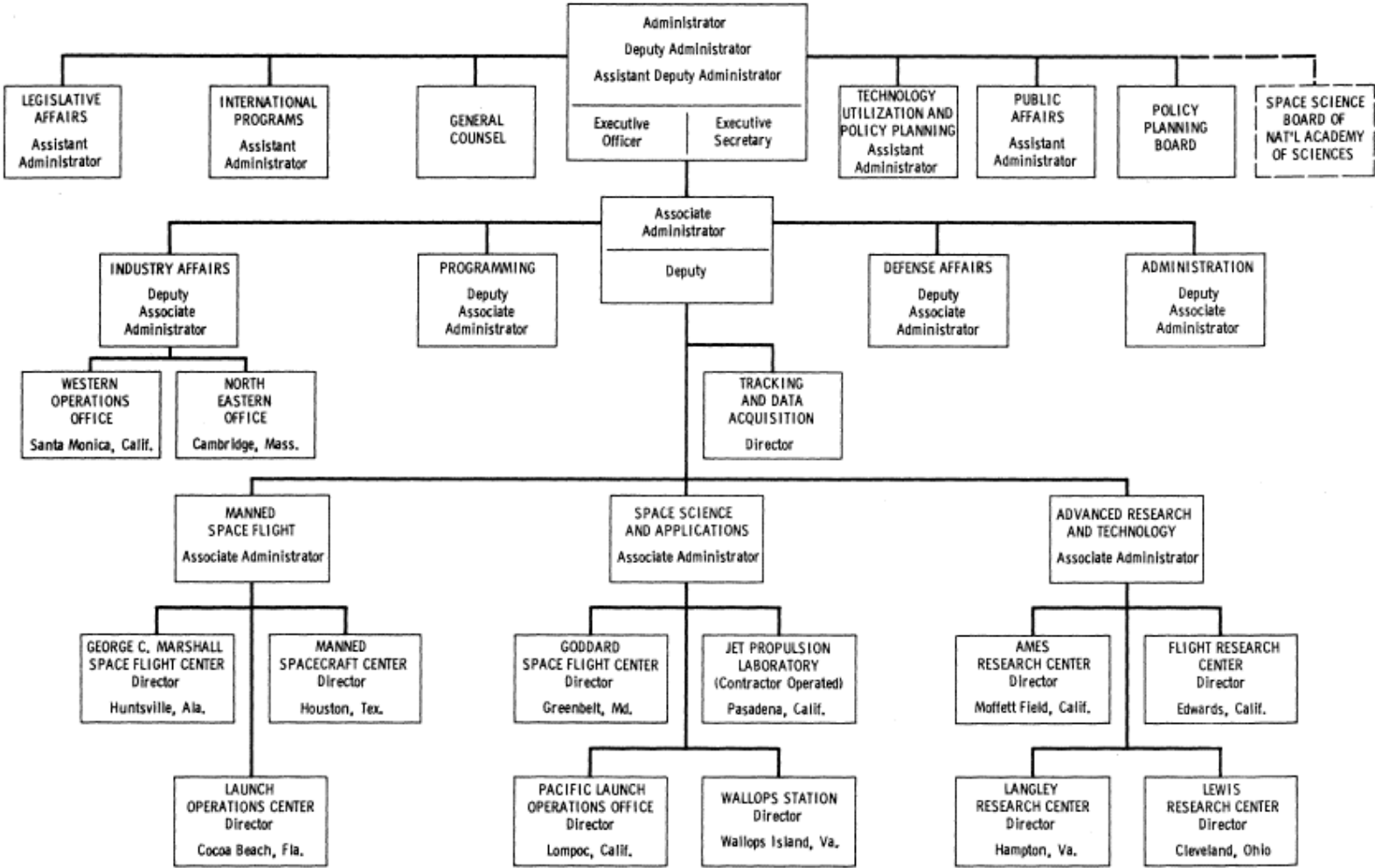
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National Aeronautics and Space Administration

November 1, 1963



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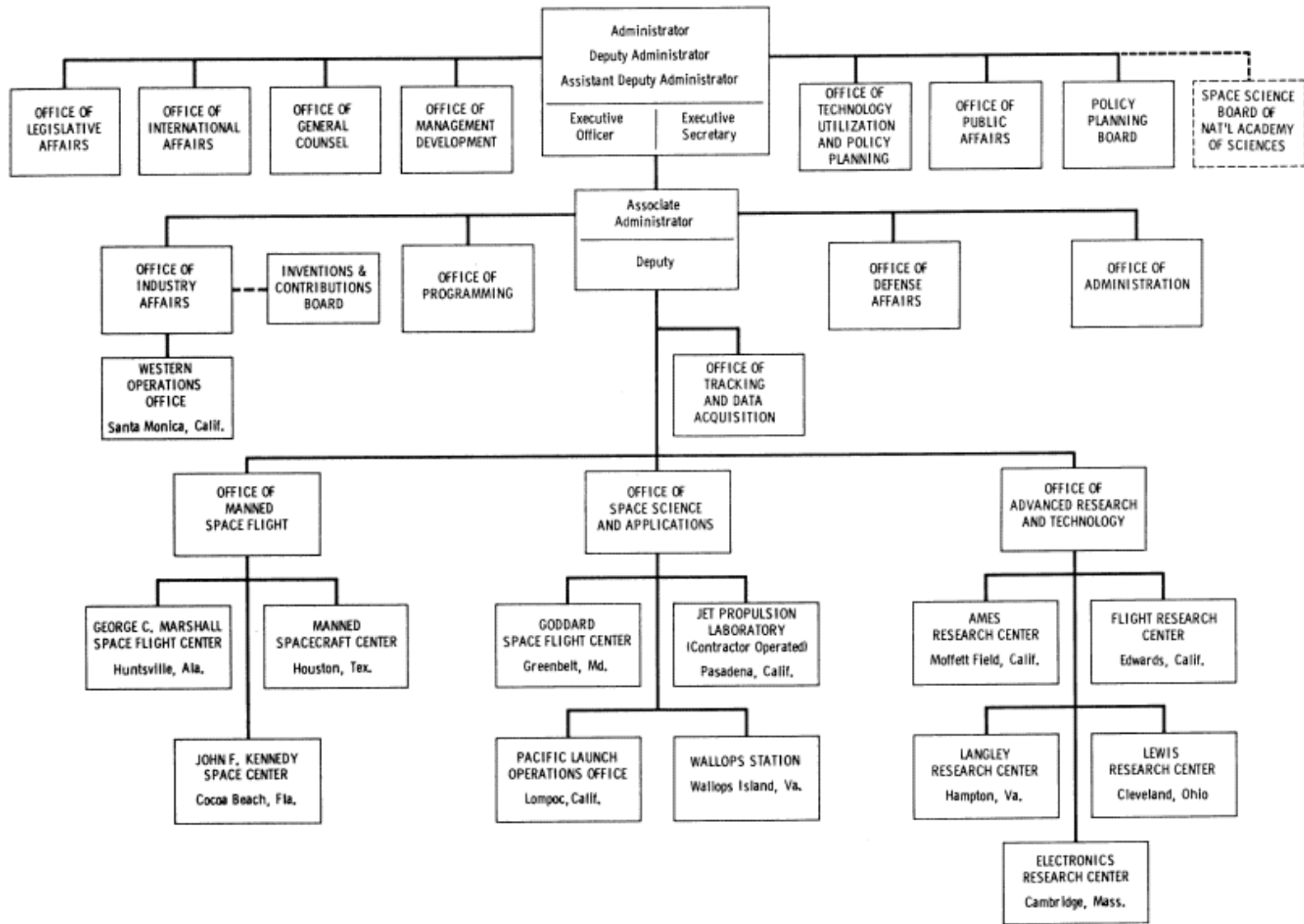
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National Aeronautics and Space Administration

April 1963



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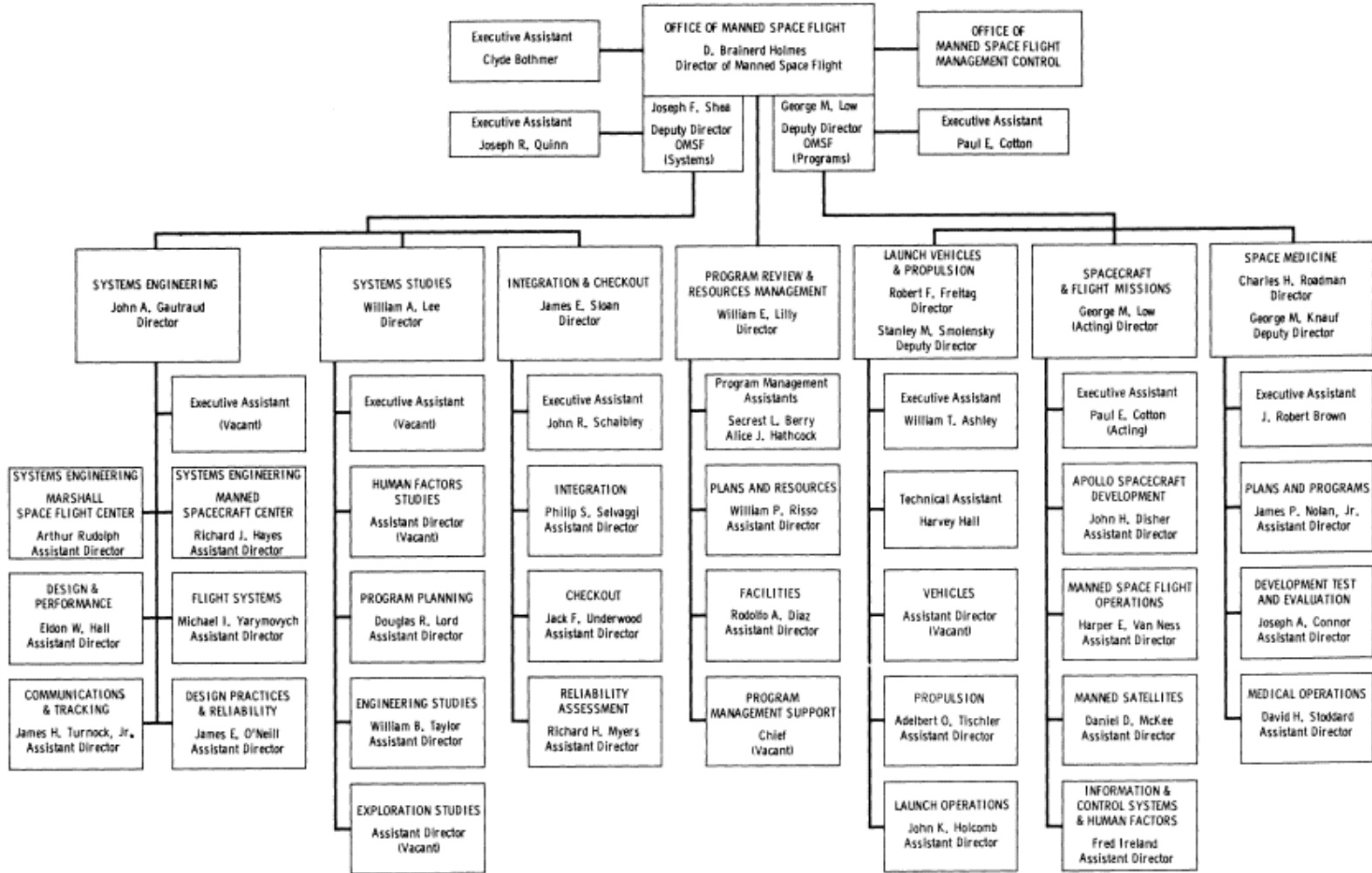
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Office of Manned Space Flight

March 7, 1963



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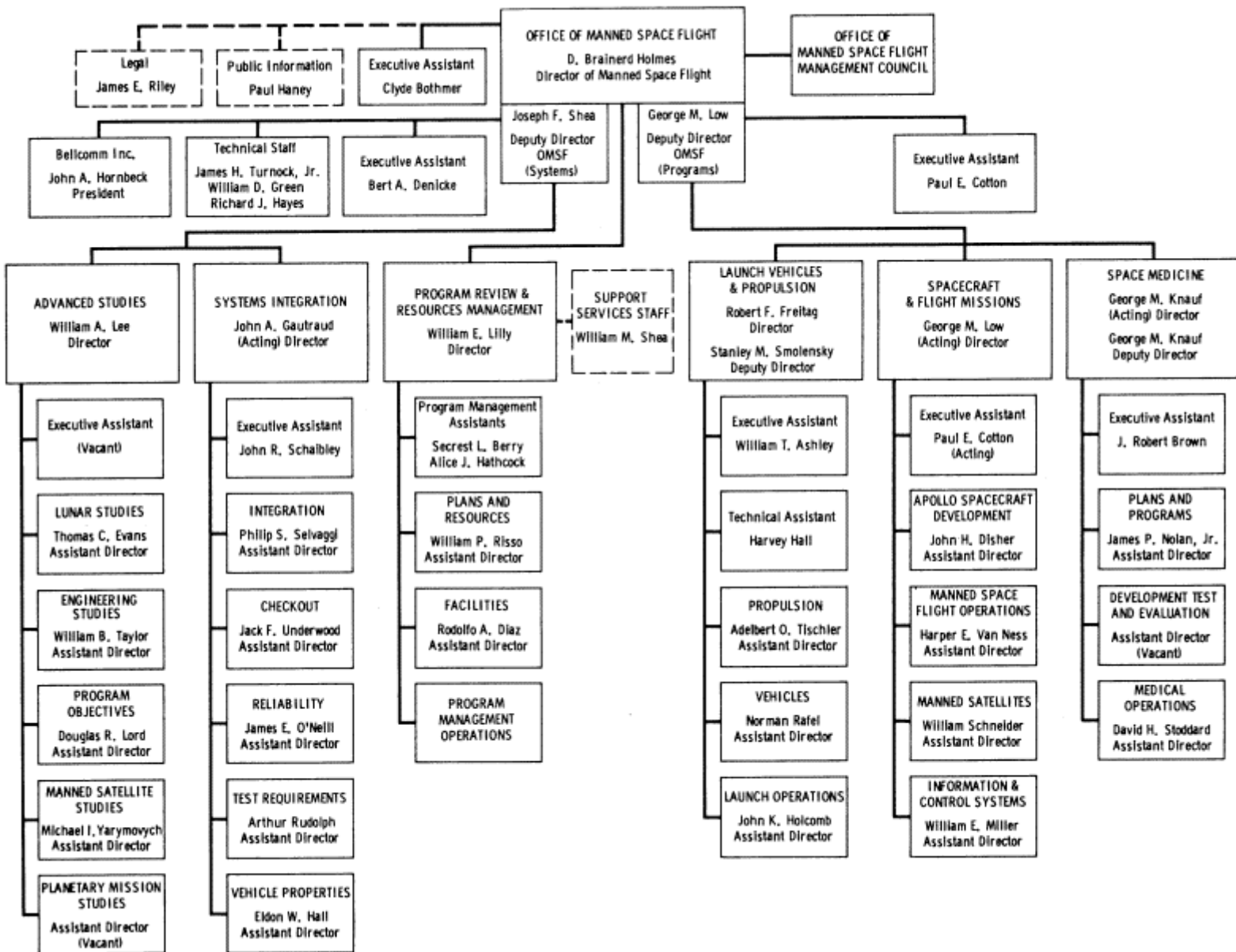
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Office of Manned Space Flight

July 18, 1963



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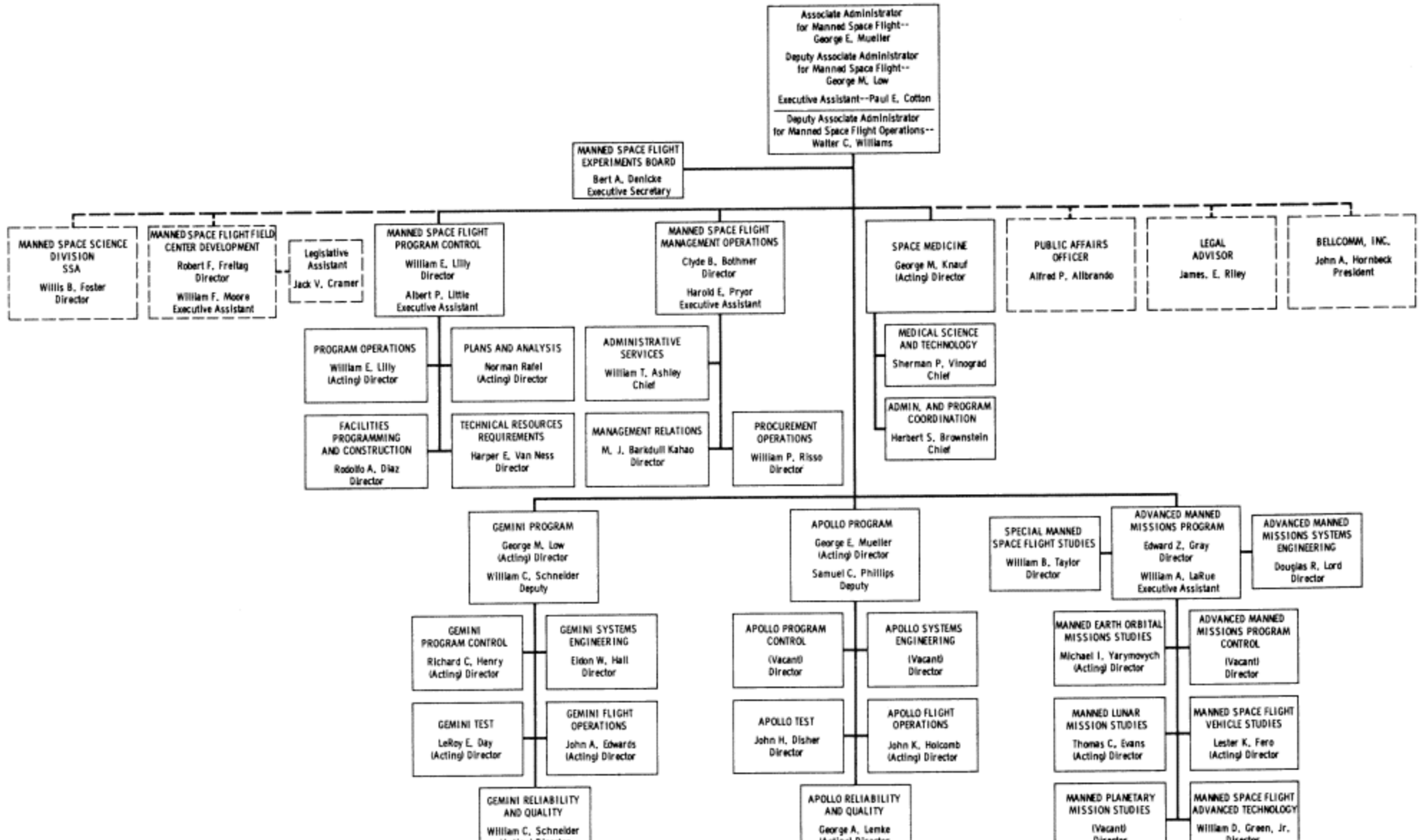
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Office of Manned Space Flight

January 31, 1964



Acting Director

Acting Director

Acting Director

Acting Director

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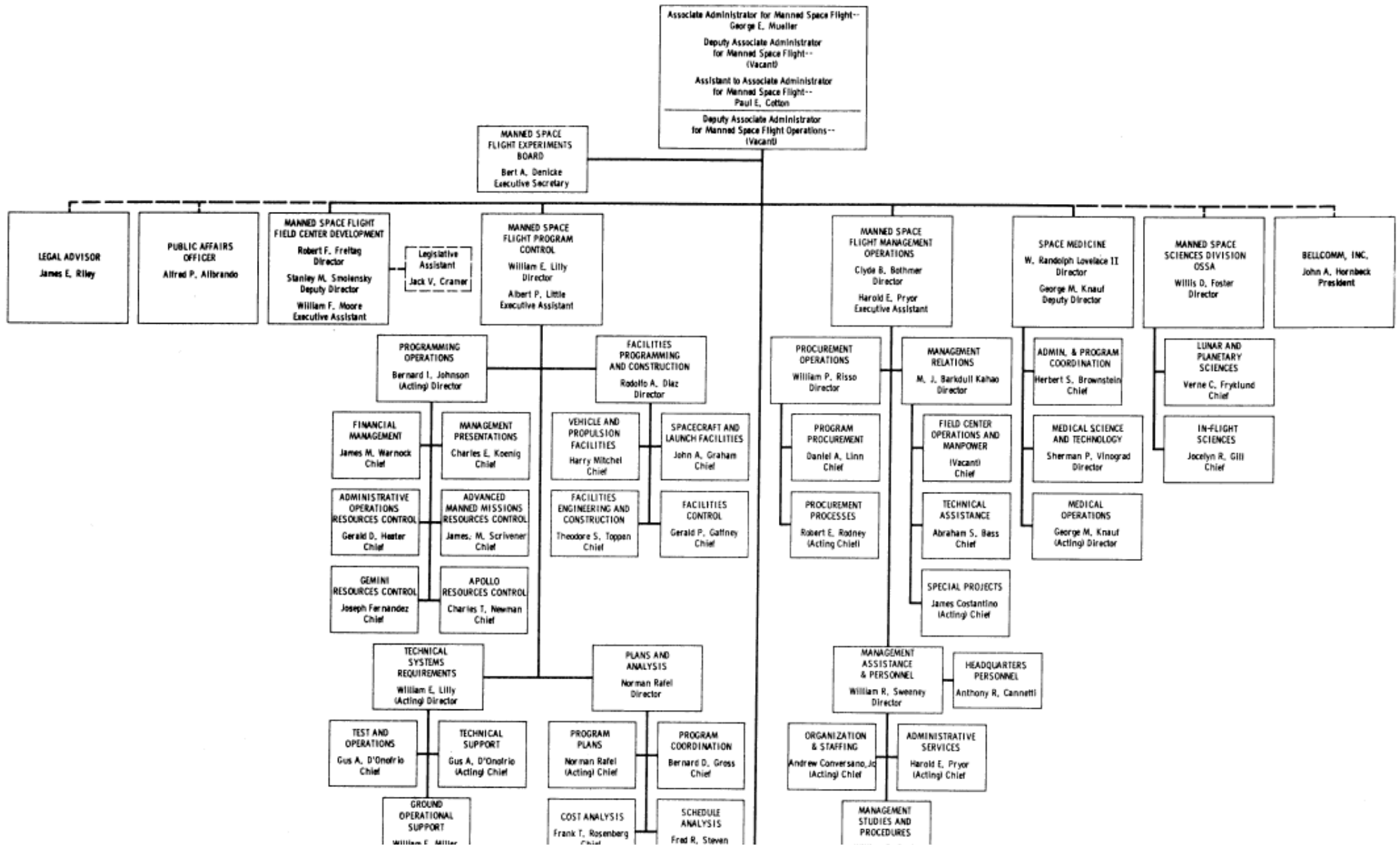
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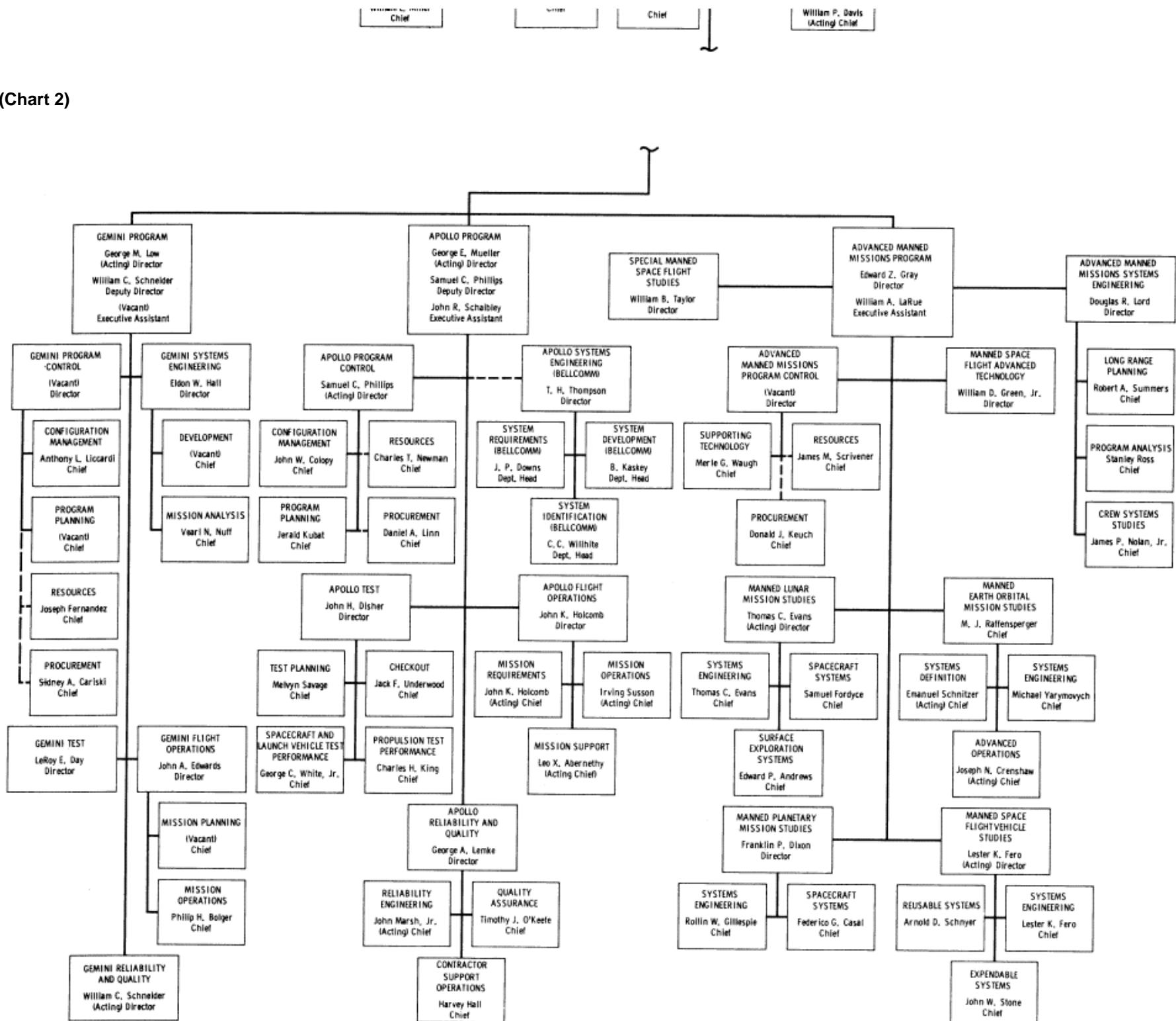
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Office of Manned Space Flight

July 1, 1964 (Chart 1)



(Chart 2)



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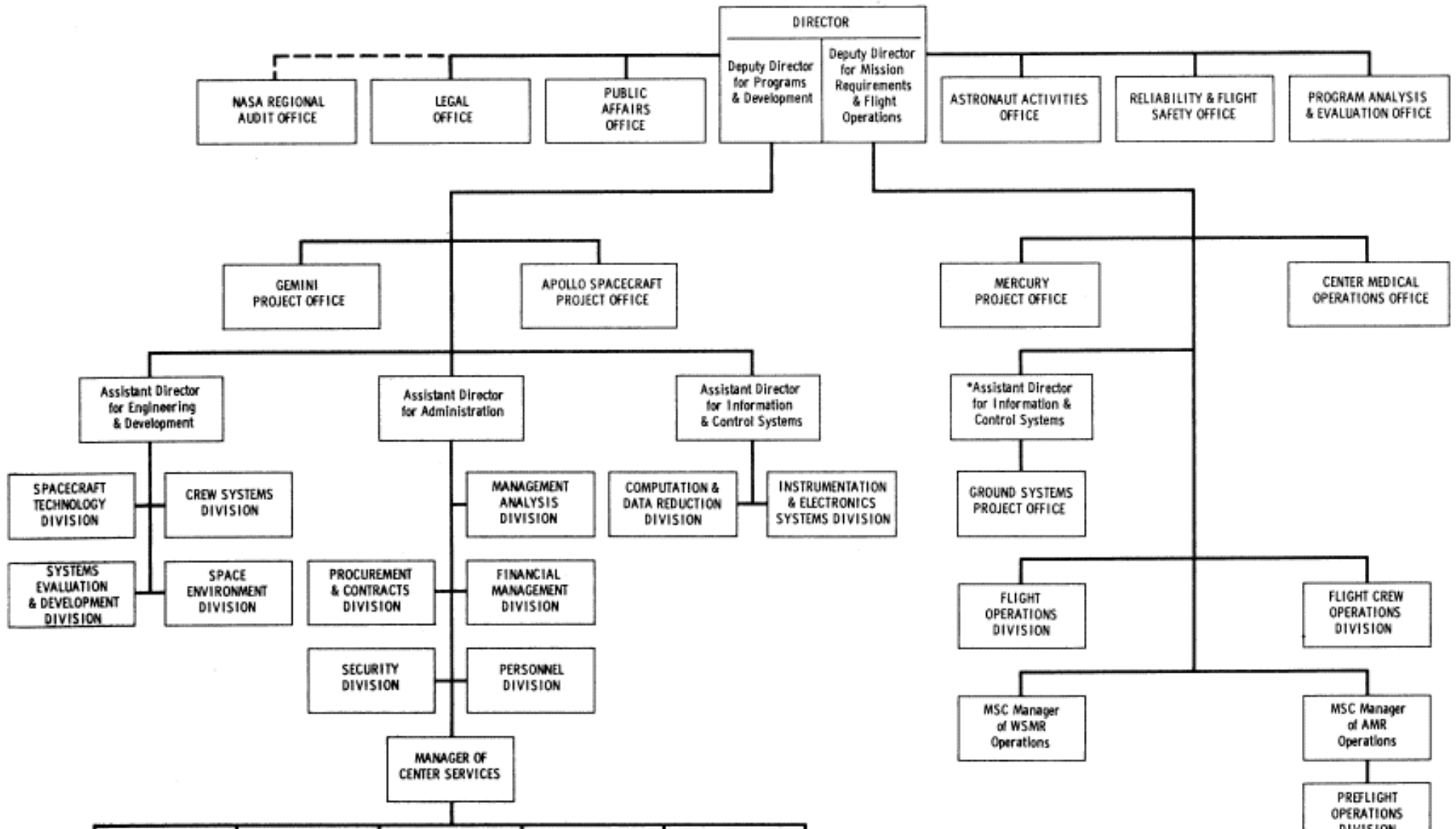
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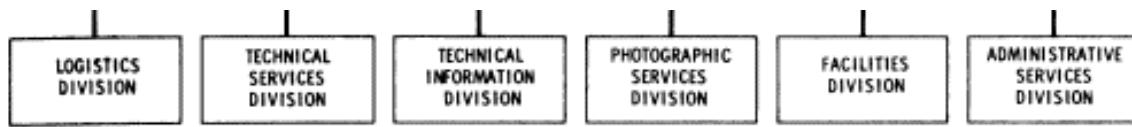
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Appendix 8h

Manned Spacecraft Center

April 29, 1963





*The Assistant Director for Info. & Control Systems reports to the Deputy Director for MR & FO for IMCC and GOS Implementation matters and reports to the Deputy Director for P&D for all other matters.

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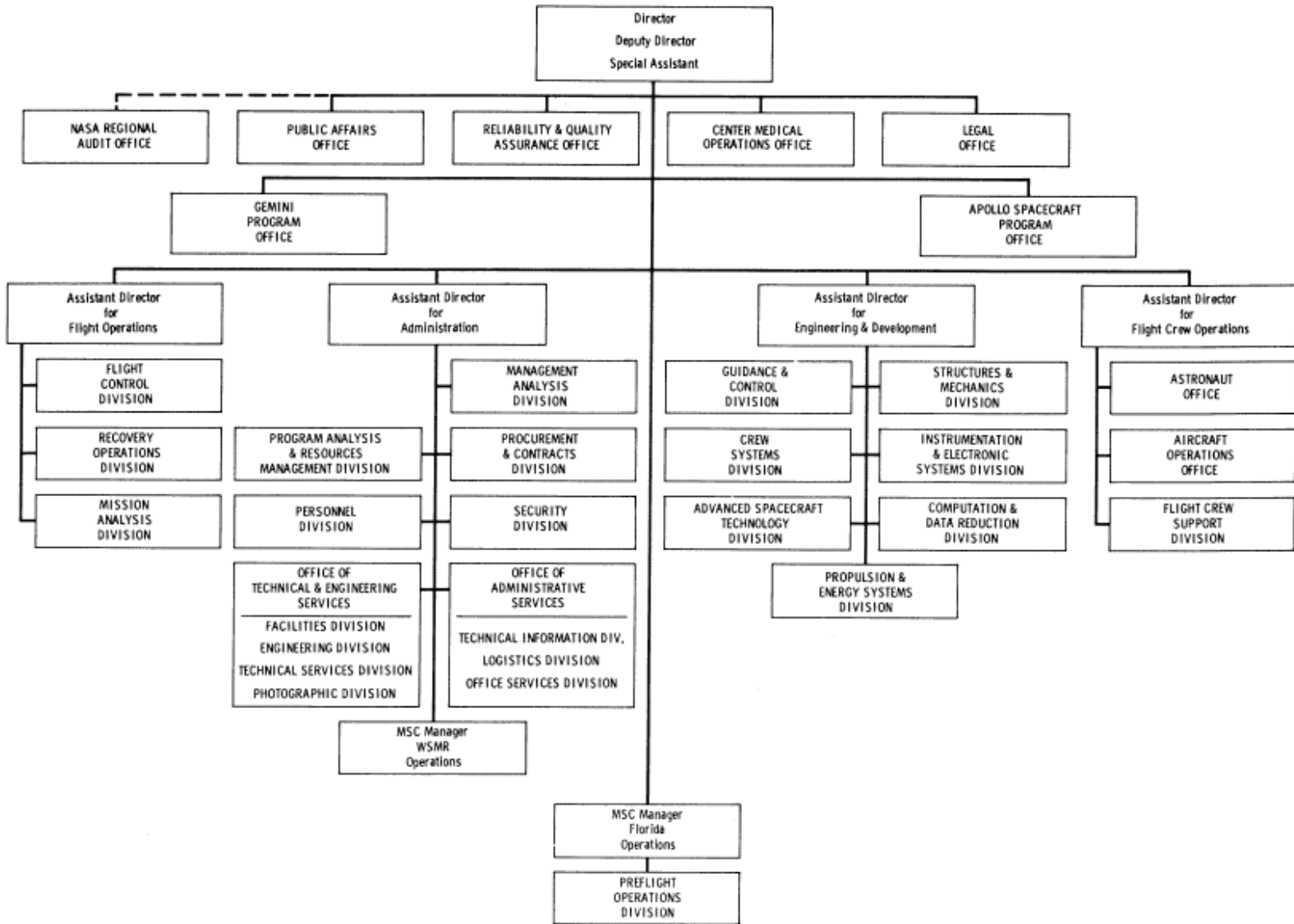
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Manned Spacecraft Center

November 1, 1963



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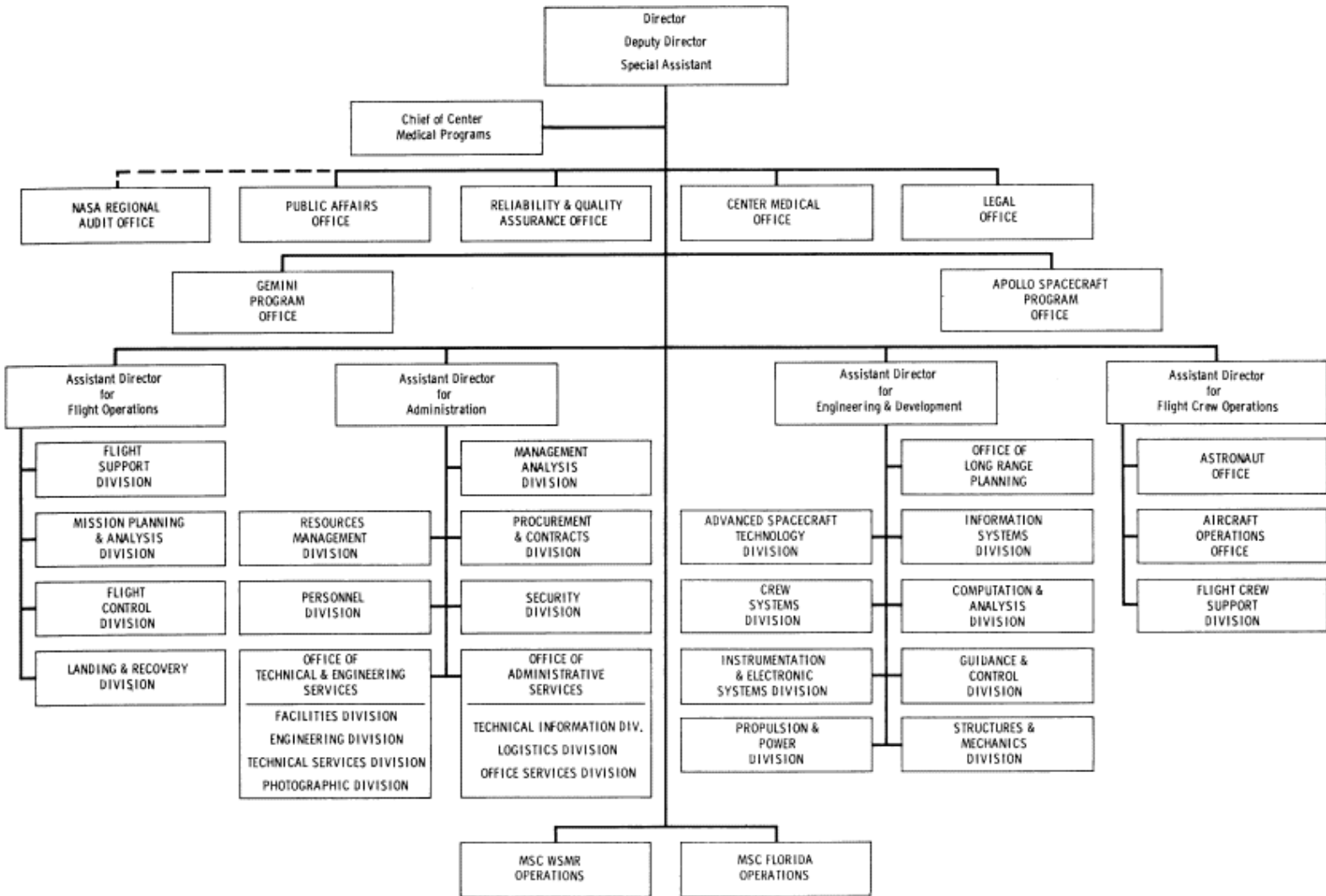
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Manned Spacecraft Center

August 13, 1964



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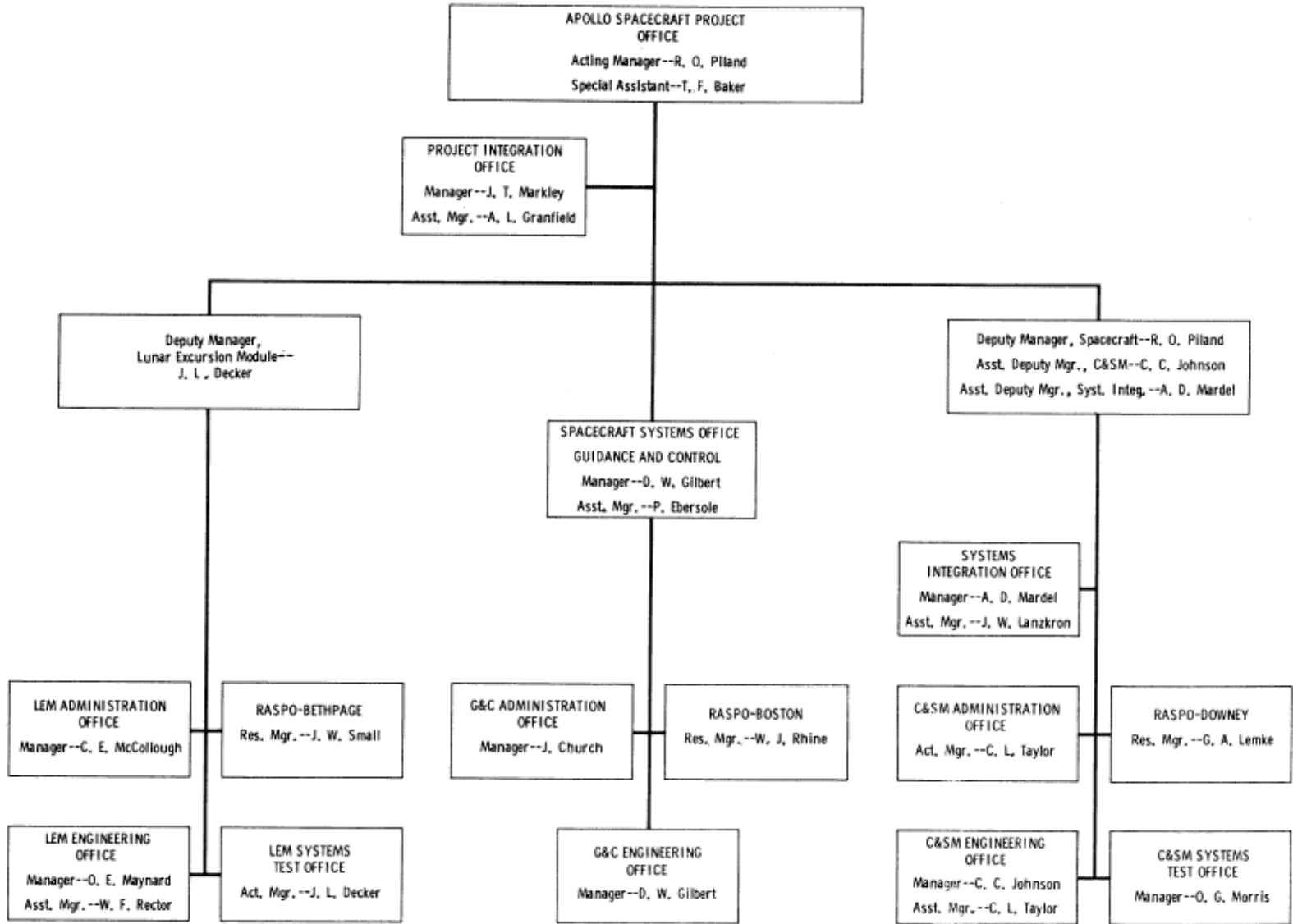
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Apollo Spacecraft Project Office

May 1, 1963



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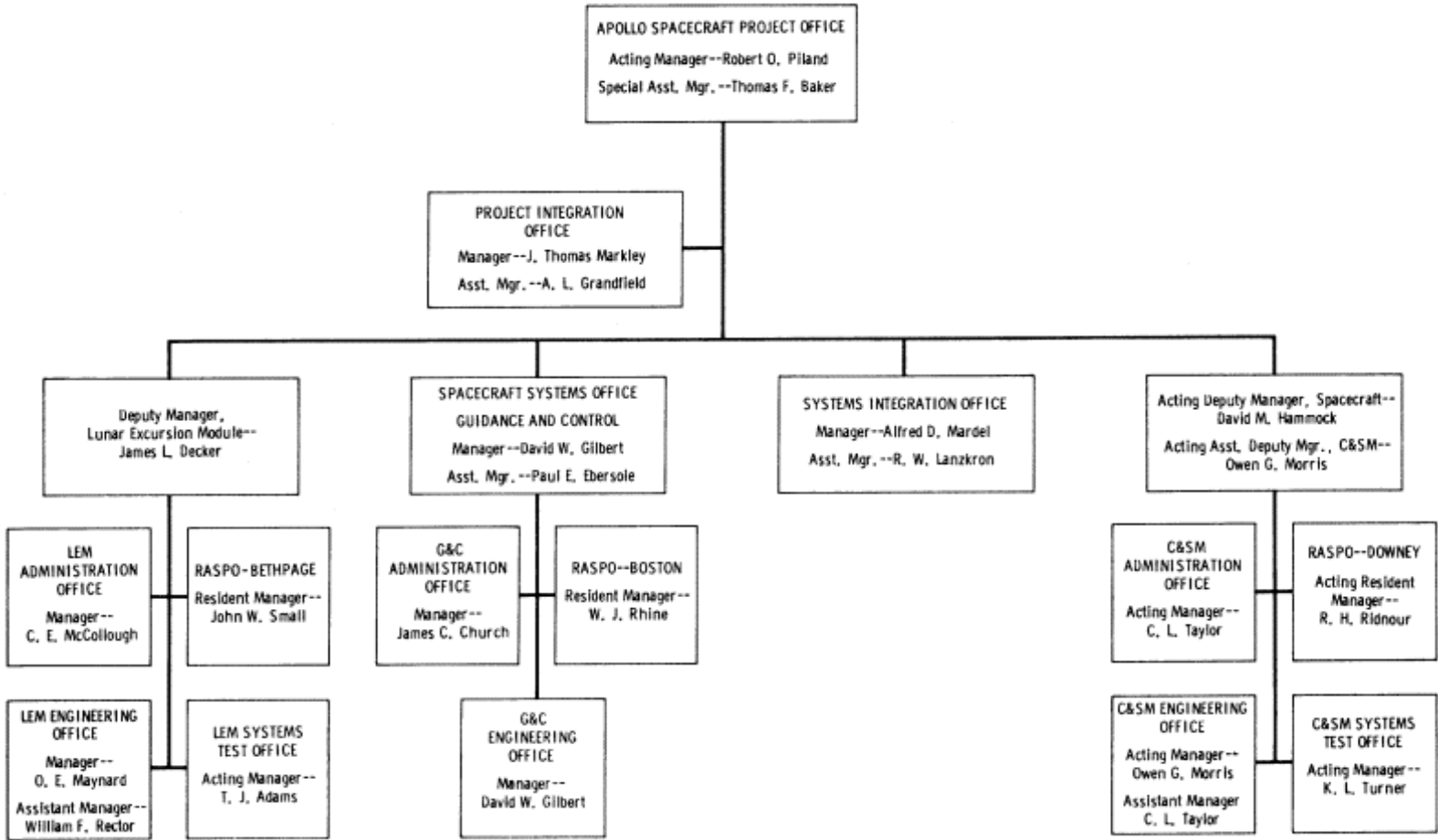
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Apollo Spacecraft Project Office

August 26, 1963



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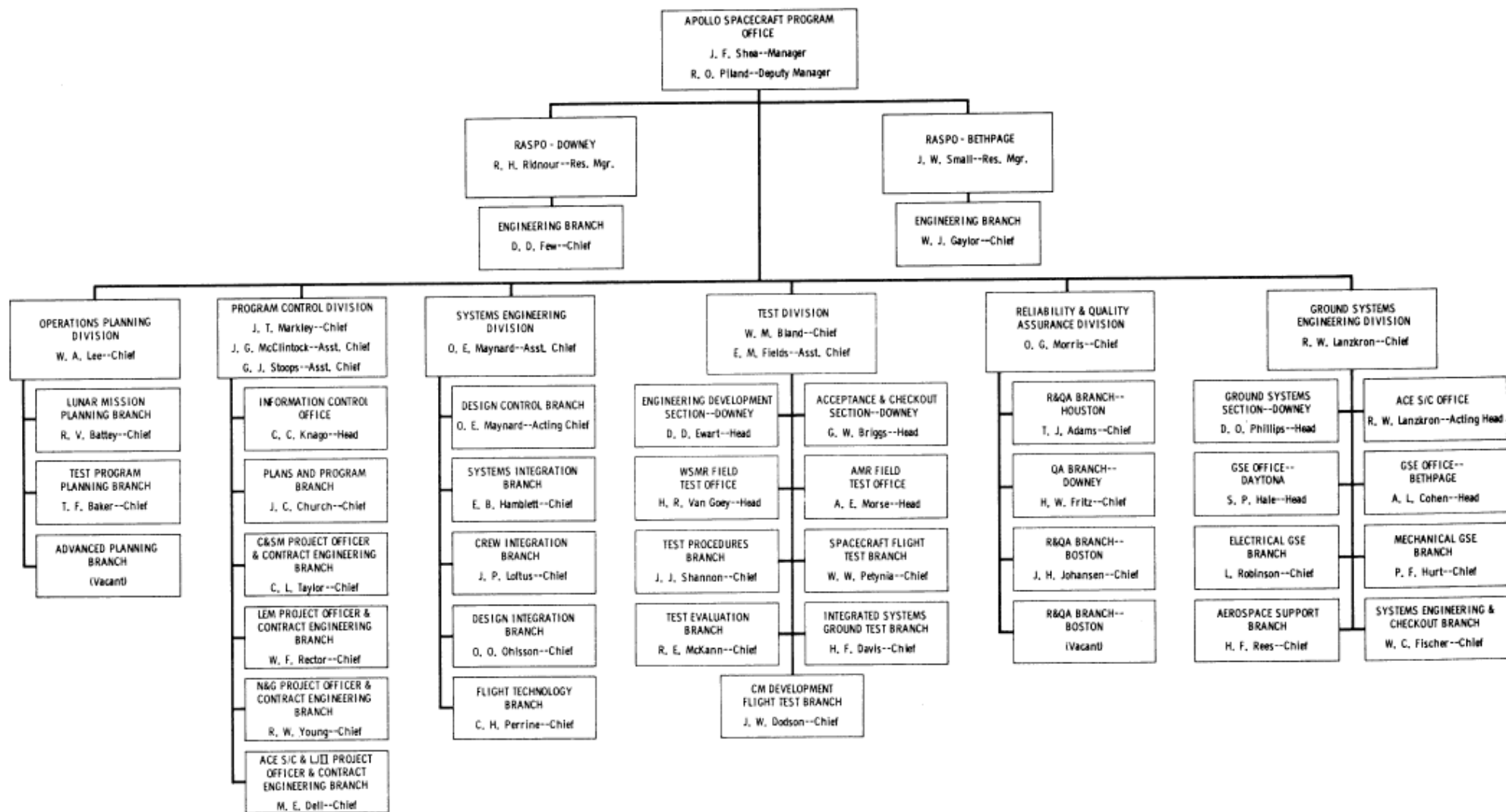
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Apollo Spacecraft Program Office

August 11, 1964



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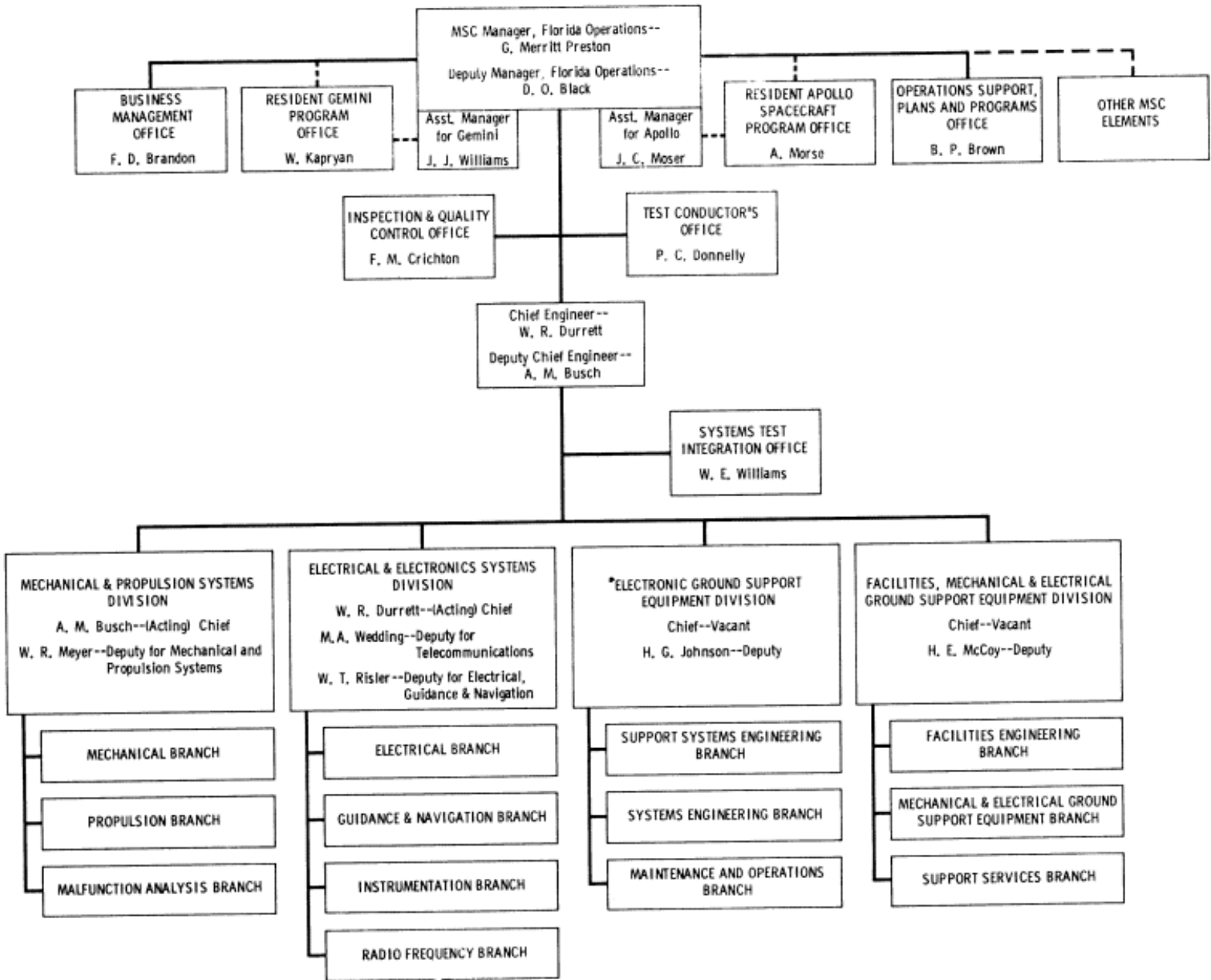
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MSC Florida Operations

December 5, 1963



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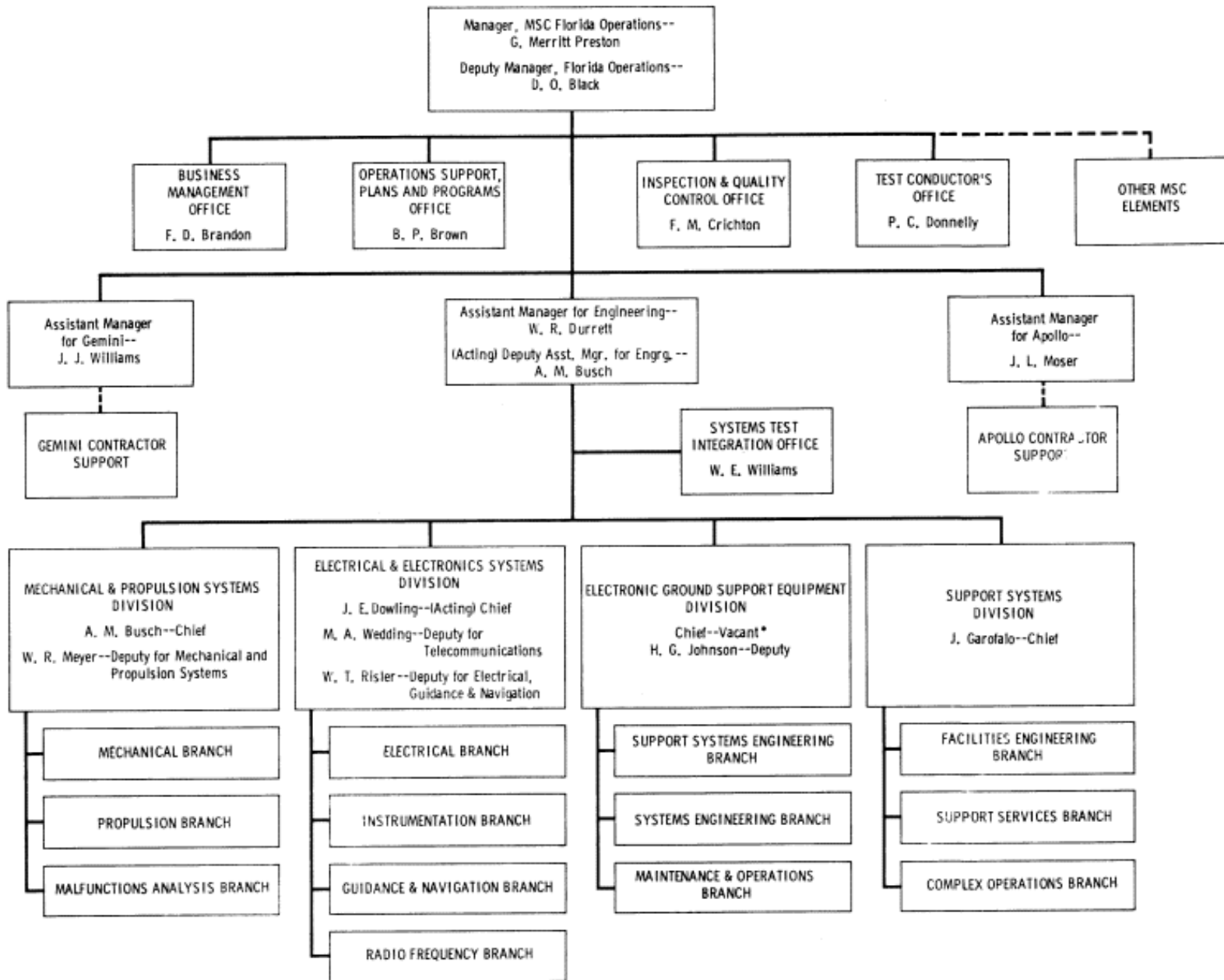
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MSC Florida Operations

July 2, 1964

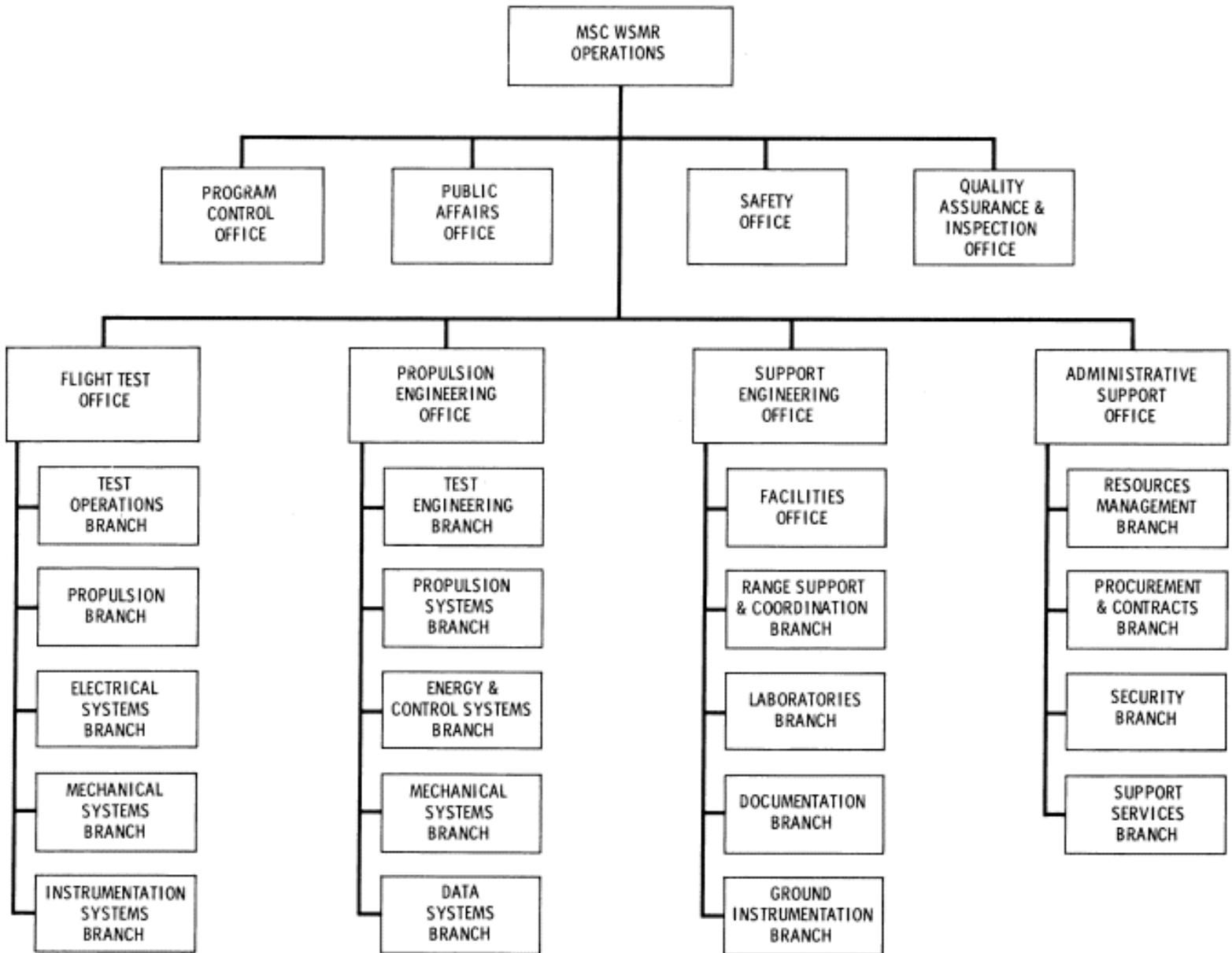


*To be filled by Walter E. Parsons upon return from special assignment in Apollo S/C Program Office.

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MSC WSMR Operations

September 16, 1964



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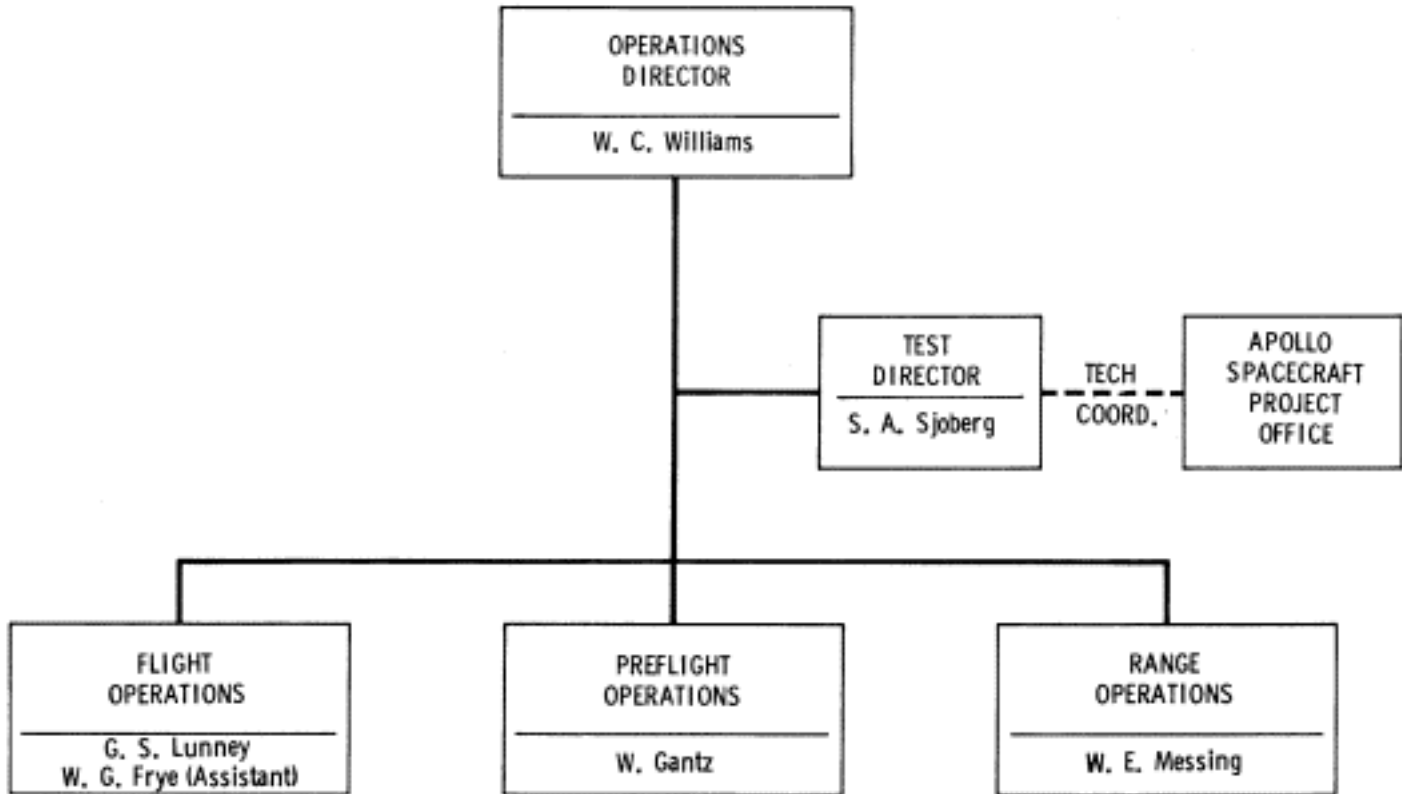
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Appendix 8q

Little Joe II and Apollo Pad Abort Test Operations

June 13, 1963



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The Authors

Mary Louise Morse has been a Research Associate with the Department of History of the University of Houston since the fall of 1966. Born in Beverly, Massachusetts, she received her B.S. in Education from Salem State College, Salem, Massachusetts (1947), and her M.A. in History from Columbia University (1950). She was a senior editor with the MIT Press, Cambridge, Massachusetts, before moving to Houston.

Jean Kernahan Bays was a Research Associate with the Department of History of the University of Houston from August 1967 to June 1969. Born in Pittsburg, Pennsylvania, she received a B.A. in History from Denison University (1965) and an M.A. in History from the University of Houston (1967), where she served as a teaching fellow. She has also worked as a Research Librarian for the Houston, Texas, Public Library. She is married and lives in Houston.

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Foreword

Work on the Command Module had progressed to the point where some full-scale testing was initiated. The launch escape system was tested for off-the-pad aborts at White Sands, New Mexico. A special test vehicle, "Little Joe II," built by Convair, San Diego, was employed at WSMR to accelerate the Command Module to "maximum q" conditions for tests of the launch escape system under this most difficult situation. At El Centro, California, the parachute system was undergoing extensive testing. Back at Downey, California, North American built a large trapeze-like structure over an artificial lake to certify the Command Module structure for water impact loads. At yet another site, the White Sands Test Facility, located on the other side (west) of the Organ Mountains from the Little Joe II launch area, the testing of the Service Module propulsion system and the ascent and descent propulsion stages for the Lunar Module was started. As might be expected in the initial development testing of advanced design hardware, a number of disappointing failures were experienced. For instance the Command Module structure ruptured and the test article sank during the first water impact test.

Considerable analytical and experimental work was underway on engineering problems associated with landing the LEM on the Moon. Landing loads and stability were studied by dropping dynamically scaled models on simulated lunar soil and by computer runs which utilized mathematical models of both the LEM and the lunar surface. At the same time an effort was underway to deduce in engineering terms the surface characteristics and soil mechanics of the lunar surface. Only the sparse photographic information from Ranger was available to the engineers, yet later data from Surveyor and Orbiter led to no significant change in the LEM design. In addition to lack of definition of the lunar surface, uncertainty about the cislunar space environment also handicapped design progress. The intensity of the radiation flux during solar flares was not fully understood. In addition to worry about radiation sickness, a particular concern was possible damage to the eyes in the form of cataracts of the astronauts. Thick transparent plastic eye shields were proposed. A program was instituted to learn more about predicting solar events and a network of H-alpha telescopes and radio frequency detectors was planned for this purpose. At the same time much effort was expended to assure that neither the spacecraft nor the astronauts' space suits would be damaged by micrometeors. In this regard help came from the data obtained by the Pegasus micrometeor detection satellites orbited by the last two Saturn I launch vehicles.

During this same period the Gemini program entered into its operational phase with a launch rate averaging once every two months. Significant to the Apollo mission were the development of operational procedures for orbital rendezvous, "shirtsleeve" operation by the crew in orbit, and exposure to fourteen days of weightlessness with only incidental physiological effects.

Finally, important scientific aspects of the mission were defined. Studies of lunar sample return and back contamination had progressed to the point that the essential features of the Lunar Receiving Laboratory were established. Further definition of the lunar geological surveys was achieved. With a goal of better precision in selection of Apollo landing sites, a coordinated activity was instituted with the Orbiter

project. The Apollo Lunar Science Experiment Package (ALSEP) design progressed to the point of commitment to a 56-watt radioisotope power generator. Thus these small automated science stations would be assured an extended lifetime of operation after departure of the astronauts. It was also during this period that NASA recruited its first group of scientist astronauts.

In summary, during this period the Apollo program settled into the substance and routine of making the lunar landing a reality. The tremendous challenge in scope and depth of the venture was unmistakably clear to the government-industry team mobilized to do the job.

Maxime A. Faget

Director of Engineering and Development

Johnson Space Center

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The Key Events

1964

October 5-8: NASA conducted formal review of LEM mockup M-5 at Grumman factory.

October 12: U.S.S.R. launched *Voskhod I*, world's first multi-manned spacecraft.

October 14: AC Spark Plug reported first Apollo guidance system completed and shipped to NAA.

October 27: NASA announced appointment of Maj. Gen. Samuel C. Phillips as Director of Apollo Program.

November 23: NASA gave NAA a formal go-ahead on the Block II spacecraft.

December 7: Douglas Aircraft Company delivered first S-IVB stage to MSFC for testing.

December 8: Apollo Mission A-002 was flown at WSMR, with BP-23 launched by a Little Joe II booster.

1965

January 14-21: NAA completed acceptance tests on the CSM sequential and systems trainers.

January 21-28: Space Technology Laboratories was named sole contractor for the LEM descent engine.

February 9: NAA completed the first ground test model of the S-II stage of the Saturn V.

February 17: *Ranger VIII* was launched by NASA from Cape Kennedy. It transmitted pictures back to earth before lunar impact.

March 2: MSC decided in favor of an "all-battery" LEM rather than the previously planned fuel cells.

March 17: Crew Systems Division recommended "shirtsleeve" environment be retained in CM.

March 18: U.S.S.R. launched *Voskhod II* on a 17-orbit mission. Lt. Col. Aleksei Leonov performed man's first "walk-in-space."

- March 21:** NASA launched *Ranger IX*, last of series. It transmitted 5,814 pictures of lunar surface to earth.
- March 23:** *Gemini III* was launched from Cape Kennedy with astronauts Virgil I. Grissom and John W. Young aboard; the first U.S. multi-manned mission lasted three orbits.
- March 23-24:** Part I of the Critical Design Review of the CM Block II crew compartment and docking system was held at NAA.
- April 1:** The first stage of the Saturn IB booster underwent its first static firing at MSFC.
- April 9:** Control over manned space flights, after liftoff, was transferred from the Cape Kennedy Control Center to Mission Control Center, Houston.
- April 14:** Final beam was emplaced in the structural skeleton of the Vertical Assembly Building at KSC.
- April 16:** MSFC conducted first clustered firing of Saturn V's first stage (S-IC).
- April 27-30:** Part II of the Block II CM crew compartment and docking system Critical Design Review was held at NAA.
- April 28:** ASPO Manager Joseph F. Shea approved the Crew Systems Division recommendation to retain "shirtsleeve" environment in the CM.
- May 19:** Apollo mission A-003 was flown at WSMR. Little Joe II booster disintegrated 25 sec after launch but launch escape system worked perfectly.
- May 22:** NASA launched Project Fire II from Cape Kennedy to obtain test data on heating during reentry.
- June 3:** Northrop-Ventura began qualification testing of the Apollo earth landing system.
- June 3:** NASA launched *Gemini IV* from Cape Kennedy on a Titan II booster. Astronauts James A. McDivitt and Edward H. White II were crew members for the four-day mission. During the flight White made America's first "space walk."
- June 7:** George E. Mueller, NASA Associate Administrator for Manned Space Flight, approved procurement of lunar surface experiments package.
- June 7-13:** NAA's Rocketdyne Division began qualification testing on the CM's reaction control system

engines.

June 14: A Technical Working Committee was appointed at MSC to oversee the design of the Lunar Sample Receiving Laboratory.

June 29: NASA launched pad abort (PA)-2, a test of the launch escape system at WSMR.

June 29: NASA formally announced the selection of six scientist-astronauts for the Apollo program.

June 30: Langley Research Center put its Lunar Landing Research Facility into operation.

July 4-10: NASA approved a Grumman subcontract to Eagle-Picher for the LEM batteries.

July 19: MSC directed Grumman to implement changes to limit the total LEM weight to 14,515 kg (32,000 lbs).

July 30: NASA launched SA-10 from Cape Kennedy, marking the end of the Saturn I program and its 10 successful launches.

August 5: The Saturn V's first stage made a "perfect" full-duration firing at MSFC by burning for the programmed 2.5 min at full thrust.

August 9: Two Saturn milestones occurred: (1) NAA conducted first full-duration captive firing of S-II stage; and (2) Douglas Aircraft Co. static-tested first flight model S-IVB stage.

August 12: Apollo Program Director Samuel C. Phillips listed six key checkpoints in development of Apollo hardware.

August 18: Grumman put "Operation Scrape" into effect in an effort to lighten the LEM.

August 21: *Gemini V* was launched from Cape Kennedy with astronauts L. Gordon Cooper, Jr., and Charles Conrad, Jr., as crew members. The eight-day flight was the first in which fuel cells were used as primary electrical power source.

August 27: NAA reported ground testing of service propulsion system had been concluded.

September 10: NASA announced a plan to recruit additional pilot-astronauts.

September 13: ASPO Manager Joseph F. Shea announced a new plan to control Apollo spacecraft weight.

September 16-23: Grumman established final design parameters for the LEM landing gear.

September 20: MSC recommended to NASA Hq that International Latex Corp. be awarded a contract for development and fabrication of space suits and associated equipment.

September: A total of 13 flights were made in the LLRV, including one in which the lunar simulation mode was flown for the first time.

October 15: Recovery requirements for the Apollo spacecraft were specified by ASPO.

October 20: NASA accepted spacecraft 009 in ceremonies at NAA, first of the kind that would be used on lunar missions.

October 21: MSC announced that the bubble-type helmet designed by Crew Systems Division engineers had been adopted for use in the Apollo extravehicular mobility unit.

November 1: MSC established a Lunar Sample Receiving Laboratory Office pending development of a permanent organization to operate the facility.

November 5: NASA announced it would negotiate a contract with International Latex Corp. for fabrication of the Apollo space suit, and a contract with Hamilton Standard for continued development and manufacture of the portable life support system.

November 30: Apollo Mission Simulator No. 1 was shipped by Link Group, General Precision, to MSC.

December 4: *Gemini VII*, manned by astronauts Frank Borman and James A. Lovell, Jr., was launched from Cape Kennedy on a 14-day mission.

December 5: Hamilton Standard successfully tested a life support back pack designed to meet the requirements of the lunar surface suit.

December 6-17: The Block II CSM Critical Design Review was held at NAA.

December 15-16: *Gemini VI-A* was launched from Cape Kennedy with astronauts Walter M. Schirra, Jr., and Thomas P. Stafford aboard. The spacecraft rendezvoused with *Gemini VII* less than six hours after liftoff.

December 31: The SM reaction control system engine qualification was completed.

1966

January 3: OMSF listed operational constraints for Apollo experimenters in order to prevent experiment- generated operational problems.

January 7: MSC outlined the general purpose and plans for the Lunar Sample Receiving Laboratory.

January 8-11: The first fuel system test was successfully conducted at WSTF.

January 20: Apollo mission A-004 was successfully accomplished at WSMR. It was the final suborbital test in the Apollo program.

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Preface

Project Apollo, America's premier space effort during the 1960's, had a twofold objective. The more immediate goal, as proclaimed by President John F. Kennedy before Congress on May 25, 1961, was to land men on the moon and return them safely to Earth before the end of the decade. But a second and far broader objective was to make the United States preeminent in space, taking a leading role in space achievement and ensuring that this nation would be second to none in its ability to explore and use the vast new ocean.

Apollo therefore served as the spearhead for NASA's overall program during the sixties. Although the lunar landing generally overshadowed other important activities - critics of the agency often saw the near-term goal as an end in itself - the program stimulated phenomenal progress in aerospace technology. Building upon the pioneering achievements of Mercury and Gemini, Apollo produced dramatic advances in launch vehicles, spacecraft, and operational techniques. But the moon provided only the essential focus, the clearly identifiable and attainable target to channel this immensely diverse technological momentum.

As NASA spokesmen often pointed out, of all the hardware being developed for Apollo only the lunar module was narrowly conceived. The other components represented tangible advances in space flight technology essential to space preeminence, irrespective of the formal moon landing program per se.

In essence, that is the thrust of this third installment of *The Apollo Spacecraft: A Chronology*. Spanning October 1, 1964, through January 20, 1966, this volume traces the development of "Apollo's Chariots," the lunar spacecraft - along with the Saturn V a paramount ingredient in America's campaign to secure preeminence in space. That period encompassed the detailed engineering design and exhaustive testing to qualify both the command and service modules and the lunar module for manned flight. Although other significant events elsewhere in Apollo are not ignored, the detailed work on the spacecraft - which thus served directly to foster America's spacefaring capabilities - forms the chief focus of this book. By the end of this sixteen-month period, Apollo had clearly shifted to manufacturing and flight testing, steppingstones to manned operations.

Like the two previous volumes in this series (Volume I covers the origins of the program and conceptual development through the selection of Grumman in November 1962 to build the lunar module; and Volume II the period of fundamental configurational work on both vehicles, culminating in the mockup review of the Block II version of the command and service modules at North American on September 30, 1964), and like similar works on Mercury and Gemini, this volume is intended as a reference and a guide. In addition, the several volumes serve as the foundation for a narrative history of the Apollo spacecraft underway as part of the NASA Historical Series, providing tools for more in-depth interpretive and analytical study. Unlike the first two volumes, this volume is not divided into sections, since its content is similar and related throughout.

As far as possible primary sources were consulted, with chief reliance being placed on records held at the recently renamed (February 1973) Lyndon B. Johnson Space Center in Houston. These primary sources included congressional documents, official correspondence, government and contractor status and progress reports, memorandums, working papers, minutes of meetings, and in some cases interviews with participants. In addition, the authors also drew upon press releases, newspaper accounts, and magazine articles. Indeed, the staggering amount of documentation for Apollo is sufficient to give pause to even the most dedicated historical researcher. A principal methodological problem has therefore been to cover adequately relevant events throughout the program without departing from the tactical aim of the book. Inevitably, subjective evaluation became the ultimate criterion for inclusion or rejection of specific events.

The authors are indebted to many individuals, both within NASA and among many of its supporting contractors, who contributed additional materials and commented on draft portions of the manuscript. Historians, editors, and archivists of the NASA Historical Office in Washington gave valuable assistance: Eugene M. Emme, Frank W. Anderson, Jr., Thomas W. Ray, Lee D. Saegesser, and Carrie Karegeannes. Likewise, Loyd S. Swenson, Jr., of the University of Houston and James M. Grimwood and Sally D. Gates of the JSC Historical Office made useful suggestions. And in particular, Corinne L. Morris, now at the Smithsonian Institution, helped immeasurably in assembling scattered documentation, weeding out trivia and "engineeringese," and editing and typing comment drafts. To these and many other informants, readers, and critics, the authors wish to express sincere and appreciative thanks.

C.G.B.

I.D.E.

April 1974

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Advanced Design, Fabrication, and Testing

October 1964

1964

October 1

Ceremonies in Washington marked the sixth anniversary of the National Aeronautics and Space Administration (NASA). Administrator James E. Webb reminded those present of NASA's unique contribution to America's mission and destiny, then read a message from President Johnson: "We must be first in space and in aeronautics," the President said, "to maintain first place on earth. . . . Significant as our success has been, it is but indicative of the far greater advances that mankind can expect from our aeronautical and space efforts in the coming years. We have reached a new threshold . . . which opens to us the widest possibilities for the future." Two days later, in an address in White Sulphur Springs, W. Va., Webb observed that "as the national space program moves into its seventh year, the United States has reached the half-way point in the broad-based accelerated program for the present decade." America was halfway to the moon.

Astronautics and Aeronautics, 1964: Chronology on Science, Technology, and Policy (NASA SP-4005, 1965), pp. 335, 338.

October 1-2

Representatives from Grumman Aircraft Engineering Corporation, North American Aviation, Inc., and Massachusetts Institute of Technology's (MIT) Instrumentation Laboratory, three of the Manned Spacecraft Center's (MSC) principal contractors, met with radar and guidance and navigation experts from Houston and Cape Kennedy. They formulated a detailed plan for testing and checkout of the lunar excursion module (LEM) rendezvous and landing radar systems both at the factory and at the launch site.

MSC, "Minutes of Implementation Meeting #3, Apollo LEM G&D Systems, September 29, 1965";
MSC, "ASPO Weekly Management Report, October 1-8, 1964."

October 1-8

North American switched to a spring-activated pop-up antenna for the command module (CM) high-frequency recovery radio.

"ASPO Weekly Management Report," October 1-8, 1964.

October 1-8

On the basis of new abort criteria (failure of one fuel cell), extended operating periods, and additional data on fuel cell performance, Grumman recommended a 20.4 kg (45-lb), 1,800 watt-hour auxiliary battery for the LEM. MSC approved the recommendation and Grumman completed the redesign of the electrical power distribution system and resizing of the battery during late October and early November.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, September 20-October 17, 1964," p. 54; MSC, "ASPO Weekly Management Report, September 17-24, 1964"; "ASPO Weekly Management Report, September 24-October 1, 1964"; "ASPO Weekly Management Report, October 1-8, 1964"; "Monthly Progress Report No. 21," LPR-10-37, p. 26.

October 2

MSC submitted a Request for Proposals to General Electric Company (GE) for two additional spacecraft acceptance checkout ground stations. Eight million dollars was the estimated cost of the added equipment.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, September 20-October 17, 1964," p. 40.

October 2

MSC's Apollo Spacecraft Program Office (ASPO) approved a plan (put forward by the MSC Advanced Spacecraft Technology Division to verify the CM's radiation shielding. Checkout of the radiation instrumentation would be made during manned earth orbital flights. The spacecraft would then be subjected to a radiation environment during the first two unmanned Saturn V flights. These missions, 501 and 502, with apogees of about 18,520 km (10,000 nm), would verify the shielding. Gamma probe verification, using spacecraft 008, would be performed in Houston during 1966. Only Block I CM's would be used in these ground and flight tests. Radiation shielding would be unaffected by the change to Block II status.

Memorandum, Joseph F. Shea, MSC, to Assistant Chief for Space Environment, "Apollo Radiation Shielding Verification," October 5, 1964.

October 5-8

NASA conducted a formal review of the LEM mockup M-5 at the Grumman factory. This inspection was intended to affirm that the M-5 configuration reflected all design requirements and to definitize the

LEM configuration. Members of the Mockup Review Board were Chairman Owen E. Maynard, Chief, Systems Engineering Division, ASPO; R. W. Carbee, LEM Subsystem Project Engineer, Grumman; Maxime A. Faget, Assistant Director for Engineering and Development, MSC; Thomas J. Kelly, LEM Project Engineer, Grumman; Christopher C. Kraft, Jr. (represented by Sigurd A. Sjoberg), Assistant Director for Flight Operations, MSC; Owen G. Morris, Chief, Reliability and Quality Assurance Division, ASPO; William F. Rector III, LEM Project Officer, ASPO; and Donald K. Slayton, Assistant Director for Flight Crew Operations, MSC.

The astronauts' review was held on October 5 and 6. It included demonstrations of entering and getting out of the LEM, techniques for climbing and descending the ladder, and crew mobility inside the spacecraft. The general inspection was held on the 7th and the Review Board met on the 8th. Those attending the review used request for change (RFC) forms to propose spacecraft design alterations. Before submission to the Board, these requests were discussed by contractor personnel and NASA coordinators to assess their effect upon system design, interfaces, weight, and reliability.

The inspection categories were crew provisions; controls, displays, and lighting; the stabilization and control system and the guidance and navigation radar; electrical power; propulsion (ascent, descent, reaction control system, and pyrotechnics ; power generation cryogenic storage and fuel cell assemblies ; environmental control; communications and instrumentation; structures and landing gear; scientific equipment; and reliability and quality' control. A total of 148 RFCs were submitted. Most were aimed at enhancing the spacecraft's operational capability; considerable attention also was given to quality and reliability and to ground checkout of various systems. No major redesigns of the configuration were suggested.

As a result of this review, the Board recommended that Grumman take immediate action on those RFC's which it had approved. Further, the LEM contractor and MSC should promptly investigate those items which the Board had assigned for further study. On the basis of the revised M-5 configuration, Grumman could proceed with LEM development and qualification. This updated mockup would be the basis for tooling and fabrication of the initial hardware as well.

MSC, "Lunar Excursion Module, Project Apollo, Board Report for NASA Inspection and Review of M-5 Mockup Lunar Excursion Module, October 5-8, 1964," pp. 1-7, 10-27.

October 8

Radio Corporation of America's (RCA) Aerospace Systems Division received a 9 million contract from Grumman for the LEM attitude translation control assembly (ATCA). The ATCA, a device to maintain the spacecraft's attitude, would fire the reaction control system motors in response to signals from the primary guidance system.

Space Business Daily, October 9, 1964, p. 210.

October 8-15

On the basis of reentry simulations, North American recommended several CM instrument changes. An additional reaction control system display was needed, the company reported. Further, the flight attitude and the stabilization and control system indicators must be modified to warn of a system failure before it became catastrophic. The entry monitor system for Block I spacecraft would have to be replaced and the sample g-meter was not wholly satisfactory.

MSC, "ASPO Weekly Management Report, October 8-15, 1964."

October 8-15

Analysis by MSC of the performance of the environmental control system radiators for Block I CM's placed their heat rejection capability at 4,000 Btus per hr, far below the anticipated mission load of 7,220. Water boiled at the rate of 1.46 kg (3.22 lbs) per hr would be needed to supplement the radiators. This, in turn, would limit the mission to 45 hours duration, at which time all of the spacecraft's water supplies (both that in the water tanks at launch and that collected as a byproduct from the fuel cells) would be exhausted.

As MSC saw it, potential solutions were to redesign the radiators themselves, to increase the size of the tanks to hold another 194 kg (428 lbs) of water, or to reduce the operating power level.

Memorandum, Owen E. Maynard, MSC, to Chief, Operations Planning Division, "Limited mission duration capability for Block I Command and Service Modules," October 21, 1964.

October 8-15

MSC established the configuration of the reaction control system engines for both the service module (SM) and the LEM, and informed North American and Grumman accordingly. The Center also directed North American to propose a design for an electric heater that would provide thermal control in lunar orbit and during contingency operations. The design would be evaluated for use in Block I spacecraft as well.

MSC, "Minutes, Apollo/E and D Technical Management Meeting No. 8, 10/5 and 10/12, 1964," pp. 4-5; letters, W. F. Rector III, MSC to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Temperature control for the RCS engines in the Service Module and LEM," October 19, 1964.

October 8-15

RCA reduced the weight of the LEM rendezvous radar from 39.9 to 31.98 kg (88 to 70.5 lbs).

Memorandum, Robert C. Duncan and Ralph S. Sawyer, MSC, to Manager, ASPO, "Apollo Radar

Systems Design Review," September 16, 1964, with enclosure: "Apollo Radar Design Review," undated.

October 8-15

North American representatives visited the Grumman plant to discuss design features and to inspect the electroluminescent lighting on the LEM. North American intended to adopt this same feature on Block II CMs.

"ASPO Weekly Management Report, October 8-15, 1964."

October 9

NASA and Grumman representatives discussed a weight reduction program for the LEM. Changes approved at the M-5 mockup review portended an increase in LEM separation weight of from 68 to 453 kg (150 to 1,000 lbs). Both parties agreed to evaluate the alternatives of either resizing the spacecraft or finding ways to lighten it about nine percent, thus keeping the improved LEM within the present control weight.

GAEC, "Monthly Progress Report No. 21," LPR-10-37, November 10, 1964, p. 6.

October 9

NASA approved Grumman's selection of Airite to supply the LEM helium tanks, and the two firms started negotiations.

Ibid., pp. 7, 16.

October 11-November 10

Grumman completed contract negotiations with Arma Division, American Bosch Arma Corporation, for the LEM caution and warning electronics assembly.

Ibid., p. 22.

October 11-November 10

Grumman lighting experts evaluated self-luminous materials produced by the Minnesota Mining and Manufacturing Company and found them feasible for use in docking lighting.

Ibid., p. 4.

October 12

The U.S.S.R. launched the world's first multi-manned spacecraft, *Voskhod I*, the first to carry a scientist and a physician into space. The crew were Col. Vladimir Komarov, pilot; Konstantin Feoktistov, scientist; and Boris Yegorov, physician. According to Tass, orbital parameters of the spacecraft were 409 by 177 km (254 by 110 mi) with a 90.1 minute period and a 65 degree plane. Purposes of this flight, according to the Russian source, were to prove the operational compatibility of the spacecraft and crew and to conduct scientific and medical investigations during actual space flight. The mission featured television pictures of the crew from space. The trio landed after 16 orbits of the earth, 24 hours and 17 min after they had left it. The flight had a significant worldwide impact. In the United States, the "space race" was again running under the green flag. NASA Administrator James E. Webb, commenting on the spectacular, called it a "significant space accomplishment." It was, he said, "a clear indication that the Russians are continuing a large space program for the achievement of national power and prestige."

Astronautics and Aeronautics, 1964, pp. 348, 350.

October 12

At a North American-Grumman interface meeting on September 23-24, two possible relative role alignments for CSM-active docking were agreed upon. The major item blocking final selection was the effect of the SM's reaction control system engines upon the LEM antennas. ASPO requested Grumman to investigate the problem, to analyze the design penalties of the two-attitude docking mode, and to report any other factors that would influence the final attitude selection.

TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, October 12, 1964.

October 12

MSC notified Grumman of several additional LEM guidance and navigation ground rules that were applicable to the coasting phase of the mission. During this portion of the flight, the LEM abort guidance system must be capable of giving attitude information and of measuring velocity changes. Navigational data required to take the LEM out of the coasting phase and to put it on an intercept course with the CSM would be provided by the CSM's rendezvous radar and its guidance and navigation system, and through the Manned Space Flight Network back on earth.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Additional Ground Rules for LEM Guidance anti Navigation Operation and Monitoring," October 12, 1964.

October 13

North American and MIT Instrumentation Laboratory representatives met in Houston to discuss electrical power requirements for the guidance and control systems in Block II CMs. They had

determined the additional electrical power needed for the guidance and control system 24 volts was available,

Jerold P. Gilmore, MIT/IL, "MIT GN&C-Saturn Interfaces," prepared for Implementation Meeting #8, "Apollo CSM Block II Guidance & Control Systems," October 13, 1964.

October 14

Eagle-Picher Company completed qualification testing on the 25-ampere-hour reentry batteries for the CM. Shortly thereafter, Eagle-Picher received authorization from North American to proceed with design and development of the larger 40-ampere-hour batteries needed for the later Block I and all Block II spacecraft.

MSC, "ASPO Weekly Management Report, October 15-22, 1964"; North American Aviation, Inc. [hereafter cited as NAA], "Apollo Monthly Progress Report," SID-62-300-31, December 1, 1964, pp. 15-16; MSC, "Project Apollo Quarterly Status Report No. 10 for Period Ending December 31, 1964," p. 12.

October 14

In a letter to Apollo Program Director General Samuel C. Phillips, ASPO Manager Joseph F. Shea pointed out that Bellcomm, under contract to NASA, had a subcontract with Space Technology Laboratories (STL) and that MSC had a contract with STL covering the same basic areas as the Bellcomm-STL subcontract. Shea told Phillips that STL was not allowed to use the information on the MSC contract which had been obtained on the Bellcomm contract, and requested that STL be permitted to use the information on the MSC contract.

Letter, from Manager, ASPO, to NASA Headquarters, Attn: General Phillips, "Space Technology Laboratories Contract with Bellcomm Corporation," October 14, 1964.

October 14

In a letter to NASA Administrator James E. Webb, AC Spark Plug reported that the first Apollo guidance system completed acceptance testing and was shipped at 11:30 p.m. and arrived at Downey, California, early the following day. AC reported that in more than 2,000 hours of operation they had found the system to be "remarkably reliable, accurate and simple to operate."

Letter, to NASA Administrator Webb, from B. P. Blasingame, Manager, Milwaukee Operations, October 19, 1964.

October 15

A number of outstanding points were resolved at a joint MSC-Grumman meeting on LEM

communications. Most significant, the VHF key mode was deleted, and it was decided that, during rendezvous, voice links must have priority over all other VHF transmissions. Further, the echo feature of the current configuration (i.e., voice sent to the LEM by the ground operational support system, then relayed back via the S-band link) was undesirable.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Minutes of Lunar Excursion Module Communications Subsystem Review October 15 and 16, 1964," October 29, 1964, with enclosure: subject minutes, pp. 2-3.

October 15

MSC's Systems Engineering Division reported on the consequences of eliminating the command and service module (CSM) rendezvous radar:

Coasting period:

During this phase of the mission, the rendezvous radar on the CSM would be used to track the LEM and the rendezvous radar on the LEM would be used to track the CSM. With the use of Mission Control through the Manned Space Flight Network (MSFN), three sources of information could be used as a vote for guidance system monitoring. Without the CSM rendezvous radar, the monitoring task would become more difficult; however, this was not to imply that it was impossible. The conclusion was that CSM rendezvous radar was highly desirable, but not absolutely necessary.

Lunar descent and ascent:

During powered flight, the CSM would be tracking the LEM. This was desirable because if the LEM guidance computer (LGC) failed, it was very doubtful that the astronauts could manually acquire radar lock-on with the CSM. Also, if the LEM rendezvous radar failed, CSM lock-on would be highly desirable. There were several alternative solutions to this problem. First of all, Mission Control through the MSFN could relieve the problem. If this did not satisfy all requirements, it was possible for the LEM rendezvous radar to track the CSM during powered descent and ascent. If the LGC then failed, the tracking acquisition would no longer be a problem. In summary, there did appear to be other ways of fulfilling the functions of the CSM rendezvous radar during the powered phases.

Lunar surface:

While the LEM was on the lunar surface, it would be tracked with the CSM rendezvous radar in order to update launch conditions. This could be accomplished by the LEM tracking the CSM and the MSFN.

Rendezvous:

This was the most critical phase for the use of the rendezvous radar on the CSM. If the LEM primary guidance system should fail (i.e., the LGC, inertial measurement unit [IMU], and LEM rendezvous radar), navigation information for long-range midcourse corrections would be provided by the rendezvous radar on the CSM. The MSFN, however, could supply this information. The terminal rendezvous maneuver would become a problem if the LEM

rendezvous radar failed and there was not a rendezvous radar on the CSM. It had not been established that the MSFN could supply the required terminal rendezvous information. If MSFN could, a restricted mission profile would have to be employed. There were other methods of supplying terminal rendezvous information such as optical tracking. The scanning telescope or sextant on the CSM could be used with the IMU and Apollo guidance computer on the CSM to derive navigation information, meaning that the LEM would require flashing lights. There was a delta-V penalty associated with using angle-only information in place of range range rate and angle information, its importance depending on the accuracy of the angle data and the range/range rate data.

Memorandum, Aaron Cohen, MSC, to Chief, Operations Planning Div., "CSM Rendezvous Radar," October 15, 1964.

October 15

The Guidance and Control Implementation Sub-Panel of the MSC-MSFC Flight Mechanics Panel defined the guidance and control interfaces for Block I and II missions. In Block II missions the CSM's guidance system would guide the three stages of the Saturn V vehicle; it would control the S-IVB (third stage) and the CSM while in earth orbit; and it would perform the injection into a lunar trajectory. In all of this, the CSM guidance backed up the Saturn ST-124 platform. Actual sequencing was performed by the Saturn V computer.

Memorandum, Aaron Cohen, MSC, to Chief, Flight Technology Branch, "Flight Mechanics Panel's Activities," October 15, 1964.

October 15

Remote operation of the CSM's rendezvous radar transponder and its stabilization and control system (SCS) was not necessary, ASPO told North American. Should the CSM pilot be incapacitated, it was assumed that he could perform several tasks before becoming totally disabled, including turning on the transponder and the SCS. No maneuvers by the CSM would be required during this period. However, the vehicle would have to be stabilized during LEM ascent, rendezvous, and docking.

Letter, C. L. Taylor, MSC, to NAA, Attn: E. E. Sack, "Contract NAS 9-150, Operations Groundrule and Disabled CSM Astronaut," October 15, 1964.

October 15-22

The Air Force Eastern Test Command concurred in the elimination of propellant dispersal systems for the SM and the LEM. Costs, schedules, and spacecraft designs, NASA felt, would all benefit from this action. ASPO thus notified the appropriate module contractors.

MSC, "ASPO Weekly Management Report, October 15-22, 1964."

October 15-22

Because they were unable to find a satisfactory means of plating the magnesium castings for the CM data storage equipment (to fulfil the one percent salt spray requirement), Collins Radio Company and the Leach Corporation were forced to use aluminum as an alternative. This change would increase the weight of the structure by about 2.3 kg (5 lbs) and, perhaps even more significant, could produce flutter when the recorder was subjected to vibration tests. These potential problems would be pursued when a finished aluminum casting was available.

Ibid.

October 15-22

Grumman completed the fuel cell assembly thermal study and was preparing a specific directive to Pratt and Whitney Aircraft Company which would incorporate changes recommended by the study. These changes would include the cooling of electrical components with hydrogen and the shifting of other components (water shutoff valves, and oxygen purge valve) so that they would operate at their higher design temperatures.

Ibid.

October 15-22

Representatives from the MSC Astronaut Office, and ASPO's Systems Engineering, Crew Systems, and Mission Planning divisions made several significant decisions on crew transfer and space suit procedures:

- Crew transfer, both pressurized and unpressurized, would be accomplished using the environmental control system umbilicals. The CM and LEM umbilicals would be designed accordingly. Crew Systems would request the necessary engineering changes.
- The requirement for "quick-don" capability for the space suit would be reevaluated by Systems Engineering people. If the probability of a rapid decompression of the spacecraft during "noncritical" mission phases was negligible, "quick-don" capability might be eliminated. This would ease several design constraints on the suit.
- The question of a crossover valve in the CM, for ventilation during open-faceplate operation, was postponed pending the decompression study and ventilation tests at Hamilton Standard.

Ibid.

October 16

In a letter on August 25, 1964, the LEM Project Office had requested Grumman to define the means by which CSM stabilization and rendezvous radar transponder operation could be provided remotely in the event the CSM crewman was disabled.

In another letter on October 16, the Project Office notified Grumman that no requirement existed for remote operation of either the rendezvous radar transponder or the stabilization and control system. The letter added, however, that the possibility of an incapacitated CSM astronaut must be considered and that for design purposes Grumman should assume that the astronaut would perform certain functions prior to becoming completely disabled. These functions could include turning on the transponder and the SCS. No CSM maneuvers would be required during the period in which the CSM astronaut was disabled but the CSM must remain stabilized during LEM ascent coast and rendezvous and docking phases.

Letter, W. F. Rector III to GAEC, "Contract NAS 9-1100, Operations Groundrule for Disabled CSM Astronaut," October 16, 1964.

October 16-November 15

Three Pratt and Whitney fuel cells were operated in a simulated space vacuum at North American for 19, 20, and 21 hours. This was the first time three cells were operated as an electrical power generating subsystem.

"Apollo Monthly Progress Report," SID-62-300-31, p. 1.

October 16-November 15

North American and Honeywell reviewed the Block II CSM entry monitor subsystem's compatibility with the stabilization and control system. The proposed configuration, they found, combined maximum reliability with minimum size and weight and would provide adequate mission performance.

Ibid., p. 13.

October 17

MSC and International Business Machines Corporation (IBM) negotiated a \$1,500,000 fixed-price contract for the Apollo guidance and navigation system backup computer.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, October 18-November 30, 1964," p. 39; MSC, "ASPO Weekly Management Report, October 15-22, 1964."

October 19

MSC ordered Grumman to halt work on the LEM test article (LTA) 10. The LTA-10's descent stage would be replaced with one cannibalized from LEM test mockup 5.

"Monthly Progress Report No. 21," LPR-10-37, pp. 12, 18.

October 19

On October 19, a supplemental agreement in the amount of \$115,000,000 was issued to North American, bringing the total funded amount of the CSM contract to \$1,136,890,000.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, October 18-November 30, 1964," p. 39.

October 22

In response to inquiries from General Samuel C. Phillips, Apollo Program Deputy Director, ASPO Manager Joseph F. Shea declared that, for Apollo, no lunar mapping or survey capability was necessary. Shea reported that the Ranger, Surveyor, and Lunar Orbiter programs should give ample information about the moon's surface. For scientific purposes, he said, a simpler photographic system could be included without requiring any significant design changes in the spacecraft.

TWX, Shea, MSC, to NASA Headquarters, Attn: Phillips, October 22, 1964; letter, J. A. Hornbeck, Bellcomm, to S. C. Phillips, NASA, November 5, 1964.

October 22-29

Heavy black deposits were discovered on the environmental control system (ECS) cold plates when they were removed from boilerplate 14. Several pinholes were found in the cold plate surfaces, and the aluminum lines were severely pitted. This was, as ASPO admitted, a matter of "extreme concern" to the ECS design people at North American, because the equipment had been charged with coolant for only three weeks. This evidence of excessive corrosion reemphasized the drawbacks of using ethylene glycol as a coolant.

MSC, "ASPO Weekly Management Report, October 22-29, 1964."

October 2-29

ASPO notified Grumman and North American that it had canceled requirements for Apollo part task trainers.

Ibid.

October 22-29

MSC's Crew Systems Division investigated environmental control system (ECS) implications of using Gemini suits in Block I missions. The results indicated that the ECS was capable of maintaining nominal cabin temperature and carbon dioxide partial pressure levels; however, this mode of operation always had an adverse effect on cabin dewpoint temperature and water condensation rate.

Ibid.

October 23

ASPO deleted the requirement for LEM checkout during the translunar phase of the mission. Thus the length of time that the CM must be capable of maintaining pressure in the LEM (for normal leakage in the docked configuration) was reduced from 10 hours to three.

Ibid.

October 23

Jet Propulsion Laboratory proposed a meeting on October 29 between representatives of NASA Headquarters, Bellcomm, MSC, MIT, and JPL to present the requirements and status of projects underway as they related to the landing aid problem. The Surveyor Block II study effort was concentrating on determining needs of obtaining data on the lunar surface and environment for Apollo.

JPL proposed the following agenda items:

- LEM requirements and specifications on a Surveyor deployed transponder.
- MSC planned active and passive landing aids study program.
- Landing aids capabilities under consideration by the Surveyor study:
 1. Active RE device.
 2. Passive RF device - corner reflector or other.
 3. Visual markers - visible during terminal phase and landing only; visible during terminal phase and landing as well as from lunar orbit; or visible during terminal phase and landing from lunar orbit as well as photographically from the unmanned Lunar Orbiter.
- Landing aids lifetime and checkout problems.
- LEM-Surveyor mission interface problems.

MSC personnel would present a summary of results to date on the first two items and JPL personnel would present similar results on items three and four.

TWX from JPL to NASA Hq., MSC, Bellcomm, Inc., and MIT, "Surveyor Employed Landing Aids for Apollo," signed Lou Divone, October 23, 1964.

October 26

The trajectory summary of the Design Reference Mission (DRM) prepared by the Apollo Mission Planning Task Force was sent to Grumman by the LEM Project Office with a note that the operational sequence-of-events would be forwarded in November.

It was acknowledged that a single mission could not serve to "completely define all the spacecraft functional requirements" but "such a mission has considerable value as a standard for various purposes on the Apollo Program."

Specifically, the DRM would be used for weight reporting, electrical power reporting, reliability modeling, engineering simulation, crew task analyses, mission-related Interface Control Documents, and trade-off studies.

Letter, MSC, W. F. Rector III, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Transmittal of the Apollo Lunar Landing Design Reference Mission Trajectory," October 26, 1964.

October 27

ASPO requested Grumman to list all single-point failures that would cause loss of the crew during a lunar orbit rendezvous mission. Grumman was to consider only the equipment that it was responsible for.

TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, October 27, 1964.

October 27

NASA announced the appointment of Major General Samuel C. Phillips as Director of the Apollo Program. Phillips thus assumed part of the duties of George E. Mueller, Associate Administrator of Manned Space Flight, who had been serving as Apollo Director as well. Phillips had been Deputy Director since January 15.

NASA News Release 64-267, "General Phillips Appointed Director of Apollo Program," October 27, 1964.

October 27

MSC ordered North American to halt procurement of a CM simulator. Instead, the company was to begin a simulator program using the two existing evaluator-type CMs in conjunction with the digital-

analog computer facility. These evaluators would be used to verify the guidance and navigation and stabilization and control system software, and to analyze crew tasks and failure effects.

Letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. 263," October 27, 1964.

October 27

Because of the redesign of the portable life support system that would be required, MSC directed Grumman and North American to drop the "buddy system" concept for the spacecraft environmental control system (ECS) umbilicals. The two LEM crewmen would transfer from the CM while attached to that module's umbilicals. Hookup with the LEM umbilicals, and ventilation from the LEM ECS, would be achieved before disconnecting the first set of lifelines. MSC requested North American to cooperate with Grumman and Hamilton Standard on the design of the fetal end of the umbilicals. Also, the two spacecraft contractors were directed jointly to determine umbilical lengths and LEM ECS control locations required for such transfer.

TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, October 27, 1964; TWX, C. L. Taylor, MSC, to NAA, Attn: E. E. Sack, October 27, 1964; TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, October 29, 1964; MSC, "ASPO Weekly Management Report, October 29-November 5, 1964."

October 28

Testing of the first flight-weight 15-cell stack of the LEM fuel cell assembly began. Although the voltage was three percent below design, the unit had a 980-watt capability. Earlier, the unit completed 150 hours of operation, and single cell life had reached 662 hours.

MSC, "ASPO Weekly Management Report, October 29-November 5, 1964."

October 28

ASPO's Operations Planning Division defined the current Apollo mission programming as envisioned by MSC. The overall Apollo flight program was described in terms of its major phases: Little Joe II flights (unmanned Little Joe II development and launch escape vehicle development); Saturn IB flights (unmanned Saturn IB and Block I CSM development, Block I CSM earth orbital operations, unmanned LEM development, and manned Block II CSM/LEM earth orbital operations); and Saturn V flights (unmanned Saturn V and Block II CSM development, manned Block II CSM/LEM earth orbital operations, and manned lunar missions).

Memorandum, William A. Lee, MSC, to Distr., "Apollo Spacecraft Flight Development Mission Program," October 28, 1964.

October 28

At Langley Research Center, representatives from Langley, MSC, Ames Research Center, Avco Corporation, and North American met to discuss their independent conclusions of the data gathered from the Scout test of the Apollo heatshield material and to determine whether a second test was advisable. Langley's report revealed that: the heatshield materials performed as predicted within the flight condition appropriate to Apollo; the excessive recession rates occurred during flight conditions which were more severe than those considered for the design of the heatshield or expected during Apollo reentries.

Each group represented had a different interpretation of the reasons for the excessively high surface recession. The conclusion was that a second flight of the heatshield materials on the Scout would not particularly improve the understanding of the material's performance because of the limited variation in reentry trajectory and flight conditions obtainable with the Scout vehicle.

Memorandum, Owen E. Maynard, MSC, to Mgr., ASPO, "Significance of Langley Working Paper on Scout Test of Apollo Heat Shield Material," December 11, 1964.

October 29

North American conferred with representatives from Shell Chemical Company, Narmco, Epoxylite, and Ablestick on the problems of bonding the secondary structure to the CM. They agreed on improved methods of curing and clamping to strengthen the bond and prevent peeling.

MSC, "ASPO Weekly Management Report, October 29-November 5, 1964"; "ASPO Weekly Management Report, November 5-12, 1964."

October 29-November 5

North American conducted the first operational deployment of the launch escape system canards. No problems were encountered with the wiring or the mechanism. Two more operational tests remained to complete the minimum airworthiness test program, a constraint on boilerplate 23.

MSC, "ASPO Weekly Management Report, October 29-November 5, 1964."

October 29-November 5

After studying the merits of three flush-mounted versus two scimitar VHF antennas for the Block II CSM, the MSC Instrumentation and Electronics Systems Division recommended the flush-mounted type.

Ibid.

October 29-November 5

MSC directed North American to halt development of a portable light assembly for the CM. It was not required, the Center said, because the spaceship's primary lighting system included extendable floodlights. Small lights on the fingertips of the space suit and a flashlight in the survival kit were also available if needed.

Ibid.

October 29-November 5

The MSC Meteoroid Technology Branch inspected a hard shell meteoroid garment built by the Center's Crew Systems Division. It was only a crude prototype, yet it in no way hampered mobility of the pressurized suit. The Meteoroid Technology people were satisfied that, should a hard garment be necessary for protection of the Apollo extravehicular mobility unit, this concept was adequate. The garment might present stowage problems, however, and investigations were underway to determine the minimum area in the LEM that would be required.

Ibid.

October 29-November 5

An MSC Crew Systems Division (CSD) medical representative attended a meeting on U.S. Atomic Energy Commission (AEC) participation in those NASA Office of Manned Space Flight (OMSF) and MSC radiobiology programs aimed at delineating the effects of high doses of whole-body radiation on man. The meeting was attended by NASA's Dr. W. R. Lovelace, Director, Office of Space Medicine; Dr. Dunham, Medical Director of the AEC; Dr. Grahn, head of the Argonne National Laboratory, Biology Division; Dr. Gould Andrews, Chief, Oak Ridge Institute for Nuclear Studies, Medicine Division; and OMSF and NASA Office of Advanced Research and Technology. CSD requested that the AEC whole-body radiation analysis be extended to include all future cases throughout the country and that the low dose rates being planned for a number of clinical conditions particularly be included. The ultimate objective was a computer, for MSC use, which would accept sequential radiation flux and type information and predict the occurrence of subsequent acute or chronic radiation illness or death. The program was agreed by everyone to be highly desirable. Dr. Dunham said that the AEC would not undertake it unless he had reasonable assurance of long-term support from NASA. A letter giving such assurance was being prepared for Dr. George E. Mueller's signature.

Ibid.

October 29-November 5

MSC conducted a week-long salt spray test on the CM television camera's magnesium housing. This

was necessitated by similar tests on the Leach data storage structure, which had disclosed the inadequacy of that equipment's nickel plating. The television camera, with its protective coating (AMS 2478, Dow 17 treatment), withstood the ordeal quite well. MSC therefore decided that the magnesium housing was acceptable.

Ibid.; "ASPO Weekly Management Report, November 5-12, 1964."

October 29-November 5

Grumman reported to MSC the results of development tests on the welding of the LEM cabin's thin-gauge aluminum alloy. The stress and corrosion resistance of the metal, Grumman found, was not lessened by environments of pure oxygen, varying temperatures, and high humidity.

MSC, "ASPO Weekly Management Report, October 29-November 5, 1964."

October 30

North American conducted the first drop test of boilerplate 28 at Downey, Calif. The test simulated the worst conditions that were anticipated in a three-parachute descent and water landing. The second drop, it was expected, would likewise simulate a landing on two parachutes. In the week preceding the drop, the MSC Structures and Mechanics Division had sounded a note of caution. The aft heatshield, they said, "might not respond to the impact loading as static loading." In this event, they predicted, pressures imposed on the heatshield would "greatly exceed" design allowables.

The drop appeared normal, but the spacecraft sank less than four minutes after hitting the water. Inspection of the vehicle immediately afterward disclosed that the heatshield had broken open on impact and that the welds of the stainless-steel honeycomb core had failed. The cabin interior also sustained considerable damage, especially the aft bulkhead and the cabin floor, which were forced upward and struck the crew couch. Three instrumented manikins were seated in the crew positions. The two outboard "crewmen" sustained 25 g's each at impact. The dummy in the second couch, however, suffered stresses of 50 g's, a condition that might euphemistically be called "unacceptable." MSC and North American personnel were investigating further.

MSC, "ASPO Weekly Management Report, October 22-29, 1964"; "ASPO Weekly Management Report, October 29-November 5, 1964"; "ASPO Weekly Management Report, November 5-12, 1964"; "Apollo Monthly Progress Report," SID-62-300-31, pp. 3-4.

October 31

Astronaut Theodore C. Freeman died in an aircraft accident at Ellington Air Force Base, near Houston. Freeman, an Air Force captain and a member of NASA's third group of spacemen, was preparing to land his T-38 training jet when it struck a goose and lost power. He ejected from his aircraft, but did not have

sufficient altitude for his parachute to open. Freeman thus became the first American astronaut to lose his life in the quest for the moon.

Astronautics and Aeronautics, 1964, pp. 370, 388; *The Houston Chronicle*, November 1, 1964; *The Houston Post*, November 17, 1964.

During the Quarter

MSC spelled out additional details of the LEM environmental control system (ECS) umbilical arrangements. The hoses were to be permanently bonded to the ECS; a crossover valve, to permit flow reversal, was mandatory; and a bypass relief would be added, if necessary, to prevent fan surge. Grumman was to coordinate with North American to ensure that all umbilicals were long enough for crew transfer and to determine the optimum location for the spacecraft's ECS switches.

MSC, "ASPO Weekly Management Report, October 29-November 5, 1964"; memorandum, Robert E. Smylie, MSC, to Chief, Program Control Div., "Apollo Spacecraft Program Quarterly Status Report No. 10," January 19, 1965, with enclosures; memorandum, W. F. Rector III, MSC, to Contracting Officer, LEM, "Contract NAS 9-1100, LEM Environmental Control System (ECS), Suit Supply Connector and Flow Control," November 3, 1964.

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November 2

Bellcomm, Inc., presented its evaluation of the requirement for a q-ball in the emergency detection system. [The device, enclosed in the nose cone atop the launch escape tower, measured dynamic pressures and thus monitored the vehicle's angle of attack, and was designed to warn the crew of an impending breakup of the vehicle.] Bellcomm's findings confirmed that the q-ball was absolutely essential and that the device was ideally suited to its task.

Letter, P. R. Knaff, Bellcomm, to O. E. Maynard, MSC, November 6, 1964, with enclosure: Memorandum for File, "The Contribution of the Q-Ball to the Emergency Detection System," P. R. Knaff and M. M. Purdy, November 2, 1964.

November 3

International Telephone and Telegraph Corporation (ITT) Federal Laboratories' Astrionics Center received a \$125,000 contract from Collins Radio for the S-band acquisition receivers that position the ground-based dish antennas toward the spacecraft.

Space Business Daily, November 3, 1964, p. 11.

November 3

NASA announced the appointment of Brig. Gen. David M. Jones as Deputy Associate Administrator for Manned Space Flight (effective December 15). Most recently, Jones had been Deputy Chief of Staff, Systems, in the Air Force Systems Command. He would be "primarily concerned with major development problems in the Gemini and Apollo Programs, the planning for Advanced Missions and all Mission Operations." Further, Jones would "work with other NASA program offices to insure optimum use of other elements of NASA to accomplish program objectives."

NASA News Release 64-277, "NASA Names Gen. Jones Deputy Associate Administrator for Manned Space Flight," November 3, 1964.

November 5

MSC authorized Grumman to proceed with procurement of a battery charger for the LEM, to replenish the portable life support system's power source. On the following day, Houston informed North American such a device was no longer needed in the CSM.

TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, November 5, 1964; letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract Change Authorization No. 269," November 6, 1964.

November 5

The Apollo Space Suit Assembly received a new designation, the Apollo Extravehicular Mobility Unit. The purpose of the change was to make it more descriptive of its function in the Apollo mission.

Memorandum, Maxime A. Faget, MSC, to Distr., "Change in Designation of the Apollo Space Suit Assembly (SSA)," November 5, 1964.

November 5-12

Engineers from Grumman and the MSC Instrumentation and Electronics Systems Division (IESD) reviewed the coverage requirements for the LEM's S-band radio and the incompatibility of those requirements with the present location of the steerable antenna. Most observers felt that a deployable boom was the only feasible solution. The two groups therefore recommended that IESD verify with ASPO the S-band coverage requirements and that Grumman analyze the design effects of such a boom. In the meantime, Dalmo-Victor, the antenna vendor, should continue its design effort on the basis of the current location.

MSC, "ASPO Weekly Management Report, November 5-12, 1964."

November 5-12

During a mechanical loading test (simulating a 20-g reentry) the CM aft heatshield failed at 120 percent of maximum load. Structures and Mechanics Division engineers inspected the structure. They found that the inner skin had buckled, the damage extending three quarters of the way around the bolt circle that secured the heatshield to the spacecraft's inner structure. Their findings would be used along with data from the recent drop of boilerplate 28 to determine what redesign was necessary.

Ibid.

November 5-12

MSC informed North American that a flashing light on the CSM, as an aid for visual rendezvous, was not required. [A request for some such device had been generated at the Block II mockup review.] Houston's

position was based on the current CSM/LEM configuration, which called for rendezvous radar on both spacecraft and the ability of both vehicles to effect the rendezvous using either its own radar or that in the target vehicle.

Ibid.

November 5-12

Engineers from the MSC Crew Systems Division and from North American discussed testing of the breadboard environmental control system. During all flights - both manned and unmanned - North American must monitor the cabin atmosphere by gas chromatography and mass spectrography. The company should also compare the materials for the breadboard with those for Mercury, Gemini, and other applicable space chambers.

Ibid.; memorandum, Frank H. Samonski, Jr., MSC, to R. C. Stults, "Transmission and coordination of Request for Engineering Change Proposal (RECP) to add a gas chromatograph in the North American Aviation environmental control system (ECS) breadboard test facility," November 18, 1964.

November 5-12

ASPO officials completed a preliminary evaluation of the design and weight implications of an all-battery electrical power system (EPS) for the LEM. Investigators reviewed those factors that resulted in the decision (in March 1963) to employ fuel cells; also, they surveyed recent technological improvements in silver-zinc batteries.

At about the same time, Grumman was analyzing the auxiliary battery requirements of the spacecraft. The contractor found that, under the worst possible conditions (i.e., lunar abort), the LEM would need about 1,700 watt-hours of auxiliary power. Accordingly, Grumman recommended one 1,700 watt-hour or two 850 watt-hour batteries (23 and 29.5 kg [50 and 65 lbs], respectively) in the spacecraft's ascent stage.

MSC would use both Grumman's and ASPO's findings in determining the final design of the LEM's EPS. MSC, "ASPO Weekly Management Report, Nov. 5-12, 1964."

November 6

By this date, all major LEM subcontracts had been let.

"NASA Administrator's Apollo Program Review, LEM Program," November 6, 1964, item A-10.

November 6

NASA anticipated five significant milestones for the LEM during the forthcoming year:

1. A major review of the entire LEM program (with especial emphasis upon the fiscal picture for 1965 and 1966)
2. Start of production on LEM-1 (the first LEM flight article)
3. Delivery of LEM Test Article (LTA)-2 (a dynamic test article) to Huntsville
4. Start of vibration and static testing on the complete LEM structure
5. Sea level and altitude qualification testing in the continuing development of the LEM's propulsion systems.

Ibid., item C.

November 9

NASA and AC Spark Plug amended the company's contract for guidance and navigation equipment. The change embodied an incentive clause, based on a cost-schedule-performance scheme, and placed the estimated cost of the contract at \$235,000,000.

MSC, "Consolidated Activity Report for the Office of the Associate Administrator, Manned Space Flight, October 18-November 30, 1964," p. 39.

November 10

MSC's Structures and Mechanics Division and ASPO reviewed the LTA-10 test program to resolve the stop-work imposed upon Grumman. The review resulted in an agreement to have LTA-10 remain in the program with a modified configuration. LTA-10 would be used by North American at Tulsa, Oklahoma, for adapter/LEM modal and separation testing and would consist only of descent stage structure. Subsystems for LTA-10 which were eliminated were the ascent stage, landing gear, ascent propulsion and descent propulsion.

Memorandum, W. F. Rector III, MSC, to LEM Contracting Officer, "Contract NAS 9-1100, Deletion of Stop Work Order on LTA-10," November 10, 1964.

November 10

Joseph G. Thibodaux, Jr., MSC Propulsion and Power Division, reported at an Apollo Engineering and Development technical management meeting that the first J-2 firing of the service propulsion system engine was conducted at White Sands Missile Range (WSMR). Two fuel cell endurance tests of greater than 400 hours were completed at Pratt and Whitney. MSC would receive a single cell for testing during the month.

MSC, "Minutes, Apollo E and D Technical Management Meeting No. 9, November 10, 1964."

November 12-19

There appeared to be some confusion and/or disagreement concerning whether one or two successful Saturn V reentry tests were required to qualify the CM heatshield. A number of documents relating to

instrumentation planning for the 501 and 502 flight indicated that two successful reentries would be required. The preliminary mission requirements document indicated that only a single successful reentry trajectory would be necessary. The decision would influence the measurement range capability of some heatshield transducers and the mission planning activity being conducted by the Apollo Trajectory Support Office. The Structures and Mechanics Division had been requested to provide Systems Engineering with its recommendation.

MSC, "ASPO Weekly Activity Report, November 12-19, 1964."

November 12-19

More careful examination of the boilerplate 28 aft heatshield indicated that the shear failures were in the face sheet splices which were not in the same locations as the core splices.

Ibid.

November 12-19

In its search for some method of reducing water impact pressures, North American was considering adding a 15- to 30.5-cm (6- to 12-in) "lump" to the CM's blunt face. The spacecraft manufacturer was also investigating such consequent factors as additional wind tunnel testing, the effect on heatshield design, and impact upon the overall Apollo program.

Ibid.

November 12-19

MSC reviewed a number of alternatives to the current design of the space suit helmet. Engineers selected a modified concept, one with the smallest feasible dimensions and began fabricating a thin fiber glass shell. The product would serve as the test article in a series of tests of an immobile, bubble-type helmet. The whole of this effort would support MSC's in-house program to find the best possible helmet design.

Ibid.

November 12-19

MSC analyzed Grumman's report on their program to resize the LEM. On the basis of this information, ASPO recommended that the propellant tanks be resized for separation and lunar liftoff weights of 14,742 and 4,908 kg (32,500 and 10,820 lbs), respectively. Studies should investigate the feasibility of an optical rendezvous device and the substitution of batteries for fuel cells. And finally, engineering managers from both Grumman and MSC should examine a selected list of weight reduction changes to determine whether they could immediately be implemented.

Ibid.; letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, LEM Weights Meeting," November 19, 1964; Bob Button, MSC, "Apollo Status," November 20, 1964.

November 12-19

Shorting had become a significant problem in the LEM fuel cells, and exemplified the continuing difficulties that plagued the system's development. MSC, "ASPO Weekly Activity Report, November 5-12, 1964."

November 13

Robert E. Smylie, of the MSC Crew Systems Division, cited Hamilton Standard's reliability figures for the Apollo space suit assembly, including the suit per se and the portable life support system (PLSS):

Item	Mission Success	Crew Safety
Space suit	0.9995	0.99991
PLSS (Liquid cooled)	0.9995	0.99999
Complete assembly	0.999	0.9999

Memorandum, Robert E. Smylie, MSC, to Crew Integration Branch, Attn: C. Haines, "Space Suit Assembly Reliability Apportionment," November 13, 1964.

November 13

MSC defined the requirements for visual docking aids on both of the Apollo spacecraft:

- At a range of 305 m (1,000 ft), the astronaut must be able to see the passive spacecraft and determine its gross attitude.
- From 61 m (200 ft) away, he must be able to judge the target's relative attitude and the alignment of his own vehicle.
- And from this latter distance - and still solely through visual means the pilot must be able to calculate the distance between the two spacecraft and the closing rate.

TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, November 13, 1964; MSC, "ASPO Weekly Activity Report, November 12-19, 1964."

November 16

NASA test pilot Joseph A. Walker flew the LLRV for the second time. The first attempted liftoff, into a 9.26-km (5-nm) breeze, was stopped because of excessive drift to the rear. The vehicle was then turned to head downwind and liftoff was accomplished. While airborne the LLRV drifted with the wind and descent to touchdown was accomplished. Touchdown and resulting rollout (at that time the vehicle was on casters)

took the LLRV over an iron-door-covered pit. One door blew off but did not strike the vehicle.

Pilot Report, Joseph A. Walker, November 16, 1964.

November 16

Crew Systems Division (CSD) was proceeding with procurement of an inflight metabolic simulator in response to a request by Systems Engineering Division. The simulator would be used to support the LEM mission for SA-206 and would be compatible for use in the CM. Responsibility for the project had been assigned to the Manager of the LEM Environmental Control System Office. It was projected that the Statement of Work would be completed by January 15, 1965; the proposals evaluated by April 1; the contract awarded by June 1, 1965; the prototype delivered by April 1, 1966, with two qualified simulator deliveries by July 1, 1966.

Letter, Richard S. Johnston, MSC, to Chief, Engineering Systems Division, "Inflight metabolic simulator," November 16, 1964.

November 16-December 15

After investigating the maximum radiation levels that were anticipated during Apollo earth orbit missions, North American confirmed the need for some type of nuclear particle detection system (NPDS). Except for periods of extremely high flux rates, the current design of the NPDS was considered adequate. During the same reporting period, North American awarded a contract to Philco to build the system.

NAA, "Apollo Monthly Progress Report," SID-62-300-32, January 1, 1965, p. 18.

November 17-18

The Emergency Detection System (EDS) Design Sub-Panel of the Apollo-Saturn Electrical Systems Integration Panel held its first meeting at North American's Systems and Information Division facility at Downey, Calif. A. Dennett of MSC and W. G. Shields of MSFC co-chaired the meeting.

Personnel from MSC, MSFC, KSC, OMSF, and North American attended the meeting. Included in the discussions were a review of the EDS design for both the launch vehicle and spacecraft along with related ground support equipment; a review of the differences of design and checkout concepts; and a review of EDS status lights in the spacecraft.

Proceedings, Emergency Detection System Design Sub-Panel of the Apollo-Saturn Electrical Systems Integration Panel, sgd. A. Dennett and W. G. Shields, December 2, 1964.

November 17-18

The Apollo Mission Planning Task Force met in Bethpage, New York, to define prelaunch handling

procedures at the launch complex during lunar missions. At the meeting were representatives of those groups most intimately concerned with pad operations ASPO and the MSC Flight Operations Directorate, Grumman, North American, GE, and the Kennedy launch center. The task force agreed on several fundamental items:

- The mobile arming tower (MAT) would be installed just once, and would be moved back only for the final launch preparations (at T minus seven hours).
- All operations that had to be performed with the MAT removed should be accomplished before that structure was mated to the launch umbilical tower.
- Checkout equipment would be removed for simulated flights and would be reconnected only after data from the simulation had been evaluated.
- Total pad time was set at 12 days.

MSC, "ASPO Weekly Management Report, November 26-December 3, 1964."

November 18

Ling-Temco-Vought received a contract from MSC, valued at \$365,000, for unmanned testing of Gemini and Apollo space suits in the firm's space environment simulator.

Space Business Daily, November 18, 1964, p. 84.

November 19

MSC's Assistant Director for Flight Crew Operations, Donald K. Slayton, told the Apollo Program Manager that the current display and keyboard (DSKY) for the Block II CSM and for the LEM were not compatible with existing display panel design of both vehicles from the standpoint of lighting, nomenclature presentation, and caution warning philosophy. In his memorandum, Slayton pointed out mandatory operational requirements of the DSKY to ensure compatibility and consistency with the existing spacecraft display panel design.

With reference to lighting, he said all numerics should be green, nomenclature and status lights white, and caution lights should be aviation yellow. All panel lighting should be dimmable throughout the entire range of brightness, including off.

In regard to nomenclature, Slayton pointed out that abbreviations on the DSKY should conform to the North American Interface Control Document (ICD). The referenced ICD was being reviewed by Grumman and North American and was scheduled to be signed December 1, 1964.

Referring to the caution and warning system, he pointed out that all caution lights on the DSKY should be gated into the primary navigation and guidance system (PNGS) caution light on the main instrument panel of both vehicles and into the PNGS caution light on the lower equipment bay panel of the CM.

Slayton requested that preliminary designs of the DSKY panel be submitted to the Subsystem Managers for Controls and Displays for review and approval.

Memorandum, Donald K. Slayton, MSC, to Apollo Program Manager, "Incompatibility of DSKY with LEM and CM Controls and Displays," November 19, 1964.

November 19

MSC was giving serious thought to using radioisotope generators to power the Apollo lunar surface experiments packages. If some method could be found to control waste heat, such a device would be the lightest source of power available. Accordingly, the Center asked Grumman to study the feasibility of incorporating it into the LEM's scientific payload. The company should analyze thermal and radiological problems, as well as methods of stowage, together with the possibility of using the generator for power and heat during the flight. To minimize the problem of integration, Grumman was allowed much flexibility in designing the unit. Basically, however, it would measure about 0.07 cu m (2.5 cu ft) and would weigh between 13 and 18 kg (30 and 40 lbs). Its energy source (plutonium 238) would produce about 50 watts of electricity (29 volts, direct current).

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Radioisotope power supply for lunar scientific experiments," November 19, 1964; MSC, "ASPO Weekly Management Report, November 19-26, 1964."

November 19-26

The MSC-Marshall Space Flight Center (MSFC) Guidance and Control Implementation Sub-Panel set forth several procedural rules for translunar injection (TLI):

- Once the S-IVB ignition sequence was started, the spacecraft would not be able to halt the maneuver. (This would occur about 427 sec before the stage's J-2 engine achieved 90 percent of its thrust capability.)
- Because the spacecraft would receive no signal from the instrument unit (IU), the exact time of sequence initiation must be relayed from the ground.
- The vehicle's roll attitude would be reset prior to injection.
- And when the spacecraft had control of the vehicle, the IU would not initiate the ignition sequence.

Memorandum, Secretaries, Guidance and Control Implementation Sub-Panel, MSFC and MSC, to Distr., "Action Items and Agreements from the Guidance and Control Implementation Sub-Panel Meeting" (November 17, 1964), November 19, 1964; with enclosures; MSC, "ASPO Weekly Management Report, November 19-26, 1964."

November 19-26

To solve the persisting problem of the integrity of the CM's aft heatshield during water impacts, MSC

engineers were investigating several approaches: increasing the thickness of the face sheet (but with no change to the core itself); and replacing the stainless-steel honeycomb with a type of gridwork shell. Technicians felt that, of these two possibilities, the first seemed more efficient structurally.

MSC, "ASPO Weekly Management Report, November 19-26, 1964."

November 19-26

North American and Grumman agreed on the alignment of the two spacecraft during docking maneuvers: the LEM's overhead window would be aligned with right-hand docking window of the CM.

Ibid.

November 19-26

MSC determined that the lights on the fingertips of the space suits were adequate to supplement the CM's interior lighting. Thus North American's efforts to develop a portable light in the spacecraft were canceled. The exact requirements for those fingertip lights now had to be defined. The astronauts preferred red bulbs, which would necessitate a redesign of the existing Gemini system. [See October 29-November 5.]

Ibid.; letter, C. L. Taylor, MSC, to NAA, Attn: J. C. Cozad, "Contract NAS 9-150, Crewman portable light," November 4, 1964.

November 19-26

The MSC Crew Systems Division reviewed the extravehicular mobility unit micrometeoroid protection garment. It was estimated a total weight of 13 to 18 kg (30 to 40 lbs) would be required for the two micrometeoroid protection garments which had a crew safety reliability goal of 0.9999 for the meteoroid hazard. Ground rules for their design were being defined.

MSC, "ASPO Weekly Management Report, November 19-26, 1964"; memorandum, Robert E. Smylie, MSC, to Paige B. Burbank, "Investigation of meteoroid protection for Apollo space suit," December 9, 1964.

November 19-26

MSC conducted studies to determine problems in donning and doffing the Apollo external thermal garment (ETG) and portable life support system (PLSS) by a subject in a full-pressure suit. The subject donned and doffed the ETG and PLSS unassisted with the suit in a vented condition and with assistance while the suit was pressurized to 25.5 kilonewtons per sq m (3.7 psig). Tests showed the necessity of redesigning the ETG in the neck and chest area to prevent a gathering of excess material which restricted downward visibility.

MSC, "ASPO Weekly Management Report, November 19-26, 1964"; memorandum, Francis J. Devos,

MSC, to Chief, Crew Systems Div., "Trip Report - Contract NAS 9-2820," November 19, 1964.

November 19-26

Officials from North American and MSC Crew Systems Division defined the container design and stowage of survival kits in the Block II CM. The equipment would be packed in fabric rucksacks and would be installed in the spacecraft's stowage compartment. [This method eliminated a removable hard container used in the Block I vehicle and would save weight.]

MSC, "ASPO Weekly Management Report, November 19-26, 1964"; letter, C. L. Taylor, MSC, to NAA, Attn: J. C. Cozad, "Contract NAS 9-150, Block II mockup - request for change disposition," December 1, 1964.

November 19-26

To ensure that the redesigned landing gear on the resized LEM would be consistent with earlier criteria, MSC sent to Grumman revisions to those design criteria:

- Maximum rate of descent - 3.05 m (10 ft) per sec
- Maximum horizontal velocity - 1.22 m (4 ft) per sec
- Maximum attitude rates (any axis) - 3 degrees per sec

MSC, "ASPO Weekly Management Report, November 19-26, 1964."

November 19-26

In flights that simulated the moon's gravity, MSC technicians evaluated the astronaut's ability to remove scientific packages from the descent stage of the LEM. They affirmed the relative ease with which large containers (about 0.226 cu m [8 cu ft] and weighing 81.65 kg [180 lbs]) could be extracted and carried about.

Ibid.

November 19-26

The current thrust buildup time for the LEM ascent engine was 0.3 second. To avoid redesigning the engine valve-which was already the pacing item in the ascent engine's development - MSC directed Grumman simply to change the specification value from 0.2 to 0.3 second.

At the same time, engineers at the Center began studying ways to increase the engine's thrust. Because of the LEM's weight gains, the engine must either be uprated or it would have to burn longer. Preliminary studies showed that, by using a phase "B" chamber (designed for a chamber pressure of 689.5 kilonewtons per sq m (100 psia)), thus producing chamber pressure of about 792.9 kilonewtons (115 psia), the thrust

could be increased from 1,587 to 1,814 kg (3,500 to 4,000 lbs). Moreover, this could be accomplished with the present pressurization and propellant feed systems.

Ibid.; TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, November 27, 1964.

November 19-26

MSC and Grumman representatives reviewed individual subsystem test logics for the LEM and agreed on test logic and associated hardware requirements for the entire subsystem development. Agreement was also reached on the vehicle ground test program which Grumman proposed to implement with their respective subcontractors during December. Cost and effort associated with the revised program would be jointly reviewed by MSC and Grumman during January and February 1965.

Memorandum, W. F. Rector III, MSC, to LEM Subsystem Managers, "Subsystem Test Logic and Hardware Review at GAEC," November 18, 1964; MSC, "ASPO Weekly Management Report, November 19-26, 1964"; memorandum, W. F. Rector III, MSC, to Chief, Program Control Div., "Staff Meeting Actions," November 20, 1964, with enclosures.

November 19-26

MSC asked Grumman to design and fabricate a prototype for a lunar sample return container. This effort would explore handling procedures and compatibility with both spacecraft. Concurrently, the Center's Advanced Spacecraft Technology Division was studying structural and packaging requirements for such a container.

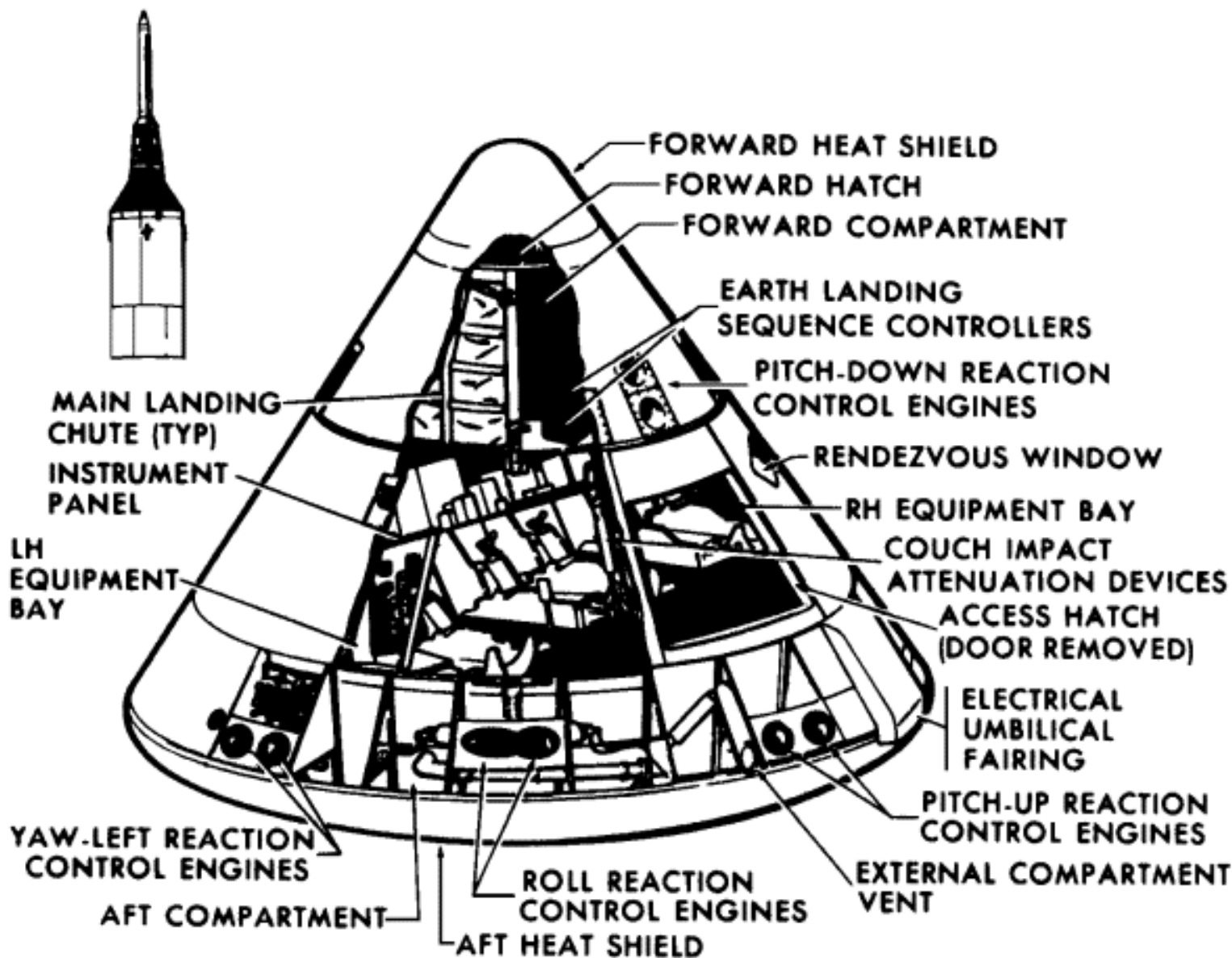
MSC, "ASPO Weekly Management Report, November 19-26, 1964."

November 23

NASA concluded contract negotiations with AC Spark Plug for Apollo guidance and navigation equipment.

Ibid.

November 23



Apollo Command Module, Block II.

North American received NASA's formal go-ahead on manufacture of the Block II spacecraft.

Ibid.

November 23

The CSM Configuration Control Panel, at its first meeting, approved several engineering changes. Perhaps the most significant was the substitution of an elapsed time display for the clock on the main display console.

Ibid.

November 23

A "pre-FRR" laid some preliminaries for the formal Flight Readiness Review (ERR) of boilerplate 23 (held at WSMR on December 4, 1964). Because the boost protective cover had not been designed to sustain the dynamic pressures that would follow deployment of the canards and vehicle "turn-around," North American was asked to analyze the possibility of its failing.

Several other problems were aired - fluttering of the canards and the likelihood of damage to the parachute compartment during jettisoning of the launch escape tower and the boost cover. Joseph N. Kotanchik, chief of the Structures and Mechanics Division, confidently reported to ASPO that "these items will also be resolved prior to the ERR."

MSC, "Minutes, Mission A-002 (BP 23/LJ II 12-51-1), Preliminary Flight Readiness Review, November 23, 1964"; MSC, "ASPO Weekly Management Report, November 26-December 3, 1964."

November 23

Grumman and MSC representatives met at Bethpage, New York, to establish requirements for a new hardware delivery schedule for the LEM ground development test program. This program would involve changes in the workload at the subcontractors, WSMR, AEDC, and Grumman. New delivery schedules for flight engines were also finalized at the meeting.

MSC, "ASPO Weekly Management Report, November 26-December 3, 1964."

November 23-25

MSC and Grumman reviewed the ground test program for the LEM guidance and navigation subsystem (including radar). All major milestones for hardware qualification would be met by the revised test logic, and both LEM and CSM radar were expected to be delivered on time. The major problem area was permissible deviations from fully qualified parts for pre-production equipment. Since this was apparently true for all LEM electronics equipment, it was recommended that an overall plan be approved by ASPO.

Ibid.

November 25

ASPO Manager Joseph F. Shea informed Apollo Program Director Samuel C. Phillips that it was his desire to review the progress of the two subcontractors (Space Technology Laboratory and Rocketdyne) prior to the final evaluation and selection of a subcontractor for the LEM descent engine.

Shea had asked MSC's Maxime A. Faget to be chairman of a committee to accomplish the review, and would also ask the following individuals to serve: C. H. Lambert, W. F. Rector III, and J. G. Thibodaux, all

of MSC; L. F. Belew, MSFC; M. Dandridge and J. A. Gavin, Grumman; I. A. Johnsen, Lewis Research Center; C. H. King, OMSF; Maj. W. R. Moe, Edwards Rocket Research Laboratory; and A. O. Tischler, NASA Office of Advanced Research and Technology.

The Committee should

1. establish review criteria during a planning meeting at MSC during the week of November 30, 1964;
2. visit the two subcontractors' facilities during the week of December 7, 1964, for review of technical status, manufacturing resources, and test facilities; and
3. prepare a written report and brief appropriate NASA personnel on their findings by December 18, 1964.

"Both GAEC and NASA will be parties to the final selection and it is not my intent to usurp GAEC's responsibility in this matter; but I do feel we should have the intelligence at our disposal to appreciate all ramifications of GAEC's final selection," Shea said.

Letter, Joseph F. Shea, MSC, to Maj. Gen. Samuel C. Phillips, November 25, 1964.

November 26-December 3

The Configuration Control Panel approved a deployment angle of 45 degrees for the adapter panels on Block I flights. North American anticipated no schedule impact. MSC and North American were jointly evaluating the acceptability of this angle for Block II missions as well. A most important consideration was the necessity to communicate via the CM's high-gain antenna during the transposition and docking phase of the flight.

MSC, "ASPO Weekly Management Report, November 26-December 3, 1964."

November 26-December 3

MSC's Flight Operations Directorate accepted KSC's proposal for emergency nitrogen deluge into the SM and spacecraft LEM adapter (SLA) in case of a hydrogen leak on the pad. The proposal was based upon no changes to the spacecraft and insertion to the SM SLA area in about three minutes. However, errors in volume estimation and inlet conditions in the spacecraft required reevaluation of the proposal to assure that insertion could be accomplished in a reasonable length of time without changes in the spacecraft.

Ibid.

November 26-December 3

Because of heat from the service propulsion engine (especially during insertion into lunar orbit), a serious thermal problem existed for equipment in the rear of the SM. Reviewing the rendezvous radar's installation, the Guidance and Control Division felt that a heatshield might be needed to protect the equipment. Similar

problems might also be encountered with the steerable antenna.

Ibid.

November 26-December 3

MSC informed North American that the Center would furnish a VHF transmitter to serve as a telemetry dump for all manned Block I flights. This would permit wide flexibility in testing the CSM S-band's compatibility with the Manned Space Flight Network prior to Block II missions.

Ibid.

November 26-December 3

Crew Systems Division (CSD) engineers evaluated the radiator for the environmental control system in Block I CSM's. The division was certain that, because of that item's inadequacy, Block I missions would have to be shortened.

During the same period, however, the Systems Engineering Division (SED) reported "progress" in solving the radiator problem. SED stated that some "disagreement" existed on the radiator's capability. North American predicted a five-day capability; CSD placed the mission's limit at about two days. SED ordered further testing on the equipment to reconcile this difference.

Ibid.

November 26-December 3

Crew Systems Division gave space suit manufacturers the responsibility of providing personal communications equipment in their products.

Ibid.

November 26-December 3

Bell Aerosystems Company tested a high-performance injector for the LEM ascent engine. The new design was similar to the current one, except that the mixture ratio of the barrier flow along the chamber wall had been changed from 0.85 to 1.05. Bell reported a performance increase of 0.8 percent (about 2.5 sec of specific impulse). Subsequent testing, however, produced excessive erosion in the ablative wall of the thrust chamber caused by the higher temperature. The MSC Propulsion and Power Division (PPD) felt this method of increasing the ascent engine's performance might not be practicable.

At the same time, PPD reported that Bell had canceled its effort to find a lighter ablative material (part of the weight reduction program). A number of tests had been conducted on such materials; none was

successful.

Ibid.; "ASPO Weekly Management Report" [December 10, 1964-January 7, 1965]; TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, November 27, 1964.

November 26-December 3

Grumman selected the Leach Corporation to supply data storage electronics assemblies for the LEM. Conclusion of contract negotiations was anticipated about February 1, 1965. The resident Apollo office at Grumman gave its approval to the selection, with only two conditions:

1. because of its toxic characteristics, beryllium must not be used in the assemblies; and
2. Leach should demonstrate the feasibility of the proposed time-voice multiplexing scheme.

MSC, "ASPO Weekly Management Report, November 26-December 3, 1964."

November 27

General Precision's Link Group received a \$7 million contract from NASA, through a subcontract with Grumman, for two LEM simulators, one at Houston and the other at Cape Kennedy. Along with comparable equipment for the CSM (also being developed by Link), the machines would serve as trainers for Apollo astronauts. The devices would duplicate the interior of the spacecraft; and visual displays would realistically simulate every phase of the mission.

Space Business Daily, November 27, 1964, p. 124.

November 30

North American tested the canard thrusters for the launch escape system, using both single and dual cartridges. These tests were to determine whether the pressure of residual gases was sufficient to maintain the canards in a fully deployed position. Investigators found that residual pressures remained fairly constant; further, the firing of a single cartridge produced ample pressure to keep the canards deployed. "Apollo Monthly Progress Report," SID-64-300-32, pp. 1,3, 31; "ASPO Weekly Management Report, November 26-December 3, 1964."

November 30

Acceptance testing was completed at Downey, California, on three principal systems trainers for the CSM (the environmental control, stabilization and control, and electrical power systems). The trainers were then shipped to Houston and installed at the site, arriving there December 8. They were constructed under the basic Apollo Spacecraft contract at a cost of \$953,024.

"Apollo Monthly Progress Report," SID-62-300-31, p. 24; "ASPO Weekly Management Report, December

3-10, 1964"; MSC News Release 64-191, December 8, 1964.

During the Month

Six flights of the Lunar Landing Research Vehicle (LLRV) were made during the month, bringing the total number to seven. The project pilot, Joseph Walker, made all flights and demonstrated a rapid increase in the ease and skill with which he handled the craft as the flights progressed.

Altitudes to between 18 and 21 m (60 and 70 ft) and flight duration up to three minutes were attained. With the jet engine remaining vertical, attitude angles in excess of 20 degrees were demonstrated in both pitch and roll. Lift rockets were used on the last four flights. Six knots (6 n mi per hr) had been tentatively set as the maximum permissible wind velocity for flying.

Letter, Office of Director, Flight Research Center, to NASA Headquarters, "Lunar Landing Research Vehicle progress report No. 17 for period ending November 30, 1964," sgd. De E. Beeler for Paul F. Bikle, December 8, 1964.

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Advanced Design, Fabrication, and Testing

December 1964

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December 3-10

After studying increased thrust versus increased burn time, Grumman ordered Bell Aerosystems Company to redesign the LEM's ascent engine for a longer firing duration.

GAEC, "Monthly Progress Report No. 23," LPR-10-39, January 10, 1965, p. 12; MSC, "ASPO Weekly Management Report, December 3-10, 1964."

December 3-10

MSC approved plans put forth by North American for mockups of the Block II CSM. For the crew compartment mockup, the company proposed using the metal shell that had originally been planned as a simulator. Except for the transfer tunnel and lighting, it would be complete, including mockups of all crew equipment. Mockup 12, the Block I lighting tool, would be modified to conform to the interior of Block II spacecraft.

Systems Engineering Division reported the latest review schedule for the Block II mockups:

- March 15, 1965 - crew compartment
- April 30, 1965 - interior lighting
- July 15, 1965 - Design Engineering Inspection (DEI)
- August 6, 1965 - lighting DEI

"ASPO Weekly Management Report, December 3-10, 1964"; letter, C. L. Taylor, MSC, to NAA, Attn: J. C. Cozad, "Contract NAS 9-150, Delivery of Government furnished crew equipment for Block II mockup," December 22, 1964.

December 3-10

MSC froze the design of the drogue mortar for the launch escape system. Laboratory qualification was scheduled to begin about the middle of the month. Qualification of the mortars for the pilot parachute

would then follow.

"ASPO Weekly Management Report, December 3-10, 1964."

December 3-10

Engineering and medical experts of the Crew Systems Division reviewed dumping helium from the CM's gas chromatograph into the cabin during reentry or in a pad abort. Reviewers decided that the resultant atmosphere (9.995 kilonewtons [1.45 psi] helium and 31.349 kilonewtons [4.55 psia] oxygen) posed no hazard for the crew. Systems Engineering Division recommended, however, that dump time be reduced from 15 minutes to three, which could readily be done.

MSC, "Consolidated Activity Report for Office of the Associate Administrator, Manned Space Flight, December 1964,"p. 46.

December 4

At its Sacramento test site, Douglas Aircraft Company static-fired a "battleship" S-IVB second stage of the Saturn IB vehicle, for 10 sec. (A battleship rocket stage was roughly the vehicle's equivalent to a boilerplate spacecraft.) On January 4, 1965, after further testing of the stage's J-2 engine, the stage underwent its first full-duration firing, 480 sec.

Space Business Daily, December 4, 1964, p. 159.

December 7

Douglas Aircraft Company delivered the first S-IVB stage to Marshall Space Flight Center for extensive vibration, bending, and torsional testing. The stage was not an actual flight stage and contained mockups of the engine and other components, but it duplicated the flight article in weight, mass, center of gravity, and stiffness.

Ibid., December 7, 1964, p. 167.

December 7

MSC ordered North American to fix the rotation angle of the adapter panels at 45 degrees. (This angle should give ample clearance during an SM abort.) Also, so that each panel would have two attenuators, North American should include such a device at each thruster location. (See June 16, 1965.)

On the same day, the Center directed North American to put a standard mechanical clock (displaying Greenwich Mean Time) in the lower equipment bay of the CM. [The spacecraft also had an elapsed time

device on the main display console.]

Letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Division, "Contract Change Authorization No. 275," December 7, 1964; letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Division, "Contract Change Authorization No. 277," December 7, 1964.

December 7

MSC advised Grumman that, normally, the LEM would be the active vehicle during lunar rendezvous. This would conserve reaction control system propellants aboard the CSM.

TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, December 7, 1964.

December 8

Boilerplate 23, Mission A-002, was successfully launched from WSMR by a Little Joe II launch vehicle. The test was to demonstrate satisfactory launch escape vehicle performance utilizing the canard subsystem and boost protective cover, and to verify the abort capability in the maximum dynamic pressure region with conditions approximating emergency detection subsystem limits. (See objectives in Appendix 5.)

"Apollo Monthly Progress Report," SID 62-300-32, p. 31; *Astronautics and Aeronautics*, 1964, p. 410.

December 8

A single main parachute was drop-tested at El Centro, Calif., to verify the ultimate strength. The parachute was designed for a disreef load of 11,703 kg (25,800 lbs) and a 1.35 safety factor. The test conditions were to achieve a disreef load of 15,876 kg (35,000 lbs). Preliminary information indicated the parachute deployed normally to the reefed shape (78,017 kg [17,200 lbs] force), disreefed after the programmed three seconds, and achieved an inflated load of 16,193 kg (35,700 lbs), after which the canopy failed. North American representatives would visit MSC during the week of December 14 to discuss this and other recent tests.

NAA, "Apollo Monthly Progress Report," SID 62-300-33, February 1, 1965, pp. 3-4; "ASPO Weekly Management Report, December 3-10, 1964."

December 8

Representatives of MSC's Information and Electronic Systems Division, Flight Operations Division, Flight Crew Operations Division, Guidance and Control Division, Astronaut Office, and ASPO, Goddard Space Flight Center, and Bellcomm, Inc., met to discuss communications during LEM and CSM rendezvous.

Capability of the Manned Space Flight Network (MSFN) to provide data for rendezvous was studied. Aaron Cohen of ASPO stated sufficient data could be collected, processed, and transmitted via MSFN to the LEM to achieve rendezvous. Dr. F. O. Vonbun of Goddard showed that MSFN data did little to improve data already available in the LEM before launch. Although five tracking stations would communicate with the LEM during ascent and the first 10 minutes of orbit, there would be only a slight improvement in spacecraft position and motion data over the data already contained in the LEM computer. No decision was made concerning the MSFN's capability.

Alternate rendezvous methods were discussed.

Memorandum, Donald G, Wiseman, MSC, to Chief, Instrumentation and Electronic Systems Division, "Meeting on LEM CSM rendezvous," December 9, 1964.

December 8

The Space Science Board of the National Academy of Sciences was asked to give NASA an independent evaluation of the need for a lunar sampling handling facility at Houston. NASA asked that the following questions be answered:

- What types of lunar sample analyses need to be done immediately upon return of the samples from the moon?
- What types of research can better be postponed until analyses can be handled at the best available research facility?
- What types of scientific research and handling facilities do you anticipate will be needed for such analyses?
- What do you anticipate in terms of manpower requirements for MSC to handle scientific activities in such a facility?

Letter, Homer E. Newell, NASA Associate Administrator for Space Science and Applications, to Dr. Harry H. Hess, Chairman, Space Science Board, December 8, 1964.

December 9

Grumman received from Houston criteria for firing times of the SM reaction control system (RCS). These served as a basis for the design of the LEM's steerable antenna. The thermal design proposed by Dalmo-Victor, the vendor, appeared feasible to watchdogs in MSC's Instrumentation and Electronic Systems Division. On the other hand, the unbalanced wind torque produced by the RCS engines was still a problem. RCA and Dalmo-Victor's estimates of the amount of torque varied considerably, and Grumman consequently undertook a study of this problem.

MSC, "ASPO Weekly Management Report, November 26-December 3, 1964"; TWX, W. F. Rector III,

MSC, to GAEC, Attn: R. S. Mullaney, November 19, 1964; TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, December 9, 1964.

December 9

MSC revised the weight allocation for the LEM's R&D instrumentation to bring it in line with current mission planning. Limitations established were 295 kg (650 lbs) for 206A and 181 kg (400 lbs) for all other missions.

Memorandum, W. F. Rector III, MSC, to Chief, Instrumentation and Electronic Systems Division, Attn: N. Farmer, "Lem I, 2, and 3 measurement requirements," December 9, 1964; letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, LEM 1, 2, and 3 Measurement Requirements," December 14, 1964.

December 9

MSC approved the use of one 23.68-kg (50-lb) auxiliary battery for the LEM, as recommended by Grumman, and preparations began for negotiations with Yardney Electric Corp.

TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, December 9, 1964; "Monthly Progress Report No. 23," LPR-10-39, p. 23.

December 9

Avco Corporation was under a 10-month contract amounting to \$124,578 to MSC to study the effects of solar radiation and ultra-high vacuum on the materials and components of space suits. Testing would be performed in the Avco space environment chamber.

Space Business Daily, December 9, 1964, p. 185.

December 9-10

Grumman and LEM Project Office representatives met to discuss the split bus distribution system. They decided there would be two circuit breaker panels similar to those of Mockup 5. All power distribution system controls would be located on the system engineer's center side console with remote controls and valves on the commander's center side console.

"Monthly Progress Report No. 23," LPR-10-39, p. 17.

December 10-January 7

Because of faults in both design and in testing procedures, the positive expulsion tanks for the CSM reaction control system failed their verification tests (begun during the preceding month).

"ASPO Weekly Management Report" (December 10, 1964-January 7, 1965).

December 10-January 7

Crew Systems Division received from North American a mockup of the proposed design of the food stowage compartment in the Block II CSM. This article would be used for packaging studies in preparation for the lower equipment bay mockup review in February.

Ibid.

December 10-January 7

By improving filling and preparation procedures and by using nickel foil in the oxygen electrode, Pratt and Whitney eliminated both short- and long-term plugging in the LEM's fuel cell assembly. Since then, Pratt and Whitney had consistently operated single cells for over 400 hours and - as far as the company was concerned - felt this settled the matter.

Ibid.

December 10-January 7

The resident Apollo office at North American discussed the company's tooling concepts for the Block II spacecraft with the chief of Marshall's Planning and Tool Engineering Division and the local Marshall representative. These reviewers agreed on the suitability of North American's basic approach. Though they recognized that the initial tooling cost would be high, they nonetheless felt that the total costs of manufacturing would not be appreciably affected. The substitution of mechanical for optical checking devices, it was agreed, would eliminate much of the "judgment factor" from the inspection process; mechanical checking also would assure uniformity of major components or subsystems.

Ibid.; "Apollo Monthly Progress Report," SID 62-300-33, p. 27.

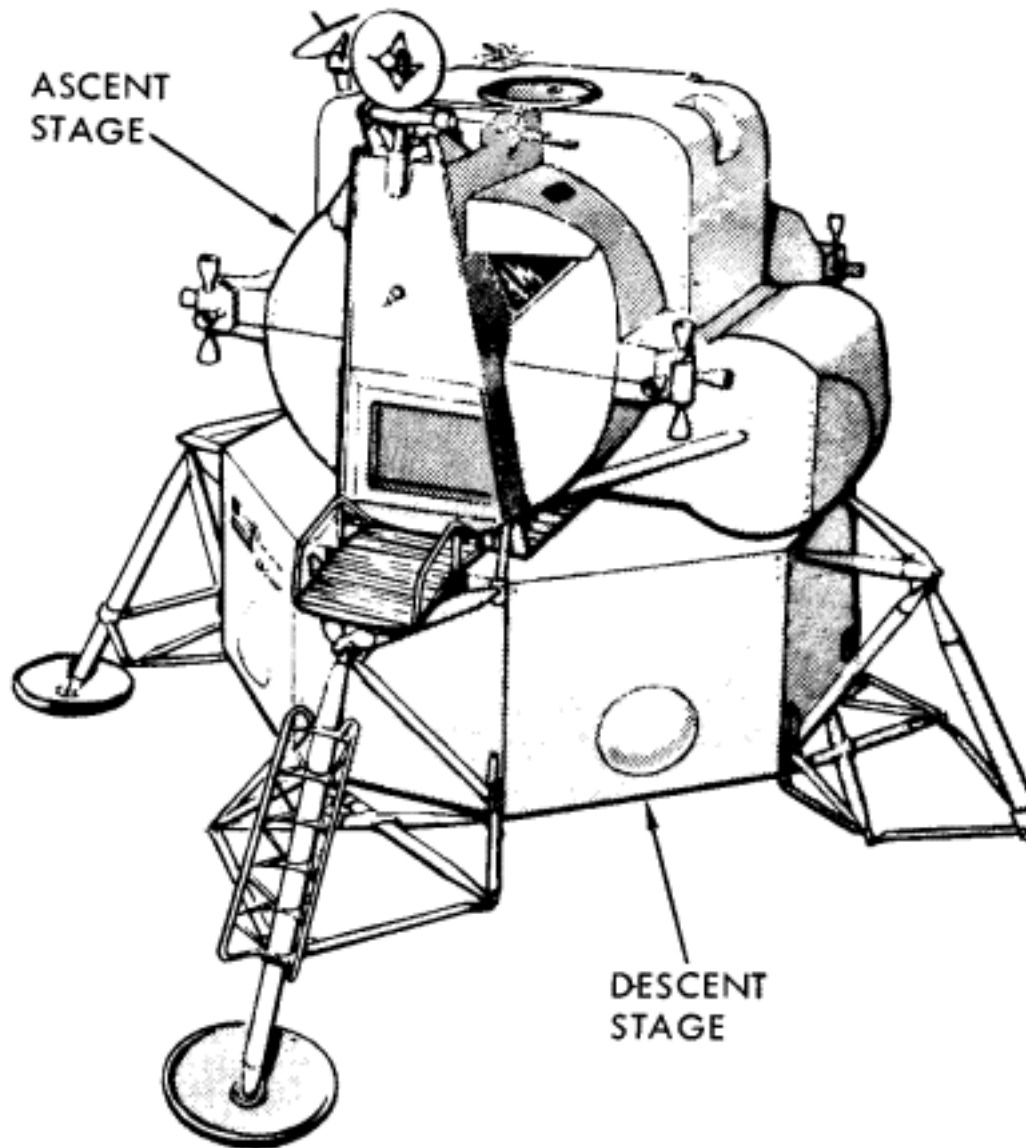
December 11

MSC directed Grumman to provide a LEM abort guidance section (AGS) having

- a computer memory of 4096 words
- the provision for in-flight null bias gyro drift compensation
- a general purpose input output device

- Bell 3B accelerometers
- input registers for rendezvous radar information such that a future interface could be mechanized if desired
- an interface between the primary navigation and guidance system (PNGS) and the AGS for position and velocity updating of the AGS from the PNGS.

Letter, Joseph F. Shea, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Abort Guidance Section Configuration," December 11, 1964.



The LEM.

December 11

From MSC, Grumman received updated criteria to be used in the design of the LEM's landing gear. The gear must be designed to absorb completely the landing impact; it must also provide adequate stability for the vehicle under varying surface conditions, which were spelled out in precise detail.) Maximum conditions that MSC anticipated at touchdown were:

vertical velocity - 3.05 m (10 ft) per sec

horizontal velocity - 1.22 m (4 ft) per sec

spacecraft attitude

pitch - 3 degrees

roll - 3 degrees

yaw - random

attitude rates - 3 degrees per sec

At touchdown, all engines (descent and reaction control would be off. "It must be recognized," MSC emphasized, "that the vertical and horizontal velocity values . . . are also constraints on the flight control system."

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Landing gear design criteria," December 11, 1964.

December 14

ASPO's Operations Planning Division directed Grumman to provide six recharges of the portable life support system (PLSS) and three PLSS batteries (rechargeable and replaceable).

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Resolution of M-5 mockup review chits 1-16 and 1-20," December 14, 1964.

December 15

Associate Administrator for Manned Space Flight George E. Mueller informed MSC Director Robert R. Gilruth that the Integrated Mission Control Center at MSC should be renamed Mission Control Center. He said, "By calling it the Mission Control Center, it has the advantage of retaining as much as possible of the original name which has become so well known to the press, the Congress and the public."

Letter, Mueller to Gilruth, December 15, 1964.

December 15-16

Dalmo-Victor studied thermal-demanded weight increases for the LEM's steerable antenna. Investigators reported to Grumman and RCA that, in the plume of the CSM's reaction control engines, 1.18 kg (2.5 lbs) was necessary merely for the survival of the antenna; another 1.18 kg would be required for tracking during this impingement.

"Monthly Progress Report No. 23," LPR-10-39, p. 5; "ASPO Weekly Management Report" (December 10, 1964-January 7, 1965).

December 16

Aboard a KC-135 from Wright-Patterson AFB, the fecal canister and urine relief tube were first tested under zero-g conditions. Similar manned tests of a complete unit were scheduled for February 1965.

"Apollo Monthly Progress Report," SID 62-300-33, pp. 4-6.

December 16

A mission planning presentation was given to ASPO Manager Joseph F. Shea, Assistant Director for Flight Operations Christopher C. Kraft, Jr., and Assistant Director for Flight Crew Operations Donald K. Slayton covering missions AS-201, AS-202, and AS-203. Shea said he wanted either a natural decaying orbit of proper lifetime or reaction control system deorbit capability for the first manned missions. It was decided not to put a C-band beacon on the SM for the post CM/SM separation tracking. This decision came back to haunt the program much later.

Memorandum, Carl R. Huss, MSC, to JSC Historical Office, "Comments on Volume III of *The Apollo Spacecraft: A Chronology*," June 6, 1973.

December 16-January 15

Phase II service propulsion system engine tests at Arnold Engineering Development Center were begun under simulated high altitude conditions with a successful first firing of 30 seconds. A total of nine firings were completed.

"Apollo Monthly Progress Report," SID 62-300-33, p. 13.

December 16-January 15

Ames researchers conducted 23 runs in the Center's wind tunnel to confirm the flight test instrumentation's compatibility with the aft heatshield of the CM. The instrumentation performed satisfactorily.

"Apollo Monthly Progress Report," SID 62-300-33, pp. 10-11.

December 17

NASA announced the selection of two firms to supply electronics equipment for the Manned Space Flight Network:

1. Dynatronics, Inc., to design and manufacture pulse code modulation (PCM) telemetry systems. (The main function of the PCM system would be to decode, or as the NASA news release put it, "decommutate," telemetry signals from the spacecraft). Dynatronics' contract would be worth an estimated 3.5 million.
2. Univac Division of Sperry Rand, to furnish data processors. (These machines, as their name indicates, would process those signals received by the PCM system. This information then would be transmitted to the Mission Control Center at Houston. The value of Univac's contract was placed at \$4.5 million.

NASA News Release 64-318, "NASA Selects Apollo Data Contractor," December 17, 1964.

December 18

Crew Systems Division (CSD) engineers, in their continuing effort to improve the design of the space suit, recommended a number of modifications to the thermal garment for example, a larger sleeve opening to facilitate inserting the second arm; and alterations to the neck and chest to increase the astronaut's downward view. By the middle of January, CSD's Robert E. Smylie could report several major design changes improved greatly the suit's don doff characteristics and made it less bulky. (See January 19, 1965.)

Memorandum, Francis J. DeVos, MSC, to Chief, Apollo Support Office, "Improved External Thermal Garment fit and donning, doffing studies," December 18, 1964.

December 18

NASA Administrator James E. Webb thanked Secretary of Defense Robert S. McNamara for providing aircraft support for the Apollo program. Webb informed McNamara that NASA had transferred \$600,000 to the Electronic Systems Division of the Air Force, and "this should provide us the ability to initiate the definition phase of the C-135 Apollo support aircraft program." The aircraft would be used to supplement telemetry and communications coverage of the pre-injection phase of the flights.

Webb added that the Bureau of the Budget had the question of identifying four additional C-135's well on its way toward resolution; and that NASA would continue planning on the basis of 12 C-135 aircraft for the Apollo program.

McNamara had written Webb on November 27, 1964, that "The Air Force has completed a study of a number of alternative combinations of aircraft to meet Apollo requirements. They conclude that the optimum solution is to equip twelve C-135's to support Apollo . . ." Total cost of instrumenting 12 C-135's was estimated to cost \$27.7 million, including the \$600,000 for the definition phase.

Letters, Webb to McNamara, December 18, 1964; McNamara to Webb, November 27, 1964.

December 18

North American delivered spacecraft 001's CM to White Sands. The SM was shipped several days later, and would be used for propulsion engine development. Aerojet-General shipped the service propulsion engine to the facility on January 6, 1965.

NAA, "Apollo Monthly Progress Report," SID 62-300-33, pp. 1, 12

December 21

The Structures and Mechanics Division (SMD) summarized the thermal status of antennas for the Apollo spacecraft (both CSM and LEM). Generally, most troubles stemmed from plume impingement by the reaction control or radiation from the service propulsion engines. These problems, SMD reported, were being solved by increasing the weight of an antenna either its structural weight or its insulation; by shielding it from the engines' exhaust; by isolating its more critical components; or by a combination of these methods.

Memorandum, R. G. Irvin, MSC, to J. W. Craig, MSC, "LEM thermal design mission," December 9, 1964; memorandum, Ralph S. Sawyer, MSC, to Chief, Propulsion and Power Division, "Reaction control system engine plume impingement on steerable high gain antenna earth tracker," December 21, 1964.

December 21-22

In response to MSC's new criteria for the landing gear of the LEM, Grumman representatives met with Center officials in Houston to revise the design. Grumman had formulated a concept for a 419-cm (165-in) radius, cantilever-type configuration. In analyzing its performance, Grumman and Structures and Mechanics Division (SMD) engineers, working separately, had reached the same conclusion: namely, that it did not provide sufficient stability nor did it absorb enough of the landing impact. Both parties to this meeting agreed that the gear's performance could be improved by redesigning the foot pads and beefing up the gear struts. Grumman was modifying other parts of the spacecraft's undercarriage

accordingly.

At the same time, Grumman advised MSC that it considered impractical a contrivance to simulate lunar gravity in the drop program for test Mockup 5. Grumman put forth another idea: use a full-sized LEM, the company said, but one weighing only one-sixth as much as a flight-ready vehicle. SMD officials were evaluating this latest idea, while they were reviewing the entire TM-5 program.

"Project Apollo, Abstract of Procedures, LEM Structures and Landing Gear Systems Meeting, December 21-22, 1964"; "Monthly Progress Report No. 23," LPR-10-39, p. 15; MSC, "ASPO Weekly Management Report" [January 7-14, 1965].

December 23

NASA Technical Services constructed the molds that would be used to make the one-piece bubble helmets for the Apollo space suits. These forms would be delivered to General Electric and to Texstar, the two firms that would actually fabricate the helmets, with the first shell expected about mid-January.

At the same time, Crew Systems Division completed drop tests on the new helmet concept. The division's engineers also began designing and fabrication of support items (neck rings, feed ports, and skull caps), as well as exploring methods of maintaining the helmet's hygiene and habitability.

Letter, Richard S. Johnston, MSC, to Curtis Jones, GE, December 23, 1964; "ASPO Weekly Management Report" [December 10, 1964-January 7, 1965].

December 24

To strengthen the Agency's managerial organization, NASA announced a realignment within the Office of Manned Space Flight:

- The post of Deputy Associate Administrator for Manned Space Flight Operations was eliminated. (It had, in fact, been vacant since April 24, 1964, when Walter C. Williams had resigned. In its stead, the position of Mission Operations Director was created and filled by E. E. Christensen.
- Two positions as mission directors were created under Christensen. Each director would have overall responsibility for a particular mission.
- A new organization to coordinate ground support efforts was created, the Operations Support Requirements Office, headed by B. Porter Brown.

Also included in this reorganization was a consolidation of activities at Cape Kennedy aimed at bringing assembly, checking, and launch responsibilities within the scope of a single organization. MSC's Florida Operations was absorbed; Kurt H. Debus assumed the title of Director of Launch Operations; and G. Merritt Preston, who had headed the local MSC group, became Debus' deputy.

NASA News Release 64-327, "NASA Realigns Manned Space Flight Unit in Gemini, Apollo Programs," December 24, 1964.

December 28

MSC directed North American to modify the CM so that the sight assembly could be used from either docking window.

Letter, James L. Neal, MSC, to NAA, Space and Information Systems Division, "Contract Change Authorization No. 283," December 28, 1964; "Apollo Monthly Progress Report," SID 62-300-32, p. 11.

December 29

The Lunar Sample Receiving Laboratory, currently being planned for construction at MSC, would support - in addition to its vital role as a quarantine area - two important activities:

1. Research on the samples to support succeeding Apollo flights.
2. Sorting and distribution of lunar samples to the scientific community.

Technical requirements for the facility were being defined by MSC's Space Environment Group, various Apollo science teams, and an ad hoc committee established by NASA Headquarters.

Memorandum, John M. Eggleston, MSC, to Distr., "MSC Requirements for Apollo Operational Lunar Sample Measurements," December 29, 1964.

December 31

After conferring with the Space Medicine Branch and with the Gemini and Apollo support offices, Crew Systems Division officials opted for identical bioinstrumentation in both blocks of Apollo spacecraft. Hamilton Standard would also try to use identical harnesses.

"ASPO Weekly Management Report" [December 10, 1964-January 7, 1965].

During the Month

Grumman ordered its major subcontractors supplying electronic equipment for the LEM to implement revised test programs and hardware schedules (in line with the new design approach). A similar directive went to RCA to modify the attitude and translation and the descent engine control assemblies as required for the new concept of an integrated assembly for guidance, navigation, and control of the spacecraft.

"Monthly Progress Report No. 23," LPR-10-39, p. 24.

During the Quarter

Crew Systems Division approved the use of modified Gemini space suits in Block I Apollo spacecraft. MSC and David Clark Company amended their Gemini suit contract to cover design and fabrication of a prototype Block I suit.

Memorandum, Robert E. Smylie, MSC, to Chief, Program Control Division, "Apollo Spacecraft Program Quarterly Status Report No. 10," January 19, 1965, and enclosures.

During the Quarter

Ling-Temco-Vought began large-scale developmental testing of the radiator for the Block II CSM environmental control system. One problem immediately apparent was the radiator's performance under extreme conditions.

Ibid.

During the Quarter

In September 1964, Hamilton Standard, manufacturer of the portable life support system (PLSS), had established a 108-watt-hour capacity for the system's batteries. And on the basis of that figure, Grumman had been authorized to proceed with the development of the LEM's battery charger (see November 5, 1964). (The size of the charger was determined by several factors, but primarily by the size of the battery and time limits for recharging.)

During November, however, Hamilton Standard and Crew Systems Division (CSD) engineers advised the Instrumentation and Electronic Systems Division (IESD) that the PLSS's power requirements had increased to about 200 watt-hours. (CSD had jurisdiction over the PLSS, including battery requirements; IESD was responsible for the charger.) Hamilton Standard placed most of the blame on the cooling pump motor, which proved far less efficient than anticipated, as well as on the addition of biosensor equipment. ASPO Manager Joseph F. Shea, reviewing the company's explanation, commented that "this says what happened . . . but is far from a justification - this is the type of thing we should understand well enough to anticipate." "How can this happen," he wondered, ". . . in an area which has been subjected to so much discussion and delay?"

Representatives from Grumman and Hamilton Standard, meeting at MSC on December 17, redefined PLSS battery and charging requirements, and Grumman was directed to proceed with the development of the battery charger. This episode was accompanied by some sense of urgency, since Grumman had to have firm requirements before the end of year to prevent a schedule slippage.

"ASPO Weekly Management Report" (December 10, 1964-January 7, 1965); TWX, W. F. Rector III,

MSC, to GAEC, Attn: R. S. Mullaney, December 31, 1964.

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January 5

MSC's Guidance and Control Division conducted a pilot simulation study to determine whether a pilot could take over manual control of the LEM between 4,572 and 3,048 m (15,000 and 10,000 ft) above the lunar surface and satisfactorily land the vehicle. The study also determined what flight information was required for pilot control.

The study investigated deceleration techniques, approach velocity, flare attitude, and the pilot information required for landings within a given footprint. If the site was deemed unsatisfactory for landing, after "eyeballing" it from 305 m (1,000 ft), the pilot would, under normal circumstances, place the coordinates of a new landing site in the computer; then take over manually and fly while making selection of the landing site.

MSC, "MSC Internal Note No. 65-EG-3, Project Apollo, Simulation Study of Pilot Controlled Lunar Landings from the Transition Altitude," Thomas E. Moore and Clarke T. Hackler, January 5, 1965.

January 5

At the fourth meeting of the Reference Trajectory Sub-Panel, MSC and MSFC members agreed on a trajectory with a launch azimuth of 108 degrees. Translunar injection would be performed over the Pacific Ocean during the first or second orbits. First-orbit injection would fix the minimum time required before the maneuver. Injection on the second pass would determine consequent penalties. The actions were initiated by Mission Planning and Analysis Division (MPAD) and were required to solidify and minimize analytical studies and operational planning.

Memorandum, Secretaries, Reference Trajectory Sub-Panel Meeting, to Distr., "Meetings of fourth Reference Trajectory Sub-Panel meeting held January 5, 1965," January 11, 1965; memorandum, Carl R. Huss, MSC, to JSC Historical Office, "Comments on Volume III of *The Apollo Spacecraft: A Chronology*," June 6, 1973.

January 5

North American and Lockheed summarized the qualification program for the launch escape and pitch control motors. While several performance deviations were reported, these were minor and, in general, the presentation was deemed satisfactory. North American followed up on the discrepancies and, on March 22, the motors were declared flight-qualified.

NAA, "Apollo Monthly Progress Report," SID 62-300-34, March 1, 1965, p. 17.

January 6

William A. Lee, chief of ASPO's Operations Planning Division, outlined the space suit design criteria for Apollo missions 204 and 205. Modified Gemini space suits were to be used.

Memorandum, William A. Lee, MSC, to Assistant Director for Flight Crew Operations, "Spacesuit Utilization on Block I CSM Earth Orbital Missions," January 6, 1965. [See memorandum, Donald K. Slayton, MSC, to Chief, Operations Planning Division, "Spacesuit Utilization on Block I CSM Earth Orbital Missions," January 26, 1965.]

January 6

ASPO Manager Joseph F. Shea informed Apollo Program Director Samuel C. Phillips that he planned to conduct a program review with MIT during January 1965, similar to the North American, AC Spark Plug, and Grumman program reviews, but with certain differences, since MIT was a non-profit organization and the scope of its work much narrower than the prime hardware contractors. Shea pointed out that 1965 would be the most critical year of the MIT effort; during that year all drawings for the Block I, Block II, and LEM guidance navigation and control programs should be released. Consequently, the program review at MIT would examine only that one year.

Shea said he would meet with C. Stark Draper on January 14 and discuss with him "where we stand with respect to the MIT work of the past and our concerns for the future." During the week of January 18, MSC would send 14 teams to MIT to meet with their counterparts, and the following week a review board, chaired by R. C. Duncan of MSC, would go over the work of the individual MIT-NASA teams in depth and agree upon the program for 1965. The 14 teams would be: Reliability and Quality Assurance, Field Operations, Documentation and Configuration Management, Systems Assembly and Test, Guidance and Mission Analysis, Simulation, Ground Support Equipment, Optics, Inertial Systems and Sensors, Computer, Radar, Training; Terms, Conditions, Rates and Factors; and Statement of Work Integration.

Shea felt that the review would give MIT a clearer understanding of their part in the guidance, navigation, and control system development. He recommended that Phillips discuss the general nature of the program review with George E. Mueller and Robert C. Seamans, Jr., so they would both understand ASPO's objectives.

Phillips forwarded the letter to Associate Administrator for Manned Space Flight George E. Mueller along with his comments on the proposal. He said, "I think it is a good plan and that the results will be beneficial to the program. I urge your support should it become necessary."

Letter, Shea to Phillips, January 6, 1965; memorandum, Phillips to Mueller, January 15, 1965.

January 6

ASPO's Systems Engineering Division (SED) investigated the possibility of partial donning of the space suit (sans helmet and gloves) and the consequent effects upon operation of the CM environmental control system (ECS). (Current ECS design called for shirtsleeve and full-suited operations.) The systems engineers found that, with vehicle reliability based upon shirtsleeve environments, wearing part of the suit contributed little toward protecting the astronaut against loss of cabin pressure.

Most pressure-seal failures in the spacecraft would still allow the astronaut time to don the complete suit. Catastrophic failures (i.e., loss of windows or hatches) were highly improbable, but if one of this type occurred, depressurization would be so rapid as to preclude the astronaut's donning even a part of the suit. Actually, overall mission reliability was greatest with the shirtsleeve environment; continuous suit wear degraded the garment's reliability for the lunar exploration phase of the flight. Moreover, a number of design changes in the spacecraft would be required by partial suit wear.

SED concluded that, to build confidence in the spacecraft's pressurization system, Block I CM's should be outfitted for partial suit wear. In Block II vehicles the suit should not be worn during translunar mission phases (again because of mission reliability). SED recommended to the ASPO Manager, therefore, that he direct North American to incorporate provisions for partial suit wear in Block I and to retain the shirtsleeve concept for the Block II spacecraft.

Memorandum, Owen E. Maynard, MSC, to Manager, Apollo Spacecraft Program Office, "Evaluation of space suit wear criteria," January 6, 1965.

January 6-8

The Preliminary Design Review of the Block II CM was held at North American's Downey, Calif., plant. Ten working groups evaluated the spacecraft design and resolved numerous minor details. They then reported to a review board of NASA and North American officials. This board met in Houston during the middle of the month, reviewed the findings of the working groups, and submitted recommendations to ASPO. Several significant problems required the attention of Apollo managers at Houston and at North American:

- The effect of heavyweight LEM (up 1,361 kg [3,000 lbs]) on the spacecraft lunar adapter and on the CM's docking system. North American was studying this problem already.
- Wearing cycles and requirements for donning and stowage of the space suits must be resolved

and incorporated into the CSM specifications. North American's interpretation of those specifications conflicted with the MSC Crew System Division's current plan that, during the first several missions, all three crewmen should be able to wear their suits without the helmets.

"Apollo CSM-Block II Preliminary Design Review (PDR), NASA-MSC-ASPO, NAA-S&ID, 6-8 January 1965," pp. 4-40.

January 7

William A. Lee, chief of ASPO's Operations Planning Division, announced a revised Apollo launch schedule for 1966 and 1967. In 1968, a week-long earth orbital flight would be a dress rehearsal for the lunar mission. "Then the moon," Lee predicted. "We have a fighting chance to make it by 1970," he said, "and also stay within the 20 billion price tag set . . . by former President Kennedy."

Astronautics and Aeronautics, 1965: Chronology on Science, Technology, and Policy (NASA SP-4006, 1966), p. 7.

January 7

MSC Deputy Director George M. Low issued a memorandum regarding differences in the Apollo schedule as made public in an Associated Press release with a Houston, Texas, dateline. Low cited the following statement by George E. Mueller, Associate Administrator for Manned Space Flight, and said it "represents our official and only position on Apollo schedules:

- "The Apollo schedule for accomplishment of major milestones leading to the first manned lunar landing has not changed.
- The first Saturn IB flight is scheduled in 1966.
- Apollo manned flights on Saturn IB are scheduled for 1967.
- Unmanned Saturn V flights are scheduled for 1967.
- Manned Apollo earth orbital flights are scheduled for 1968.

"We believe these major milestones will be met and our goal of a manned lunar landing in this decade can be accomplished."

AP Release, Houston, Texas, January 7, 1965; memorandum, Low to Distribution, "Apollo schedules," January 7, 1965; memorandum, Alfred P. Alibrando, NASA Headquarters, to Distribution, "Apollo Schedules," April 7, 1965.

January 7-14

Changing the CM back-face temperature requirement from 600 degrees F at touchdown to 600 degrees F at parachute deployment threatened to increase the cabin air temperature. Physiologists at MSC had

previously declared that the cabin temperature should not exceed 100 degrees F. The proposed change in the back-face requirement, North American reported, would raise the cabin's interior to 125 degrees F. MSC's Crew Systems Division reviewed these factors and decided the increased cabin temperature would not be acceptable.

"ASPO Weekly Management Report" [January 7-14, 1965].

January 8

MSC was reviewing the control-display systems of the CSM and LEM to assess operational constraints. North American was requested to study all controls, displays, and systems functions for manned spacecraft to identify and eliminate single-point failures.

Letter, C. L. Taylor, MSC, to NAA, Space and Information Systems Division, Attn: J. C. Cozad, "Contract NAS 9-150, Control-display criteria for crew safety and mission success," January 8, 1965.

January 11

NASA announced that Kennedy Space Center's Launch Complex 16, a Titan missile facility, would be converted into static test stands for Apollo spacecraft. This decision eliminated the need for such a facility originally planned on Merritt Island and, it was predicted, would cost little more than a fourth of the \$7 million estimated for the new site.

Astronautics and Aeronautics, 1965, pp. 11-12.

January 11

North American selected Dalmo-Victor to supply S-band high-gain antennas for Apollo CSM's. (The deployable antenna would be used beyond 14,816 km [8,000 nm] from the earth.) Dalmo-Victor would complete the antenna design and carry out the development work, and North American would procure production units under a supplemental contract.

"Apollo Monthly Progress Report," SID 62-300-33, p. 8.

January 12

Grumman and Hamilton Standard were exploring various designs for the extravehicular mobility unit. On the basis of some early conclusions, the MSC Crew Systems Division (CSD) recommended that meteoroid and thermal protection be provided by a single garment. Preliminary hypervelocity tests placed the garment's reliability at 0.999. Each would weigh about 7.7 kg (17 lbs), about 2.3 kg (5 lbs) less than the two-garment design. CSD further recommended that the unit be stored either in the LEM's descent stage or in a jettisonable container in the ascent portion. [See November 19-26, 1964.]

Memorandum, John F. Rayfield, MSC, to Record, "Status of Apollo Support Office concept of optimum Extravehicular Mobility Unit (EMU) meteoroid/thermal protection arrangement," January 12, 1965.

January 12

MSC evaluated the VHF communications requirements and determined that there was no requirement for the LEM to communicate simultaneously over VHF with:

1. the CSM in lunar orbit
2. an extravehicular astronaut on the lunar surface.

There also was no requirement for the CSM to communicate simultaneously over VHF with:

1. an extravehicular astronaut
2. an astronaut in the LEM.

Grumman and North American were advised that voice communications during this mission phase would be maintained by the unified S-band equipment via the Manned Space Flight Network relay.

TWX, C. L. Taylor and W. F. Rector III, to NAA, Attn: J. C. Cozad, and GAEC, Attn: R. S. Mullaney, January 12, 1965.

January 12

Donald K. Slayton, MSC Assistant Director for Flight Crew Operations, pointed out to Managers of the ASPO and the Gemini Program Office that a number of units of spacecraft control and display equipment were needed to support the Spacecraft Control Office in the areas of spacecraft crew procedures development, crew station equipment development, flight crew familiarization, training, and spacecraft mission preparation. Such equipment was needed within MSC, at other NASA Centers, and at contractor facilities to support centrifuge programs, research vehicle programs, launch abort simulations, rendezvous and docking simulations, retrofire and reentry simulations, and other mission phase simulations. Slayton emphasized that uncoordinated requests for hardware procurement to support these programs were excessively costly in terms of equipment.

Slayton said that a "satisfactory method to reduce costs and increase equipment utilization and effectiveness is to assign responsibility as custodian to one technically cognizant organization which will ascertain the total requirement for equipment and be responsible for coordinating procurement and allocating and transferring hardware assignment required to meet program requirements." He recommended that the Crew Station Branch of Flight Crew Support Division be given the consolidated responsibilities.

Memorandum, Slayton to Manager, ASPO, and Manager, Gemini Program Office, "Proposed control and display utilization and cost reduction plan," January 12, 1965.

January 13

The first meeting of the Configuration Control Board was held at MSC with ASPO Manager Joseph F. Shea as chairman. Approval was given to delete 10 Apollo guidance and navigation systems; and W. F. Rector III was directed to look into the use of computers and prototype units for electronic systems integration. In other actions, a decision on changes to CSM specifications to provide for the heavyweight LEM (a proposed increase from 12,705 to 14,515 kg [28,000 to 32,000 lbs]) was deferred until the next meeting; and Owen Maynard was directed to identify all Block II changes that must be implemented regardless of impact and have them ready for Board action by February 18, 1965.

Minutes, Configuration Control Board Meeting No. 1, signed A. L. Brady, Secretary, CCB, January 13, 1965.

January 14-21

Development firings of the launch escape system's drogue and pilot parachute mortars were completed, and the units were slated for qualification trials the following month.

MSC, "ASPO Weekly Management Report, January 14-21, 1965."

January 14-21

OMSF asked MSC to provide NASA Headquarters with a statement of "the minimum definition of meteoroid environment in cislunar space" which would be necessary for confidence that Apollo could withstand the meteoroid flux. The "desirable degree of definition" was also requested. This material was to be used as inputs to the current cislunar Pegasus studies being conducted by OMSF.

Ibid.

January 14-21

Significant agreements from the Eleventh MSC-MSFC Flight Mechanics, Dynamics, Guidance and Control Panel meeting were:

- There was no requirement to inhibit the S-IVB attitude and attitude rate hold modes during the transposition and docking phase.
- The S-IVB auxiliary propulsion system had sufficient propellant to perform 21 roll maneuvers in earth orbit at 0.5 deg/sec for inertial measurement unit alignment and earth landmark sightings,

one yaw maneuver at 0.3 deg/sec for sun avoidance before transposition and docking, and one pitch and or yaw maneuver at 0.3 deg/sec before the final CSM/LEM separation maneuver from the S-IVB.

Ibid.

January 14

During testing, it was found that blast effects of the linear charge for the CM/SM umbilical cutter caused considerable damage to the heatshield. To circumvent this problem, North American designed a vastly improved pyrotechnic-driven, guillotine-type cutter. MSC readily approved the new' device for both Block I and II spacecraft.

"Apollo Monthly Progress Report," SID 62-300-33, p. 4.

January 14

North American completed acceptance tests for the CSM sequential and propulsion systems trainers. On January 15 the equipment was shipped to MSC, where it was installed the following week. This terminated the procurement program for the Apollo systems trainer.

Ibid., p. 20.

January 18

The Structures and Mechanics Division approved a low-burst factor for the gaseous helium tanks on the LEM (as recommended by Grumman). This change permitted a substantial lightening of the spacecraft's propulsion systems: descent 45 kg (99 lbs); ascent, 13 kg (29 lbs); reaction control, 2.3 kg (5 lbs).

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Reduction of burst safety factor for the gaseous helium bottles," January 18, 1965.

January 18

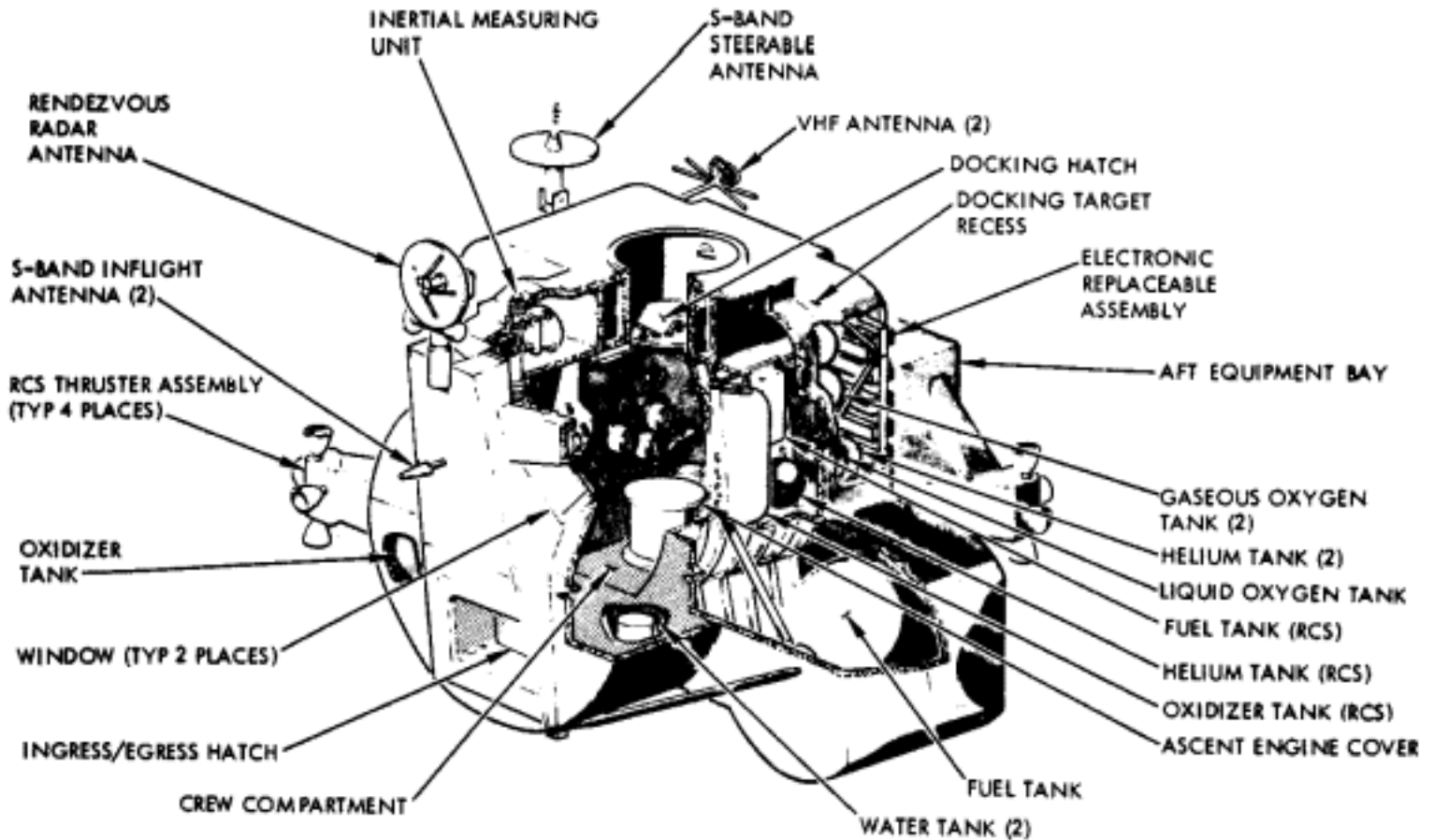
MSC White Sands Missile Operations was renamed MSC White Sands Operations to eliminate the similarity to the Army's White Sands Missile Range.

MSC Release 65-6, January 18, 1965.

January 18

After reviewing the requirement for extravehicular transfer (EVT) from the LEM to the CM, MSC reaffirmed its validity. The Center already had approved additional fuel for the CM, to lengthen its rendezvousing range, and modifications of the vehicle's hatch to permit exterior operation. The need for a greater protection for the astronaut during EVT would be determined largely by current thermal tests of the pressure suit being conducted by NASA and Hamilton Standard. While the emergency oxygen system was unnecessary during normal transfer from one vehicle to the other, it was essential during EVT or lunar surface activities.

TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, January 18, 1965.



LEM ascent stage.

January 18

General Motors' Allison Division completed qualification testing of the propellant tanks for the service propulsion system.

"Apollo Monthly Progress Report," SID-62-300-34, p. 8.

January 18

The MSC Mission Planning and Analysis Division made a presentation to Joseph F. Shea, Christopher C. Kraft, Jr., and Donald K. Slayton on Apollo Missions 201, 202, 204, 206, 207, 501, 503, and 504. It was stated that 204B was to be a repeat of 202; 204C was to be a repeat of 201; and 204D was to be the same as 204A but would be flown unmanned.

Memorandum, Carl R. Huss, JSC, to JSC Historical Office, "Comments on Volume III of *The Apollo Spacecraft: A Chronology*," June 6, 1973.

January 18

MSC was studying several approaches to the problems of automatic thermal control and automatic reacquisition of the earth by the S-band high-gain antenna while the CSM circled the moon. (The Block II spacecraft, MSC had stated, must have the ability to perform these functions wholly on its own. During an extended stay of the LEM on the lunar surface, when the CSM pilot needed uninterrupted sleep periods, antenna reacquisition was absolutely essential for telemetering data back to earth. And although the requirements for passive thermal control were not yet well defined, the spacecraft's attitude must likewise be automatically controlled.)

Robert C. Duncan, chief of the MSC Guidance and Control Division, presented his section's recommendations for solving these problems, which ultimately won ASPO's concurrence. Precise spacecraft body rates, Duncan said, should be maintained by the stabilization and control system. The position of the S-band antenna should be telemetered to the ground, where the angle required for reacquisition would be computed. The antenna would then be repositioned by commands sent through the updata link.

Memorandum, Robert C. Duncan, MSC, to Distr., "Block II Apollo High-gain antenna pointing in lunar orbit," January 18, 1965.

January 19-20

In simulated zero-g conditions aboard KC-135s, technicians evaluated a number of different devices for restraining the LEM crewmen. These trials demonstrated clearly the need for a hip restraint and for a downward force to hold the astronaut securely to the cabin floor. In mid-February a second series of flights tested the combination that seemed most promising: Velcro shoes that would be used together with Velcropile carpeting on the cabin floor of the spacecraft; a harness that enveloped the astronaut's chest and, through an intricate system of cables and pulleys, exerted a constant downward pressure; and a waist strap that secured the harness to the lighting panel immediately facing the crewman. These evaluations permitted Grumman to complete the design of the restraint system.

Memorandum, Donald K. Slayton, MSC, to Manager, ASPO, "LEM Zero Gravity Support and Restraint

Evaluation," February I, 1965.

January 20

The test altitude for mission A-004 was decreased from 22,860 to 19,507 m (75,000 to 64,000 ft) to ensure the attainment of limit loads on the CM during a tumbling power-on abort.

Memorandum, George E. Mueller, NASA Hq., to Administrator, "Apollo Spacecraft Intermediate Altitude Abort Test Mission A-004, Post Launch Report No. 1," January 26, 1966, with enclosure, "Post Launch Report No. 1."

January 20

The new membership of the MSC Manned Spacecraft Criteria and Standards Board, established September 4, 1963, was: F. John Bailey, Jr., Chairman; James W. Donnell, Secretary; James A. Chamberlin, Kenneth S. Kleinknecht, W. R. Durrett, William M. Bland, and Norman F. Smith.

MSC Circular No. 146 (Ref. 2-4-11), "MSC Manned Spacecraft Criteria and Standards Board," January 20, 1965.

January 21-28

The persistent problem of combustion instability in the LEM ascent engine, unyielding to several major injector redesigns, was still present during test firings at Bell Aerosystems. Following reviews by MSC and Grumman, the "mainstream effort" in the injector program was "reoriented" to a design that included baffles on the face of the injector. Largely because of this troublesome factor, it now appeared that the ascent engine's development cost, which only four months earlier Bell and Grumman had estimated at \$20 million, would probably approach \$34 million. Bell also forecast a 15.4-kg (34-lb) weight increase for the engine because of a longer burn design and a strengthened nozzle extension.

GAEC, "Monthly Progress Report No. 24," LPR-10-40, February 10, 1965, p. 20; MSC, "ASPO Weekly Management Report, January 21-28, 1965."

January 21

Northrop-Ventura verified the strength of the dual drogue parachutes in a drop test at El Centro, Calif. This was also the first airborne test of the new mortar by which the drogues were deployed and of the new pilot parachute risers, made of steel cables. All planned objectives were met. The deployment sequence was perfect, and there was no apparent kinking of the risers.

In the course of this drop, six of the 12 cutters, which sever the reefing lines on the main parachutes, failed. This failure, together with another cutter malfunction during the previous month, signaled an

intensive investigation at Ordco, the cutter manufacturer. Qualification of the severing device was thereby delayed.

On January 22, Northrop, North American, and MSC conducted a design review for the drogue system and found no discrepancies.

"Apollo Monthly Progress Report," SID-62-300-33, pp.3-4; "ASPO Weekly Management Report, January 21-28, 1965."

January 21

At the request of Maj. Gen. Samuel C. Phillips, Apollo Program Director, ASPO reexamined the performance requirements for spacecraft slated for launch with Saturn IBs. MSC currently assessed that the launch vehicle was able to put 16,102 kg (35,500 lbs) into a circular orbit 105 nm above the earth. Based on the spacecraft control weights, however, it appeared that the total injected weight of the modules would exceed this amount by some 395 kg (870 lbs).

A 454-kg (1,000-lb) increase in the Saturn IB's payload was the most desirable solution, ASPO Manager Joseph F. Shea wrote Phillips. However, by removing one set of propellant tanks and a helium tank from SM and slightly reducing the propellant supply, the spacecraft could still be kept within the launch vehicle's capability without affecting mission objectives or crew safety. While several other alternative approaches appeared feasible, they would seriously impair spacecraft performance.

On February 23, Phillips informed Shea that he foresaw the requisite payload boost. While the control payload for the Saturn IB would remain unchanged, Phillips said, a new design goal of 16,556 kg (36,500 lbs) would be set. At the end of July it would be decided whether or not to make this last figure a new control capability.

Letter, Joseph F. Shea, MSC, to Maj. Gen. Samuel C. Phillips, January 21, 1965; memorandum, William A. Lee, MSC, to Distr., "Mission assignments for Block II CSM's," February 12, 1965; letter, Phillips, NASA, to Shea, February 23, 1965; memorandum, Lee, MSC, to Mission Planning and Analysis Division, Attn: J. P. Bryant, "Modified mission profile for CSM-LEM flight on Saturn I-B," March 3, 1965.

January 21-28

Space Ordnance Systems was selected to develop the explosive bolts that held the LEM's two stages together.

"ASPO Weekly Management Report, January 21-28, 1965."

January 21-28

Two underwater firings verified the design concept of the main parachute disconnects.

Ibid.

January 21-28

Parallel development of the LEM descent engine was halted. Space Technology Laboratories was named the sole contractor; the Rocketdyne contract was canceled. Grumman estimated that the cost of Rocketdyne's program would be about \$25 million at termination.

Ibid.; "Monthly Progress Report No. 24," LPR-10-40, pp. 1, 30, 35.

January 22

The MSC-MSFC Mechanical Integration Panel discussed the possibility that, when deployed, the LEM adapter panels might interfere with radio communications via the S-band high-gain antenna. On earth-orbital missions, the panel found, the S-band antenna would be rendered useless. They recommended that MSC's Instrumentation and Electronic Systems Division investigate alternative modes for communications during the transposition and docking phase of the flight. During lunar missions, on the other hand, the panel found that, with panels deployed at a 45 degree angle, the high-gain antenna could be used as early as 15 minutes after translunar injection. Spacecraft-to-ground communications during transposition and docking could thus be available and manual tracking would not be needed. North American was informed that the high-gain antenna would be used during this maneuver, and was directed to fix the panel deployment angle for all Block II spacecraft at 45 degrees.

Memorandum, Lyle M. Jenkins, MSC, to Distr., "Abstract of MSC meeting on solutions to the interference of the deployed SLA panels with communications," January 25, 1965; "ASPO Weekly Management Report, January 21-28, 1965."

January 22

Two construction companies, Blount Brothers Corporation, Montgomery, Ala., and Chicago Bridge and Iron Company, Oak Park, Ill., received a joint contract (worth \$5,178,000) for construction of a vacuum chamber at the Lewis Research Center's Plum Brook Station. The facility, which would be used for spacecraft and propulsion system testing, would be one of the largest such simulators in the world.

Astronautics and Aeronautics, 1965, p. 26.

January 22

Apollo Program Director Samuel C. Phillips forecast "heavy ground testing" for Apollo during 1965. The coming months, he said, should see the completion of testing on the first Apollo spacecraft intended for manned space flight, as well as flight qualification of the Saturn IB and initial testing of the Saturn V launch vehicles.

Ibid., p. 27.

January 23

ASPO approved the technique for LEM S-IVB separation during manned missions, a method recommended jointly by North American and Grumman. After the CSM docked with the LEM, the necessary electrical circuit between the two spacecraft would be closed manually. Explosive charges would then free the LEM from the adapter on the S-IVB.

Memorandum, Joseph F. Shea, MSC, to Distr., "Lunar Excursion Module (LEM)/Saturn S-IVB Stage Separation Technique," January 23, 1965.

January 25

Dalmo-Victor, vendor of the LEM S-band antenna, was given firm requirements for tracking and coverage, thus enabling the company to freeze the antenna design.

"MSC Weekly Management Report, January 28-February 4, 1965."

January 25

The optimism that permeated the Apollo program was reflected in statements by NASA's Associate Administrator, Robert C. Seamans, Jr., during budget briefings for the forthcoming year. He was "greatly encouraged" by recent design freezes and "very reassured" by testing of propulsion systems and launch vehicle stages. "We really feel," Seamans said, ". . . that we can get off the [lunar landing] flight on an earlier mission than I would have said a year ago?" Certainly it was "conceivable" that the moon landing could come "in early 1970."

Astronautics and Aeronautics, 1965, pp. 29-30.

January 25

To determine flotation characteristics of the spacecraft, the Stevens Institute of Technology began a testing program using one-tenth scale models of the CM. Researchers found that the sequence in which the uprighting bags were deployed was equally critical in both a calm sea and in various wave conditions; improper deployment caused the vehicle to assume an apex-down position. These trials disproved predictions that wave action would upright the spacecraft from this attitude.

Further testing during the following month reinforced these findings. But because sequential deployment would degrade reliability of the system, North American held that the bags must upright the spacecraft irrespective of the order of their inflation. Stevens' investigators would continue their program, examining the CM's characteristics under a variety of weight and center of gravity conditions.

"Apollo Monthly Progress Report," SID 62-300-34, p. 7; "Apollo Monthly Progress Report," SID 62-300-35, April 1, 1965, pp. 7-8.

January 25

MSC negotiated a backup Block II space suit development program with David Clark Company, which paralleled the Hamilton Standard program, at a cost of \$176,000. Criteria for selecting the suit for ultimate development for Block II would be taken from the Extravehicular Mobility Unit Design and Performance Specification. A selection test program would be conducted at MSC using the CM mockup, the lunar simulation facility, and the LEM mockup.

Memorandum, Richard S. Johnston, MSC, to Joseph Shea, "Block II Apollo suit program," January 25, 1965.

January 25

ASPO established an operational requirement for propellant gauges in the LEM descent stage, the exact details to be worked out by Grumman. The gauges must be accurate to within one-half of one percent when less than one-fourth of the propellants remained.

Memorandum, William A. Lee, MSC, to Manager, ASPO, "Status of LEM descent Delta-V budget," January 25, 1965; "ASPO Weekly Management Report, January 21-28, 1965."

January 26

Warren J. North, Chairman of the Lunar Landing Research Vehicle (LLRV) Coordination Panel, reported to MSC Director Robert R. Gilruth that the LLRV had been flown 10 times by Flight Research Center pilots - eight times by Joe Walker and twice by Don Mallick. Maximum altitude achieved was 91 m (300 ft) and maximum forward velocity was 12 m (40 ft) per sec. Subsequent to December 14, 1964, the vehicle had been undergoing detailed x-ray inspection, lunar simulation control system checkout, and minor changes prior to extending the flight envelope in February.

North said discussions with the pilots indicated that checkout prerequisites for future LLRV pilots should include helicopter proficiency plus at least two weeks of intensive simulator and vehicle test stand activity. Prototypes of the basic LEM controls and displays were being procured by MSC and would be phased into the LLRV simulator and flight vehicles during the spring and summer.

Memorandum, North to Gilruth, "Status of Lunar Landing Research Vehicle (LLRV) Program," January 26, 1965.

January 26

At a meeting held at Grumman, RCA presented its study on thermal effects for a fixed rendezvous radar antenna assembly which would be protected from the CSM service propulsion system by a thermal shield.

"Monthly Progress Report No. 24," LPR-10-40, p. 17; "ASPO Weekly Management Report, January 21-28, 1965."

January 27

MSC evaluated Grumman's proposal to stage components of the extravehicular mobility unit to achieve a substantial weight reduction.

"Minutes of the Lunar Excursion Module Crew Integration Systems Meeting No. 3, January 27, 1965," pp. 2-4.

January 28

The first major Saturn V flight component, a 10-m (33-ft) diameter, 27,215 kg (60,000 lb) corrugated tail section which would support the booster's 6,672 kilonewtons (1.5-million-lb) thrust engines, arrived at MSFC from NASA's Michoud Operations near New Orleans. The section was one of five major structural units comprising Saturn V's first stage.

Astronautics and Aeronautics, 1965, p. 39.

January 28

After examining the CM's potable water system, engineers in the MSC Crew Systems Division found that the Gemini pistol-type water dispenser could not be used in the Apollo spacecraft without some changes in the dispenser design.

"ASPO Weekly Management Report, January 14-21, 1965" [see memorandum, G. Merritt Preston, MSC- Florida Operations, to Chief, Crew Systems Division, "Flight Water Program," January 28, 1965].

January 28-February 4

Initial development testing of LEM restraint systems was completed. Under zero-g conditions, investigators found, positive restraints for the crew were essential. While the system must be further refined, it consisted essentially of a harness that secured the astronaut's hips (thus providing a pivot point) and held him firmly on the cabin floor.

"ASPO Weekly Management Report, January 28-February 4, 1965."

January 28-February 4

MSC canceled plans (originally proposed by North American) for a device to detect failures in the reaction control system (RCS) for Block I CSMs. This was done partly because of impending weight, cost, and schedule penalties, but also because, given an RCS failure during earth orbit, the crew could detect it in time to return to earth safely even without the proposed device. This action in no way affected the effort to devise such a detection system for the Block II CSM or the LEM, however.

Ibid.

January 29

ASPO concurred with the requirement to provide an emergency defecation capability aboard the LEM as established by MSC's Center Medical Programs Office. The addition of a Gemini-type defecation glove appeared to present a satisfactory solution. Crew Systems Division was directed to proceed with their recommendation and add the Gemini gloves to the LEM crew provisions.

Memorandum, Owen E. Maynard, MSC, to Chief, Crew Systems Division, "Waste management provisions aboard the LEM," January 29, 1965.

January 29

Apollo boilerplate 28 underwent its second water impact test. Despite its strengthened aft structure, in this and a subsequent drop on February 9 the vehicle again suffered damage to the aft heatshield and bulkhead, though far less severe than that experienced in its initial test. The impact problem, it was obvious, was not yet solved.

"Apollo Monthly Progress Report," SID 62-300-33, pp. 1, 8, 16.

During the Month

ASPO Manager Joseph F. Shea reiterated the space agency's phasic view of the Apollo program. He was well pleased with the pace of the program and reported that ground testing of all CSM subsystems was "well along." Reflecting on the year just past, Shea observed that it was one in which Apollo objectives were achieved "milestone by milestone?" He was equally optimistic about Apollo's progress during the

coming months, predicting that there would be "three Apollo spacecraft in continuous ground testing" by the end of the year.

Astronautics and Aeronautics, 1965, p. 43.

During the Month

Dr. William H. Pickering, Director of Jet Propulsion Laboratory, commented on the importance of *Ranger VII* in locating possible lunar landing sites.

Ibid., pp. 43-44.

During the Month

Nine areas of scientific experiments for the first manned Apollo lunar landing mission had been summarized and experimenters were defining them for NASA. Space sciences project group expected to publish the complete report by March 1, to be followed by requests for proposals from industry on designing and producing instrument packages. A major effort was under way by a NASA task force making a time-motion study of how best to use the limited lunar stay-time of two hours' minimum for the first flight.

Ibid., p. 45.

During the Month

To make it easier to get in and out of the spacecraft, Grumman modified the LEM's forward hatch. During mobility tests on the company's mockup, a hinged, trapezoidal-shaped door had proved superior to the original circular hatch, so the earlier design was dropped.

"Monthly Progress Report No. 24," LPR-10-40, p. 13.

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Advanced Design, Fabrication, and Testing

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February 1

Pacific Crane and Rigging Company received a NASA contract, worth \$8.3 million, to install ground equipment at Kennedy Space Center's Saturn V facility, Launch Complex 39. On the following day, the Army Corps of Engineers awarded a \$2,179,000 contract to R. E. Carlson Corporation, St. Petersburg, Fla., to modify Launch Complex 34 to handle the Saturn IB.

Astronautics and Aeronautics, 1965, pp. 48, 52.

February 2-3

The Apollo-Saturn Crew Safety Panel decided on a number of emergency detection system (EDS) and abort procedures for the early Apollo flights:

- If any of the three redundant automatic abort circuits so indicated, the launch vehicle would not be released.
- The EDS would be flight-tested on the SA-201 and SA-202 missions.
- Unmanned Apollo flights should be aborted from the ground only under the most severe conditions.
- Liftoff permitted automatic abort without manual backup.
- To ensure a successful abort, a redundant mode of EDS-commanded engine shutdown was mandatory.

After hearing the results of several supporting studies, the Panel further agreed that Saturn IB flights would be automatically aborted if the vehicle's roll rate reached 20 degrees per second; if two engines should fail during the first 30 seconds of flight, the Saturn IB must be capable of aborting automatically, and the Saturn V must have the same capability for the first 60 seconds of flight; and, finally, the Panel stated that during the Saturn V's initial stages, automatic abort might be required if even one engine shut down.

"Summary of Proceedings, Apollo-Saturn Crew Safety Panel Meeting No. 11, 2-3 February, 1965,"

February 4, 1965.

February 3

ASPO established radiation reliability goals for Apollo. These figures would be used to coordinate the radiation program, to define the allowable dosages, and to determine the effect of radiation on mission success. The crew safety goal (defined as the probability of a crewman's not suffering permanent injury or worse, nor his being incapacitated and thus no longer able to perform his duties) was set at 0.99999. The major hazard of a radiation environment, it was felt, was not the chance of fatal doses. It was, rather, the possibility of acute radiation sickness during the mission. The second reliability goal, that for success of the mission (the probability that the mission would not be aborted because of radiation environment), was placed at 0.98.

These values, ASPO Manager Joseph F. Shea emphasized, were based on the 8.3-day reference mission and on emergency dose limits previously set forth. They were not to be included in overall reliability goals for the spacecraft, nor were they to be met by weight increases or equipment relocations.

Memorandum, Joseph F. Shea, MSC, to Assistant Director for E. and D., "Apollo Radiation Reliability Goals," February 3, 1965.

February 4

A device to maintain the spacecraft in a constant attitude was added to the LEM's primary attitude control system (ACS). The feature brought with it some undesirable handling characteristics, however: it would cause the vehicle to land long. Although this overshoot could be corrected by the pilot, and therefore was not dangerous operationally, it would require closer attention during final approach. The attitude hold, therefore, hardly eased the pilot's control task, which was, after all, its primary function. Instead of moving the device to the backup ACS (the abort section), the Engineering Simulation Branch of MSC's Guidance and Control Division recommended that the system be modified so that, if desired, the pilot could disengage the hold mechanism.

Memorandum, Clarke T. Hackler, MSC, to Chief, Guidance and Control Division, "Evaluation of LEM modified (zero overshoot) rate command-attitude hold control mode," February 4, 1965.

February 4-11

After considering possible impacts, MSC directed North American to implement real-time commands to the up-data link equipment on command modules 012 and 014.

MSC, "ASPO Weekly Management Report, February 4-11, 1965."

February 4-11

MSC questioned the necessity of using highly purified (and expensive) fuel-cell-type oxygen to maintain the cabin atmosphere during manned ground testing of the spacecraft. The Center, therefore, undertook a study of the resultant impurities and effect on crew habitability of using a commercial grade of aviation oxygen.

Ibid.; memorandum, Robert E. Smylie, MSC, to Chief, Environmental Physiology Branch, "Breathing oxygen for Apollo Command Module ground testing in Airframe 008," March 15, 1965.

February 5

SM 001's service propulsion engine was static-fired for 10 sec at White Sands. The firing was the first in a program to verify the mission profiles for later flight tests of the module. (SM 001 was the first major piece of flight-weight Apollo hardware.)

MSC News Release 65-18, February 5, 1965; TWX, M. L. Raines, WSMR, to NASA Headquarters, MSC, MSFC, and ASPO Field Test Office, Cape Kennedy, Fla., "Airframe 001 First Firing," February 6, 1965.

February 8

MSC deleted the requirement for a rendezvous radar in the CSM.

MSC, "Minutes, Configuration Control Board Meeting No. 5," February 8, 1965.

February 8

MSC, North American, and Grumman reviewed the results of Langley Research Center's LEM-active docking simulation. While the overhead mode of docking had been found to be acceptable, two items still caused some concern: (1) propellant consumption could exceed supply; and (2) angular rates at contact had occasionally exceeded specifications. Phase B (Grumman's portion) of the docking simulations, scheduled to begin in about two weeks, would further investigate these problems. Langley researchers also had evaluated several sighting aids for the LEM and recommended a projected image collimated (parallel in lines of direction) reticle as most practicable. Accordingly, on March 9, MSC directed Grumman to incorporate this type of sighting device into the design of their spacecraft.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Results of LEM active docking simulation at Langley Research Center," March 9, 1965.

February 8

Development tests recently completed by AiResearch on the water evaporator control system for the space suit heat exchanger disclosed its inadequacy because of its slow response time. To solve this problem, AiResearch and North American proposed an alternate control system approach similar to the glycol evaporator scheme used elsewhere in the environmental control system. This alternate design, which was tested and appeared a more desirable approach, would be incorporated on airframes 008 and 012 through Block II spacecraft. No schedule impact was anticipated.

"ASPO Weekly Management Report, February 4-11, 1965"; memorandum, Frank E. Samonski, Jr., MSC, to Chief, Test Division, "A14-033 requirements for Airframe 008 testing," February 8, 1965.

February 8

NASA invited 113 scientists and 23 national space organizations to a conference at MSC to brief them on the Gemini and Apollo missions. As a result of the conference, NASA hoped to receive proposals for biomedical experiments to be performed in Gemini and Apollo spacecraft.

MSC News Release 65-21, "Foreign Scientists Invited to Conference on Apollo Experiments," February 8, 1965.

February 9

North American completed the first ground test model of the S-II stage of the Saturn V.

Space Business Daily, February 9, 1965, p. 195.

February 10

ASPO and the MSC Instrumentation and Electronic Systems Division (IESD) formulated a program for electromagnetic compatibility testing of hardware aboard the CSM and LEM. The equipment would be mounted in spacecraft mockups, which would then be placed in the Center's anechoic chamber. In these tests, scheduled to begin about the first of September, IESD was to evaluate the compatibility of the spacecraft in docked and near-docked configurations, and of Block I spacecraft with the launch vehicle. The division was also to recommend testing procedures for the launch complex.

Memorandum, R. S. Sawyer, MSC, to Chief, Systems Engineering Division, "Test Philosophy for CSM/LEM Electromagnetic Compatibility Test to be performed in the Anechoic Chamber Test Facility at MSC," February 10, 1965.

February 10

ASPO evaluated Grumman's proposal for an "all battery" system for the LEM descent stage. ASPO was aiming at a 35-hour lunar stay for the least weight; savings were realized by lessening battery capacities,

by making the water tanks smaller, and by reducing some of the spacecraft's structural requirements.

Letter, Thomas J. Kelly, GAEC, to MSC, Attn: W. F. Rector III, "Submittal of Additional Information Relative to the Lem 'All-Battery' Study," February 10, 1965, with enclosures.

February 11

A drop test at EI Centro, Calif., demonstrated the ability of the drogue parachutes to sustain the ultimate disreefed load that would be imposed upon them during reentry. (For the current CM weight, that maximum load would be 7,711 kg [17,000 lbs] per parachute.) Preliminary data indicated that the two drogues had withstood loads of 8,803 and 8,165 kg (19,600 and 18,000 lbs). One of the drogues emerged unscathed; the other suffered only minor damage near the pocket of the reefing cutter.

"Apollo Monthly Progress Report," SID 62-300-35, pp. 3-4; MSC, "ASPO Weekly Management Report, February 11-18, 1965."

February 11-18

MSC modified its bubble helmet design to fit on an International Latex "state-of-the-art" space suit. A mockup of the helmet was used in don doff tests. Mean donning time was 4.2 sec; doff time averaged 1.47 sec. Further tests would be performed when a prototype helmet was completed (expected by February 26).

"ASPO Weekly Management Report, February 11-18, 1965."

February 11-18

Hamilton Standard, the extravehicular mobility unit contractor, completed a two-week wearing test of the Apollo liquid-cooled undergarment. Investigators found that the garment could be worn for the entire lunar mission without any serious discomfort.

Ibid.

February 11-18

To make room for a rendezvous study, MSC was forced to end, prematurely, its simulations of employing the LEM as a backup for the service propulsion system. Nonetheless, the LEM was evaluated in both manual and automatic operation. Although some sizable attitude changes were required, investigators found no serious problems with either steering accuracy or dynamic stability.

Ibid.

February 11-18

North American selected the Ordnance Division of General Precision Link Group to supply the panel thrusters for the spacecraft lunar adapter.

Ibid.

February 11-18

Evaluations of the three-foot probes on the LEM landing gear showed that the task of shutting off the engine prior to actual touchdown was even more difficult than controlling the vehicle's rate of descent. During simulated landings, about 70 percent of the time the spacecraft was less than 0.3 m (1 ft) high when shutdown came; on 20 percent of the runs, the engine was still burning at touchdown. Some change, either in switch location or in procedure, thus appeared necessary to shorten the delay between contact light and engine cutoff (an average of 0.7 sec).

Ibid.

February 12

MSC relayed to NASA Headquarters North American's cost estimates for airlocks on the Apollo CM:

Spacecraft	Development	Unit Cost
Block I	\$840,000	\$185,000
Block II	\$960,000	\$112,000
Blocks I & II	\$1,050,000	\$111,000

(The unit costs presumed two flight items for Block I and 12 for Block II spacecraft.)

During late February and early March, North American completed a conceptual design study of an airlock for the Block I CMs. Designers found that such a device could be incorporated into the side access hatch. A substitute cover for the inner hatch and a panel to replace the window on the outer hatch would have to be developed, but these modifications would not interfere with the basic design of the spacecraft.

TWX, Joseph F. Shea, MSC, to NASA Headquarters, Attn: Samuel C. Phillips, February 12, 1965; "Apollo Monthly Progress Report," SID 62-300-35, pp. 17-18.

February 12

MSC's Systems Engineering Division (SED) requested support from the Structures and Mechanics Division in determining the existence or extent of corrosion in the coolant loops of the SM electrical power subsystem (EPS) and the CM and LEM environmental control subsystems (ECS), resulting from the use of water glycol as coolant fluid. Informal contact had been made with W. R. Downs of the Structures and Mechanics Division and he had been given copies of contractor reports and correspondence between MSC, North American, and MIT pertaining to the problem. The contractors had conflicting positions regarding the extent and seriousness of glycol corrosion.

SED requested that a study be initiated to:

1. determine the existence or extent of corrosion in the EPS and ECS coolant loops; and
2. make recommendations regarding alternate materials, inhibitors, or fluids, and other tests or remedial actions if it were determined that a problem existed.

Memorandum, Owen E. Maynard, MSC, to Chief, Structures and Mechanics Division, "Water/glycol Corrosion," signed Harry W. Byington, February 12, 1965.

February 15

A study by General Electric affirmed the necessity for the steerable S-band antenna for communications between the spacecraft and the ground at lunar distances. Communications margins were so small that, at those distances, any degradation of equipment would seriously affect the spacecraft's contact with earth.

Letter, E. J. Merrick, GE, to William A. Lee, "S-Band Communications Requirements Study," February 15, 1965, with enclosure: "CSM-LEM Directional Communications Antenna Relationship to Communications Margins and Mission Requirements."

February 16

Crew Systems Division (CSD) informed the Astronaut Office that the requirements submitted by Astronaut Michael Collins on February 5 had been included in the Block II suit program plans. Those requirements for astronaut training suits were:

Suit Quantity	Type	Date Available
1	A-5H	June 1965
6	A-5H	December 1965 (or sooner if possible)
6	A-6H1	March 1966
14	A-6H2	August 1966

CSD requested the Astronaut Office to provide the type and schedule of training programs in which suit

use was anticipated, stating: "This information will be of value in assessing suit support requirements and the type of suit interface information to be gained from astronaut participation in these programs."

Memorandum, Richard S. Johnston, MSC, to Assistant Director for Flight Crew Operations, Attn: D. K. Slayton, "Apollo Block II training suits," signed E. L. Hays, February 16, 1965.

February 16

In the first of a series of manufacturing review meetings at Bethpage, N.Y., it was learned that Grumman's tooling program was behind schedule (caused primarily by engineering changes). Tool manufacturing might recoup much of the lost time, but this process was highly vulnerable to further design changes. Completion of tooling for the ascent stage of LTA-3 was now set for late April, a production delay of about two months.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "LEM Manufacture Review Meetings Minutes," March 3, 1965, with enclosure: "Minutes, LEM Manufacturing Review Meeting, February 16, 1965."

February 16

In a memorandum to ASPO, Samuel C. Phillips, Apollo Program Director, inquired about realigning the schedules of contractors to meet revised delivery and launch timetables for Apollo. Phillips tentatively set forth deliveries of six spacecraft (CSM/LEMs) during 1967 and eight during each succeeding year; he outlined eight manned launches per year also, starting in 1969.

Memorandum, Samuel C. Phillips, NASA, to MSFC, MSC, and KSC, Attn: Directors, "Apollo Delivery and Launch Schedules," February 16, 1965, with enclosures.

February 16

A Saturn I vehicle SA-9 launched a multiple payload into a high 744 by 496 km (462 by 308 mi) earth orbit. The rocket carried a boilerplate (BP) CSM (BP-16) and, fitted inside the SM, the *Pegasus I* meteoroid detection satellite. This was the eighth successful Saturn flight in a row, and the first to carry an active payload. BP-16's launch escape tower was jettisoned following second-stage S-IV ignition. After attaining orbit, the spacecraft were separated from the S-IV. Thereupon the *Pegasus I*'s panels were deployed and were ready to perform their task, i.e., registering meteoroid impact and relaying the information to the ground.

NASA News Release 65-38, "Saturn I to Launch Pegasus Meteoroid," February 15, 1965; TWX, E. R. Mathews, KSC, to NASA Headquarters, MSFC, MSC, and MSFC Resident Manager, Sacramento, California, subject: "CLN SA-9 Apollo Flash Report No. 2," February 18, 1965; *Astronautics and Aeronautics*, 1965, pp. 71-72.

February 16

NASA awarded an \$8,879,832 fixed-price contract to the Univac Division of Sperry Rand Corporation for digital data processors for the Apollo project. Univac also would assist in modifying extant computer programs to meet Apollo requirements.

NASA News Release 65-50, "NASA Buys Univac Data Processing for Moon Project," February 16, 1965.

February 16

MSC announced a realignment of specialty areas for the 13 astronauts not assigned to forthcoming Gemini missions (GT 3 through 5) or to strictly administrative positions:

Operations and Training

Edwin E. Aldrin, branch chief - mission planning

Charles A. Bassett - operations handbooks, training, and simulators

Alan L. Bean - recovery systems

Michael Collins - pressure suits and extravehicular activity

David R. Scott - mission planning and guidance and navigation

Clifton C. Williams - range operations, deep space instrumentation, and crew safety.

Project Apollo

Richard F. Gordon, branch chief - overall astronaut activities in Apollo area and liaison for CSM development

Donn F. Eisele - CSM and LEM

William A. Anders - environmental control system and radiation and thermal systems

Eugene A. Cernan - boosters, spacecraft propulsion, and the Agena stage

Roger B. Chaffee - communications, flight controls, and docking

R. Walter Cunningham - electrical and sequential systems and non-flight experiments

Russell L. Schweickart - in-flight experiments and future programs.

MSC News Release 65-27, February 16, 1965.

February 16-March 15

The CM's waste management system demonstrated its feasibility under zero-g conditions during flights from Wright-Patterson Air Force Base. The system successfully contained both solid and liquid wastes and did not leak even when filled to capacity.

"Apollo Monthly Progress Report," SID 62-300-35, p. 7.

February 17

The U.S. Navy Air Crew Equipment Laboratory began testing the Gemini Block I Apollo space suit in a wide range of environmental temperatures to determine the comfort and physiological responses of the wearer. The program, delayed because of difficulties with humidity control, was to be completed in three to four weeks.

"ASPO Weekly Management Report, February 11-18, 1965."

February 17

Ranger VIII, a lunar probe carrying six television cameras, was launched from Cape Kennedy by an Atlas-Agena B vehicle. The spacecraft's trajectory was nearly perfect; only minor midcourse corrections were required to place the craft squarely in the target area, in the Sea of Tranquillity.

Cameras in *Ranger VIII* were turned on 23 minutes before impact, and the spacecraft transmitted pictures back to earth until it struck the surface and was destroyed. The flight's product would be intensively studied by a panel of noted lunar scientists, among them Gerard P. Kuiper and Ewen A. Whitaker of the University of Arizona and Harold C. Urey of the University of California.

Astronautics and Aeronautics, 1965, pp. 73-74, 84-85.

February 17

MSC directed North American to delete the rendezvous radar from Block II CSMs. On those spacecraft North American instead would install LEM rendezvous radar transponders. Grumman, in turn, was ordered to halt its work on the CSM rendezvous radar (both in-house and at RCA) as well as all support efforts. At the same time, however, the company was directed to incorporate a tracking light on the LEM (compatible with the CSM telescope sextant) and to modify the spacecraft's VHF equipment to permit

range extraction in the CSM. (See February 8 and March 15.)

Letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Div., "Contract NAS 9-150, CCA to Cover Removal of Rendezvous Radar Installation on CSM (MSN 150-508)," February 16, 1965; letter, Yschek, to NAA, S&ID, "Contract Change Authorization No. 303," February 17, 1965; letter, J. B. Alldredge, MSC, to NAA, S&ID, "Contract Change Authorization No. 303, Revision 1," March 11, 1965; letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Item 3, Contractor Responsibilities, Rendezvous Radar and Transponder," March 8, 1965, with enclosure.

February 17

North American proposed an idea for increasing the CM's land landing capability. This could be done, the company asserted, by raising the water impact limits (thus exceeding normal tolerances) and stiffening the shock struts. Presently, the spacecraft was incapable of a land landing within established requirements (i.e., in a 46-km [25-nm] wind). While even approximate figures were not available, the maximum wind velocity in which the CM could land - without exceeding crew tolerances - was probably between 19 and 28 km (10 and 15 nm) per hr. (No precise data on land and water landings would be available until after the drop tests of boilerplate 28 late in the year.)

Personnel of the ASPO Crew Integration Branch, however, were pessimistic about the North American scheme. They doubted that shock attenuation could be readily increased, nor did they see as likely any relaxation of crew tolerances. Further, the probability of a land landing introduced tighter constraints on wind conditions at the launch site. As they viewed it, the only feasible way to improve the spacecraft's ground capability was through some mechanism that would further absorb the landing impact.

Memorandum, Joseph P. Loftus, Jr., MSC, to Chief, Systems Engineering Division, "Command Module land impact capability," February 17, 1965.

February 17

ASPO Manager Joseph F. Shea clarified the manned unmanned capabilities required of Block I CSM spacecraft to ensure that end-item specifications appropriately reflect those capabilities.

CSMs 017 and 020 would fly unmanned entry tests on the Saturn V and need not be capable of manned missions. CSMs 012 and 014 were to be delivered to KSC for manned orbital missions on the Saturn IB but must be capable of being modified to fly unmanned missions.

The planning for CSM 012 should be such that the mission type could be selected 5½ months prior to the scheduled launch of the 204 mission, yet not delay the launch.

Memorandum, Shea, MSC, to Chief, Systems Engineering Division, "Block I CSM Mission Capabilities," February 17, 1965.

February 18

LEM Test Article 2 was shipped to Marshall Space Flight Center to undergo a series of Saturn booster vibration tests.

"Monthly Progress Report No. 25," LPR-10-41, March 10, 1965, p. 1.

February 18

MSC's Crew Systems Division decreed that the extravehicular mobility unit (EMU) would employ a single garment for both thermal and meteoroid protection. By an earlier decision, the penetration probability requirement had been lowered from 0.9999 to 0.999. This change, along with the use of newer, more efficient materials, promised a substantial lightening of the garment (hopefully down to about 7.7 kg [17 lbs], excluding visors, gloves, and boots). The division also deleted the requirement for a separate meteoroid visor, because the thermal and glare visors provided ample protection against meteoroids as well. Tests by Ling-Temco-Vought confirmed the need for thermal protection over the pressure suit during extravehicular transfer by the LEM crewmen.

Memorandum, Robert E. Smylie, MSC, to Chief, Systems Engineering Division, "Extravehicular Mobility Unit (EMU) thermal anti meteoroid protection," February 18, 1965.

February 18-25

Because of the CM's recent weight growth, the launch escape system (LES) was incapable of lifting the spacecraft the "specification" distance away from the booster. The performance required of the LES was being studied further; investigators were especially concerned with the heat and blast effects of an exploding booster, and possible deleterious effects upon the parachutes.

MSC, "ASPO Weekly Management Report, February 18-25, 1965."

February 19

NASA selected Philco's Aeronutronic Division to design a penetrometer for possible use in the Apollo program. Impacting on the moon, the device would measure the firmness and bearing strength of the surface. Used in conjunction with an orbiting spacecraft, the system could provide scientific information about areas of the moon that were inaccessible by any other means. Langley Research Center would negotiate and manage the contract, estimated to be worth \$1 million.

NASA News Release 65-59, "NASA to Negotiate With Philco for Study of Moon Penetrometer," February 19, 1965; *Astronautics and Aeronautics*, 1965, p. 82.

February 19

To eliminate interference between the S-IVB stage and the instrument unit, MSC directed North American to modify the deployment angle of the adapter panels. Originally designed to rotate 170 degrees, the panels should open but 45 degrees (60 degrees during abort), where they were to be secured while the CSM docked with and extracted the LEM.

But at this smaller angle, the panels now blocked the CM's four flush-mounted omnidirectional antennas, used during near-earth phases of the mission. While turning around and docking, the astronauts thus had to communicate with the ground via the steerable high gain antenna. For Block II spacecraft, therefore, MSC concurrently ordered North American to broaden the S-band equipment's capability to permit it to operate within 4,630 km (2,500 nm) of earth.

Letter, H. P. Yschek, MSC, to NAA, Space and Information Systems Division, "Contract Change Authorization No. 304," February 19, 1965; letter, Yschek to NAA, S&ID, "Contract Change Authorization No. 305," February 19, 1965.

February 23

NASA awarded a fixed-price contract (worth 1.5 million) to IBM to design a backup guidance and navigation computer for the Apollo CM.

MSC, "Quarterly Activity Report for the Office of the Associate Administrator, Manned Space Flight, for the Period Ending April 30, 1965," p. 24.

February 23

William F. Rector III, MSC's LEM Project Officer, reported at an ASPO Manager's Staff Meeting that the expected firing date for the heavyweight ascent (HA) rig #3 at WSTF had been slipped from March 18, 1965, until April 13. Grumman personnel at White Sands said the slip was necessary because

1. a propellant loading control assembly to be mounted on the rig could not be used in the planned location because it was not accessible for checkout and would require two weeks for refabrication of certain pipelines and further checkout;
2. checkout of various wiring between the HA-3 rig and the facilities did not occur on schedule and two weeks would be required to complete the task; and
3. adequate interfacing between the fluid and gaseous ground support equipment (GSE) and various facility pipes was not maintained with many pieces of GSE putting out higher pressure than the facility pipes design allowed.

Memorandum, Rector to Distr., "First Firing of HA-3," February 23, 1965.

February 23-26

MSC and North American conducted Part 2 of the mockup review of the CM's forward compartment and lower equipment bay. (Part 1 was accomplished January 14-15. This staged procedure was in line with the contractor's proposal for a progressive review program leading up to the Critical Design Review scheduled for July 19-23.) Except for minor changes, the design was acceptable.

"Apollo Monthly Progress Report," SID 62-300-33, p. 24; MSC, "ASPO Weekly Management Report, February 25-March 4, 1965."

February 24

NASA awarded a \$2,740,000 fixed-price contract to the Collins Radio Company for S-band telemetry equipment. Collins would install the equipment at three antenna facilities that supported Apollo lunar missions (at Goldstone, Calif.; Canberra, Australia; and Madrid, Spain).

NASA News Release 65-63, "Collins to Make S-Band Systems for Three 85-Foot Apollo Antennas," February 24, 1965; *Space Business Daily*, February 26, 1965, p. 286.

February 24

MSC's Procurement and Contracts Division notified ASPO that John B. Alldredge had been assigned as the Contracting Officer for Contract NAS 9-150 (the North American contract), replacing Henry P. Yschek.

Memorandum, C. L. Taylor, MSC, to Distr., "Notification of new Contracting Officer for C&SM Contract NAS 9-150," sgd. W. R. Kelly, February 24, 1965.

February 25

MSC and the David Clark Company reached an agreement on a contract for Apollo Block I space suits. The first suits, expected by July 1, would go to North American for testing.

Memorandum, Matthew I. Radnofsky, MSC, to Gemini and Flight Support Procurement, Attn: Arc F. Lee, "Contract NAS 9-3642, Apollo Block I Suit, David Clark Company," February 25, 1965.

February 25

KSC supplemented Chrysler Corporation's contract for support services for the Saturn I and IB launch programs. Effective through June 30, 1968, the agreement would cost NASA \$41 million plus an award fee.

Astronautics and Aeronautics, 1965, p. 94.

February 25

Using a mockup Apollo CM, MSC Crew Systems Division tested the time in which an astronaut could don and doff the Block I pressure garment assembly while at various stations inside the spacecraft. The two subjects' average donning times were nine min 33 sec and 10 min; mean doffing times were four min five sec and five min 23 sec.

MSC, "ASPO Weekly Management Report, February 25-March 4, 1965."

February 25-March 4

To determine thermal and vacuum effects on the CM's parachutes, MSC Structures and Mechanics Division tested nylon samples in a vacuum under varying temperature conditions. After two weeks of exposure to this spacelike environment, the samples exhibited only a 16 percent loss of strength (as against a design allowable of 25 percent).

Ibid.

February 25-March 4

DeHavilland completed deployment tests of the CM's pop-up recovery antenna.

Ibid.

February 25-March 4

On the basis of in-house tests, Grumman recommended a scheme for exterior lighting on the LEM. The design copied standard aeronautical practice (i.e., red, port; green, starboard; and amber, underside). White lights marked the spacecraft, both fore and aft; to distinguish between the two white lights, the aft one contained a flasher.

Ibid.; "Monthly Progress Report No. 25," LPR-10-41, p. 22.

February 26

ASPO Manager Joseph F. Shea named William A. Lee as an assistant program manager. Lee, who previously headed the Operations Planning Division (which had been absorbed into Owen E. Maynard's Systems Engineering Division), now assumed responsibility for Apollo Operations (both the flight-test program and the lunar mission). Lee thus joined Harry L. Reynolds, also an assistant manager, who was

assigned to the LEM's development. Deputy Manager Robert O. Piland continued overseeing the CSM's development and, along with Shea, overall program management.

MSC News Release 65- 34, February 26, 1965.

February 26

Louis Walter, Goddard Space Flight Center geochemist, reported that his research with tektites indicated the lunar surface may be sandlike. Waiter had discovered the presence of coesite in tektites, believed to be particles of the moon sent into space when meteorites impact the lunar surface. Coesite, also found at known meteorite craters, is a form of silicon dioxide - a major constituent of sand - produced under high pressure. "If we accept the lunar origin of tektites," Walter said, "this would prove or indicate that the parent material on the moon is something like the welded tuft that we find in Yellowstone Park, Iceland, New Zealand, and elsewhere." Welded tuft was said to have some of the qualities of beach sand.

Astronautics and Aeronautics, 1965, p. 96.

During the Month

Because of a change in the size of the entry corridor, North American technicians sought to determine whether they might relax the requirements for pointing accuracy of the stabilization and control system at transearth injection. They could not. To ensure a delta-V reserve, the accuracy requirement must remain unchanged.

"Apollo Monthly Progress Report," SID 62-300-35, p. 8.

During the Month

Grumman reported three major problems with the LEM:

1. To enable the manufacturer to complete the design of the aft equipment bay, NASA must define the ground support equipment that would be supported by the LEM adapter platforms.
2. Space Technology Laboratories' difficulties with the descent engine injector (the combustion instability in the variable-thrust engine)
3. The need for a lightweight thrust chamber for the descent engine, one that would still meet the new duty cycle.

"Monthly Progress Report No. 25," LPR-10-41, p. 3.

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Advanced Design, Fabrication, and Testing

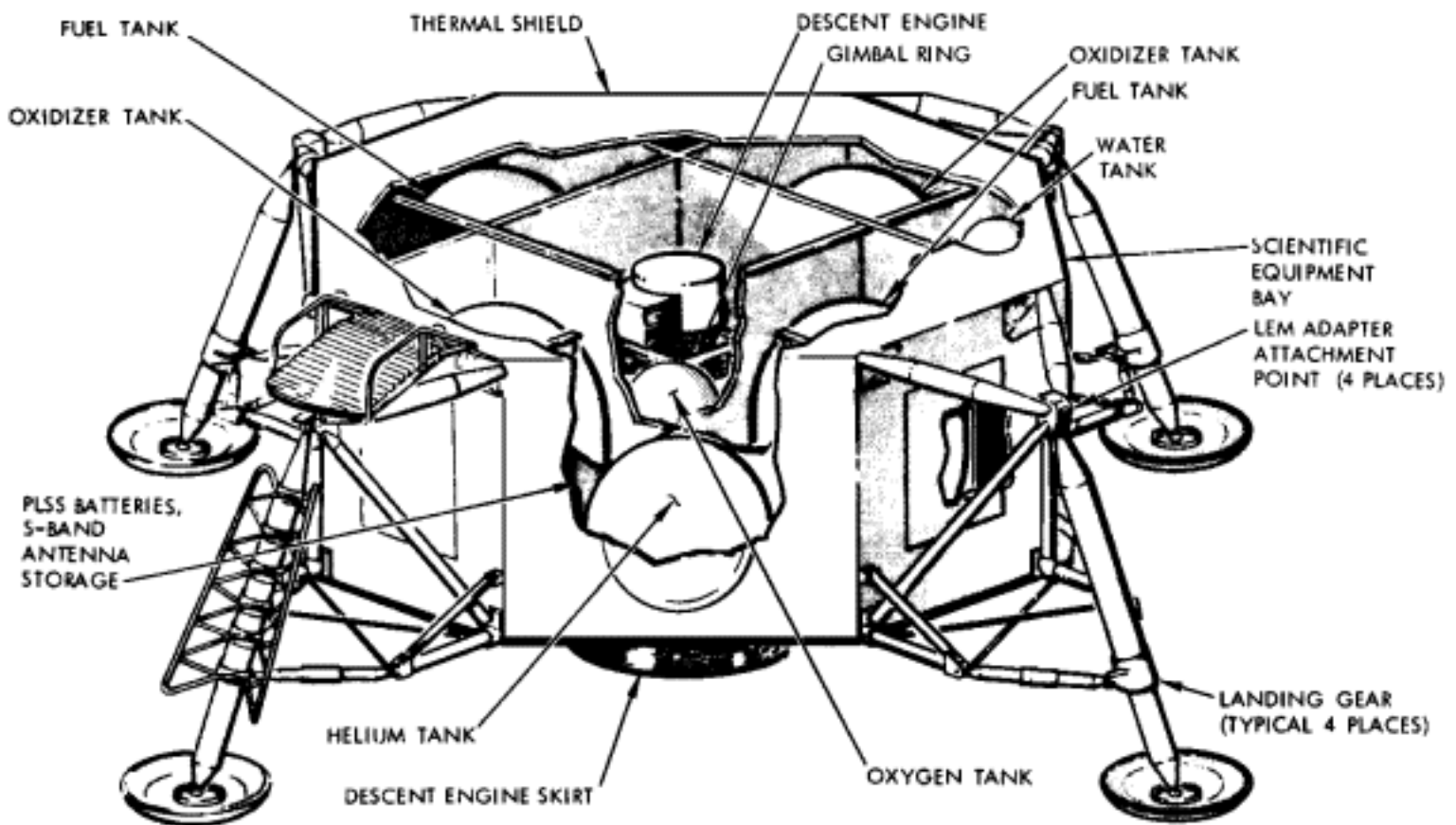
March 1965

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March 1

ASPO organized a new management group, the Configuration Control Board, to oversee proposals for engineering changes. The board comprised groups representing management, the three Apollo modules, and critical Apollo systems (guidance and navigation, spacecraft checkout equipment, and the extravehicular mobility unit).

MSC, "Apollo Spacecraft Program Office Configuration Management Plan, March 1, 1965," Revision A, March 19, 1965.



LEM descent stage.

March 2

MSC decided in favor of an "all-battery" LEM (i.e., batteries rather than fuel cells in both stages of the vehicle) and notified Grumman accordingly. Pratt and Whitney's subcontract for fuel cells would be terminated on April 1; also, Grumman would assume parenthood of GE's contract (originally let by Pratt and Whitney) for the electrical control assembly. MSC ordered an immediate cessation of all other efforts involved in the fuel-celled configuration. During the next several weeks, Grumman issued study contracts to Yardney Electric and Eagle-Picher for cost proposals. On April 1, the spacecraft manufacturer presented its proposal for an all-battery LEM; MSC's concurrence followed two weeks later.

A portable life support system (PLSS) battery charger would no longer be required, but three additional nonrechargeable PLSSs would be carried to provide for extravehicular activities. This change would now require a total of six nonrechargeable batteries.

On this same date, MSC ordered Grumman to end its work on a supercritical helium system for the LEM's ascent stage, and to incorporate an ambient mode for pressurization. All work on a supercritical system for the stage should be halted. However, Grumman should maintain the supercritical approach for the descent stage, while continuing parallel development on the ambient system. To permit the incorporation of either approach into the final design of the descent stage, components must be interchangeable.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Implementation of Electrical Power Subsystem and Supercritical Helium Pressurization Configuration Changes," March 2, 1965; memorandum, Owen E. Maynard, MSC, to Chief, Instrumentation and Electronic Systems Division, "LEM Power generation system," March 15, 1965; GAEC, "Implementation of LEM All-Battery Configuration," April 1, 1965; letter, Rector to GAEC, Mullaney, "Contract NAS 9-1100, Implementation of All-Battery Configuration," April 15, 1965; "Monthly Progress Report No. 25," LPR-10-41, pp. 1, 20; GAEC, "Monthly Progress Report No. 26," LPR-10-42, April 10, 1965, pp. 1, 31; TWX, James L. Neal, MSC, to GAEC, Attn: R. S. Mullaney, March 11, 1965.

March 2

MSC Structures and Mechanics Division presented their findings on the possibility of qualifying the spacecraft's thermal protection in a single mission. While one flight was adequate to prove the ablator's performance, the division asserted, it would not satisfy the requirements as defined in the specification.

Memorandum, Joseph N. Kotanchik, MSC, to Chief, Systems Engineering Division, "Adequacy of the SA 501 Mission to Qualify the Apollo Thermal Protection System," March 3, 1965, with enclosures.

March 3

NASA and General Motors' AC Spark Plug Division signed the definitive contract (cost-plus-incentive-fee type) for primary guidance and navigation systems for the Apollo spacecraft (both CMs and LEMs). The agreement, extending through December 1969, covered manufacturing and testing of the systems.

NASA News Release 65-33, March 3, 1965.

March 3

To prevent radiator freezing - and consequent performance degradation - in the Block I environmental control system, MSC ordered North American to supplement the system's coolant. Forty-five kg (100 lbs) of water would be stored in the SMs of airframes 012 and 014.

Letter, J. B. Alldredge, MSC, to NAA, Space and Information Systems Division, "Contract Change Authorization No. 309," March 3, 1965.

March 4

North American gave boilerplate 28 its third water drop test. Upon impact, the spacecraft again suffered some structural damage to the heatshield and the core, though much less than it had experienced on its initial drop. Conditions in this test were at least as severe as in previous ones, yet the vehicle remained watertight.

MSC, "ASPO Weekly Management Report, March 4-11, 1965."

March 5

Newton W. Cunningham, NASA's Ranger Program Manager, notified Apollo Program Manager Samuel C. Phillips that the Ranger investigators and Jet Propulsion Laboratory Ranger Project Office had submitted their unanimous choice of targets for the *Ranger IX* mission. The first two days of the launch windows were omitted from the plan; Day III: Crater Alphonsus; Day IV: Crater Copernicus; Day V: Crater Kepler; Day VI: Crater Aristarchus; Day VII: near Crater Grimaldi.

NASA's Office of Manned Space Flight agreed with Days IV-VII, but recommended a smooth highland area for Day I, a highland basin area for Day II, and the Flammarion highland basin for Day III.

Memorandum, Newton W. Cunningham, NASA, to Gen. Samuel C. Phillips, "Ranger 9 Target Selection," March 5, 1965; "Ranger D Target Selection," March 8, 1965.

March 5

Researchers at Ames Research Center began testing the stability of the Block II CM and escape tower (with canards) in the Center's wind tunnel. Tests would be conducted on the CM itself and while mated with the tower.

NAA, "Apollo Monthly Progress Report," SID 62-300-36, May 1, 1965, p. 3.

March 8

Preliminary investigation by Grumman indicated that, with an all-battery LEM, passive thermal control of the spacecraft was doubtful. (And this analysis did not include the scientific experiments package, which, with its radioisotope generator, only increased the problem. Grumman and MSC Structures and Mechanics Division engineers were investigating alternate locations for the batteries and modifications to the surface coatings of the spacecraft as possible solutions.

Memorandum, Lee N. McMillion, MSC, to Owen E. Maynard, "Radioisotope power generator," March 5, 1965.

March 8

Northrop-Ventura began qualification testing of the CM's earth landing sequence controller.

MSC, "ASPO Weekly Management Report, March 4-11, 1965."

March 8

Missiles and Rockets reported a statement by Joseph F. Shea, ASPO manager, that MSC had no serious weight problems with the Apollo spacecraft. The current weight, he said, was 454 kg (1,000 lbs) under the 40,823 kg (90,000 lb) goal. Moreover, the increased payload of the Saturn V to 43,091 kg (95,000 lbs) permitted further increases. Shea admitted, however, that the LEM was growing; recent decisions in favor of safety and redundancy could raise the module's weight from 13,381 kg to 14,575 kg (29,500 lbs to 32,000 lbs).

Astronautics and Aeronautics, 1965, p. 113.

March 9

Avco found that cracking of the ablator during cure was caused by incomplete filling, leaving small voids in the material. The company ordered several changes in the manufacturing process: a different shape for the tip of the "filling gun" to facilitate filling those cells that were slightly distorted; manual rather than automatic retraction of the gun; and x-raying of the ablator prior to curing. Using these new methods, Avco repaired the aft heatshield and toroidal corner of airframe 006, which was then re-cured.

No cracking was visible. The crew compartment heatshield for airframe 009 came through its cure equally well. Voids in the ablator had been reduced to about two percent. "It appears," Structures and Mechanics Division reported, "that the problem of cracking . . . has been solved by better manufacturing."

MSC, "ASPO Weekly Management Report, March 4-11, 1965"; MSC, "ASPO Weekly Management Report, March 11-18, 1965"; memorandum, C. H. Perrine, MSC, to B. Erb and Leo Chauvin, "Attached draft of letter to NASA Headquarters on use of Block I Command Modules for Block II Heat Shield Qualification," March 9, 1965, with attachment.

March 9

Initial flights of the LLRV interested MSC's Guidance and Control Division because they represented first flight tests of a vehicle with control characteristics similar to the LEM. The Division recommended the following specific items for inclusion in the LLRV flight test program:

- The handling qualities of the LEM attitude control system should be verified using the control powers available to the pilot during the landing maneuver. The attitude controller used in these tests should be a three-axis LEM rotational controller.
- The ability of pilots to manually zero the horizontal velocities at altitudes of 30.48 m (100 ft) or less should be investigated. The view afforded the pilot during this procedure should be equivalent to the view available to the pilot in the actual LEM.
- The LEM descent engine throttle control should be investigated to determine proper relationship between control and thrust output for the landing maneuver.
- Data related to attitude and attitude rates encountered in landing approach maneuvers were desirable to verify LEM control system design limits.
- Adequacy of LEM flight instrument displays used for the landing maneuver should be determined.

Guidance and Control Division would provide information as to control system characteristics and desired trajectory characteristics. D. C. Cheatham, a member of the Lunar Lander Research Vehicle Coordination Panel, would coordinate such support.

Memorandum, Robert C. Duncan, MSC, to Chief, Flight Crew Support Division, "Recommended items for LLRV Flight Test Program," March 9, 1965.

March 10

NASA announced that it had awarded a \$3,713,400 contract to Raytheon Company for digital systems for the Apollo program. The equipment, which would be installed at control and tracking stations, would display information telemetered from the spacecraft, and thus would support mission decisions on the ground.

NASA News Release 65-79, "NASA Names Raytheon for Apollo Digital Display Equipment," March 10, 1965.

March 11

MSC directed North American to incorporate the capability for storing a kit-type mapping and survey system into the basic Block II configuration. The actual hardware, which would be installed in the equipment bay of certain SMs (designated by MSC), would weigh up to 680 kg (1,500 lbs).

Letter, J. B. Alldredge, MSC, to NAA, Space and Information Systems Division, "Contract Change Authorization No. 317," March 11, 1965.

March 11

MSC notified Grumman that a device to recharge the portable life support system's (PLSS) batteries was no longer required in the LEM. Instead, three additional batteries would be stored in the spacecraft (bringing the total number of PLSS batteries to six).

TWX, James L. Neal, MSC, to GAEC, Attn: R. S. Mullaney, March 11, 1965.

March 11

MSC's Structures and Mechanics Division was conducting studies of lunar landing conditions. In one study, mathematical data concerning the lunar surface, LEM descent velocity, and physical properties of LEM landing gear and engine skirt were compiled. A computer was programmed with these data, producing images on a video screen, allowing engineers to review hypothetical landings in slow motion.

In another study, a one-sixth scale model of the LEM landing gear was dropped from several feet to a platform which could be adjusted to different slopes. Impact data, gross stability, acceleration, and stroke of the landing gear were recorded. Although the platform landing surface could not duplicate the lunar surface as well as the computer, the drop could verify data developed in the computer program. The results of these studies would aid in establishing ground rules for lunar landings.

MSC News Release 65-42, March 11, 1965.

March 11-18

MSC concurred in North American's recommendation that the 27½ degrees hang angle during parachute descent be retained. (Tests with one-tenth scale models of the CM indicated that, at the higher impact angles, excessive pressures would be exerted on the sidewalls of the vehicle.) Provisions for a "dual hang angle" were still in effect for Block I spacecraft up to airframe 017. Beginning with that number,

the face sheets on the aft heatshield would be modified to conform to the 27½ degree impact angle.

"ASPO Weekly Management Report, March 11-18, 1965."

March 11-18

Crew Systems Division (CSD) engineers were studying several items that, though intended specifically for the Gemini program, were applicable to Apollo as well:

- During recent tests of the urine nozzle by McDonnell, microorganisms had been found in the sample. This indicated that explosive decompression into very low temperatures had failed to sterilize the urine. To determine possible shifts in the microbial pattern, CSD was examining samples both before and after dumping.
- Division researchers completed microbiological examinations of Gemini food bags. They found that, even though disinfectant tablets were not completely effective, storage of the containers for periods up to two weeks was nonetheless feasible. (These studies thus reinforced earlier findings of bacterial growth in the bags.)

CSD engineers also evaluated the Gemini-type water dispenser and found it suitable for the Apollo CM as well.

Ibid.

March 11-18

During the flight of boilerplate (BP) 23, the Little Joe II's control system had coupled with the first lateral bending mode of the vehicle. To ensure against any recurrence of this problem on the forthcoming flight of BP-22, MSC asked North American to submit their latest figures on the stiffness of the spacecraft and its escape tower. These data would be used to compute the first bending mode of BP-22 and its launch vehicle.

Ibid.

March 12

During a pad abort, propellants from the CM's reaction control system (RCS) would be dumped overboard. Structures and Mechanics Division (SMD) therefore established a test program to evaluate possible deleterious effects on the strength of the earth landing system's nylon components. SMD engineers would expose test specimens to RCS fuel (monomethyl hydrazine) and oxidizer (nitrogen tetroxide). This testing series would encompass a number of variables: the length of exposure; the time period between that exposure and the strength test; the concentration of propellant; and the rate and direction of the air flow. Testing was completed near the end of the month. SMD reported that "no

significant degradation was produced by any of the test exposure conditions."

Memorandum, Robert B. West, MSC, to Paul E. Fitzgerald, "Preliminary report on minimum ELS requirements in the pad abort mode," March 12, 1965; "ASPO Weekly Management Report, March 11-18, 1965"; MSC, "ASPO Weekly Management Report, March 18-25, 1965."

March 15

MSC defined the functional and design requirements for the tracking light on the LEM:

- The light must be compatible for use with CSM scan telescope sextant optics in visual mode during darkside lunar and earth operations.
- The light must provide range capability of 324.1 km (175 nm) for darkside lunar operations when viewed with the CSM sextant.
- The probability of detection within three-minute search time at maximum range when viewed with CSM sextant must exceed 99 percent for worst lunar background.
- The light must flash at the optimum rate for ease of detection and tracking (60 flashes per minute ± 5 fpm).
- Brightness attenuation must be available for terminal phase operation and for minimizing spacecraft electrical energy drain.
- The light must be capable of inflight operation for continuous periods of one hour duration over four cycles.
- The light must have a total operating life of 30 hours at rated output with a shelf life of two years.
- The light was not required to be maintainable at the component level.
- The total system weight including cooling and electromagnetic interference shielding, if required, should not exceed 5.44 kg (12 lbs).

Letter, Joseph F. Shea, MSC, to GAEC, Attn: R. S. Mullaney, "Functional and design requirements for LEM tracking light," March 15, 1965.

March 15

In November 1964, MSC asked Grumman to conduct a study on the feasibility of carrying a radioisotope power supply as part of the LEM's scientific equipment. The subsequent decision to use batteries in the LEM power system caused an additional heat load in the descent stage. Therefore, MSC requested the contractor to continue the study using the following ground rules: consider the radioisotope power supply a requirement for the purpose of preliminary design efforts on descent stage configuration; determine impact of the radioisotope power supply - in particular its effect on passive thermal control of the descent stage; and specify which characteristics would be acceptable if any existing characteristics of the radioisotope power supply had an adverse effect. The radioisotope power was used only to supply power for the descent stage.

TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, subject: "Radioisotope Power Supply for Lunar Scientific Experiments," March 15, 1965.

March 15

An evaluation was made of the feasibility of utilizing a probe-actuated descent engine cutoff light during the LEM lunar touchdown maneuver. The purpose of the light, to be actuated by a probe extending 0.9 m (3 ft) beyond the landing gear pads, was to provide an engine cutoff signal for display to the pilot. Results of the study indicated at least 20 percent of the pilots failed to have the descent engine cut off at the time of lunar touchdown. The high percentage of engine-on landings was attributed to

1. poor location of the cutoff switch,
2. long reaction time (0.7 sec) of the pilot to a discrete stimulus (a light), and
3. the particular value of a descent rate selected for final letdown (4 ft per sec).

It was concluded that a 0.9-m (3-ft) probe would be adequate to ensure pilot cutoff of the descent engine before touchdown provided the pilot reaction time could be reduced to 0.4 sec or less by improving the location of the cutoff switch.

Richard Reid, MSC, MSC-IN-65-EG-10, "Simulation and Evaluation of Landing Gear Probe for Sensing Engine Cutoff Altitude During Lunar Landing," March 15, 1965.

March 15-17

North American conducted acoustic tests on the spacecraft's interior, using boilerplate (BP) 14. Noise levels generated by the spacecraft's equipment exceeded specifications. Prime culprits appeared to be the suit compressor and the cabin fans. North American engineers asserted, however, that the test vehicle itself, because of its sheet metal construction, compounded the problem. These tests with BP-14, they affirmed, were not representative of conditions in flight hardware. Data on communications inside the spacecraft were inconclusive and required further analysis, but the warning alarm was sufficiently loud to be heard by the crewmen.

"ASPO Weekly Management Report, March 18-25, 1965."

March 16

MSC estimated the number of navigational sightings that Apollo crewmen would have to make during a lunar landing mission:

- Translunar coast
 1. four maneuvers to align the inertial measurement unit (IMU)
 2. 20 navigational sightings requiring 10 maneuvers

- Transearth coast
 1. four maneuvers for IMU alignment
 2. 50 sightings, 25 maneuvers
- Lunar orbit
 1. 10 maneuvers for IMU alignment
 2. 24 sightings, 24 maneuvers.

[The Manned Space Flight Network was the primary source for navigational data during the coasting phases of the mission; and although the network could supply adequate data during the circumlunar phase as well, onboard capability must be maintained.]

Letter, C. L. Taylor, MSC, to NAA, Space and Information Systems Division, Attn: J. C. Cozad, "Contract NAS 9-150, Navigational Sightings Required for the Lunar Landing Mission," March 16, 1965.

March 16

Because the adapter panels, when deployed to 45 degrees, would block the command link with the LEM, a command antenna system on the adapter was mandatory. MSC therefore directed North American to provide such a device on the adapters for spacecraft 014, 101, and 102. This would permit command acquisition of the LEM in the interval between panel deployment and the spacecraft's clearing the adapter.

Letter, J. B. Alldredge, MSC, to NAA, Space and Information Systems Division, "Contract Change Authorization No. 322," March 16, 1965.

March 16

MSC directed North American to include nine scientific experiments on SA 204/Airframe 012: cardiovascular reflex conditioning, bone demineralization, vestibular effects, exercise ergometer, inflight cardiac output, inflight vector cardiogram, measurement of metabolic rate during flight, inflight pulmonary functions, and synoptic terrain photography. On June 25, the last five experiments were deleted and a cytogenic blood studies experiment was added.

Letter, J. B. Alldredge, MSC, to NAA, Space and Information Systems Division (S&ID), "Contract Change Authorization No. 323," March 16, 1965; letter, Alldredge to S&ID, "Contract Change Authorization No. 323, Revision 1," June 25, 1965.

March 16

MSC eliminated the requirement for relaying, via the LEM/CSM VHF link, transmissions from a moon-exploring astronaut to the earth. This change allowed the 279.0 megacycle (Mc) transmitters in both

vehicles to be eliminated; cleared the way for a common VHF configuration; and permitted duplex voice communications between astronaut and spacecraft. For communicating with the LEM, MSC directed North American to provide a 259.7 Mc transmitter in the CSM.

Letter, J. B. Alldredge, MSC, to NAA, Space and Information Systems Division, "Contract Change Authorization No. 320," March 16, 1965.

March 16

ASPO proposed deletion of a liftoff light in the Block II CM. The Block I design provided a redundant panel light which came ON at liftoff as a part of the emergency detection system (EDS). This light gave a cue to the pilot to verify enabling of the EDS automatic abort, for which manual backup was provided. The Block II CM would incorporate improved EDS circuitry without manual backup. Deletion of the liftoff light in the CM was proposed to save weight, power, space, and reliability, and to eliminate a crew distraction during the boost phase of flight.

Memorandum, Joseph F. Shea, MSC, to Assistant Directors for Flight Crew Operations and Flight Operations, "Deletion of Lift-off Light, Apollo Command Module," signed William A. Lee, March 16, 1965.

March 16-April 15

North American dropped boilerplate 1 twice to measure the maximum pressures the CM would generate during a high-angle water impact. These figures agreed quite well with those obtained from similar tests with a one-tenth scale model of the spacecraft, and supported data from the model on side wall and tunnel pressures.

"Apollo Monthly Progress Report," SID 62-300-36, p.3.

March 17

After extensive analysis, Crew Systems Division recommended that the "shirtsleeve" environment be kept in the CM. Such a design was simpler and more reliable, and promised much greater personal comfort than wearing the space suit during the entire mission.

Memorandum, Maxime A. Faget, MSC, to Manager, ASPO, "Crew Systems Division recommendation on establishment of suit wear criterion," March 17, 1965.

March 18

Russia launched *Voskhod II* from the Baikonur Cosmodrome in Kazakhstan, piloted by Colonel Pavel Belyayev and Lt. Colonel Aleksey Leonov into an orbit 497 by 174 km (309 by 108 mi) high. During

Voskhod II's second orbit, Leonov stepped from the vehicle and performed mankind's first "walk in space." After 10 min of extravehicular activity, he returned safely to the spacecraft (apparently leaving and entering through an airlock). On the following day, the two cosmonauts landed near Perm, Russia, after 17 orbits and 26 hours of flight.

Astronautics and Aeronautics, 1965, pp. 131-132, 136, 157.

March 18

Because of continuing developmental problems, Hamilton Standard chose B. F. Goodrich to replace International Latex as subcontractor for the garment portion of the Apollo space suit.

Letter, Joseph F. Shea, MSC, to NASA Headquarters, Attn: George E. Mueller, "Extravehicular Mobility Unit subcontractor change," March 18, 1965.

March 18

Grumman officials presented their findings on supercritical versus gaseous oxygen storage systems for the LEM [supercritical: state of homogeneous mixture at a certain pressure and temperature, being neither gas nor liquid]. After studying factors of weight, reliability, and thermal control, as well as cost and schedule impacts, they recommended gaseous tanks in the ascent stage and a supercritical tank in the descent stage. They stressed that this configuration would be about 35.66 kg (117 lbs) lighter than an all-gaseous one. Though these spokesmen denied any schedule impact, they estimated that this approach would cost about 2 million more than the all-gaseous mode. MSC was reviewing Grumman's proposal.

During the latter part of the month, Crew Systems Division (CSD) engineers also looked into the several approaches. In contrast to Grumman, CSD calculated that, at most, an all-gaseous system would be but 4.08 kg (9 lbs) heavier than a supercritical one. CSD nonetheless recommended the former. It was felt that the heightened reliability, improved schedules, and "substantial" cost savings that accompanied the all-gaseous approach offset its slim weight disadvantage.

During late April, MSC ordered Grumman to adopt CSD's approach (gaseous systems in both stages of the vehicle). [Another factor involved in this decision was the lessened oxygen requirement that followed substitution of batteries for fuel cells in the LEM. See March 2.]

GAEC, "Monthly Progress Report No. 27," LPR-10-43, May 10, 1965, p. 17; MSC, "ASPO Weekly Management Report, March 18-25, 1965"; "ASPO Weekly Management Report, March 25-April 1, 1965"; "ASPO Weekly Management Report, April 22-29, 1965."

March 18

Lawrence B. Hall, Special Assistant for Planetary Quarantine, Bioscience Programs, Office of Space

Science and Applications, NASA Headquarters, listed preliminary requirements for space in the Lunar Sample Receiving Station as recommended by the Communicable Disease Center of the Public Health Service. The estimates were based on CDC experience involving the design, construction, and operation of similar biological facilities and called for net space amounting to 7,201 sq m (77,492 sq ft) for laboratories, scientific support service facilities, offices and other areas, and did not reflect requirements of the U.S. Department of Agriculture or experimenters who could justify their work being done under quarantine conditions. Hall noted that Dr. Randolph Lovelace and the Chief of CDC were in agreement that the facility should be isolated, certainly not in or near a metropolitan area, and that an island would be favored.

Memorandum for Record, Lawrence B. Hall, "Primary barrier for lunar quarantine," March 18, 1965.

March 18-25

Structures and Mechanics Division engineers were studying several schemes for achieving the optimum weight of Block II CMs without compromising landing reliability: reducing velocity by retrorockets or "explosions" in the parachutes; controlling roll attitude to 0 degrees at impact through a "rotatable pot" structure; changing landing medium (i.e., shape hole in water and/or aeration of the water).

MSC, "ASPO Weekly Management Report, March 18-25, 1965."

March 18-25

Crew Systems Division (CSD) engineers, continuing their evaluation of liquid-cooled garments (LCG), tested Hamilton Standard's newest version (the LCG-8). The manufacturer had modified placement of the tubes and had used a stretchable, more closely knit fabric. CSD found this style an improvement over its predecessor (the LCG-3): it was more efficient, more comfortable, and easier to don and doff. CSD officials accordingly froze the configuration of the garment around this latest model. Further design work would be minimal (chiefly interface modifications and improvements in fabrication techniques).

Ibid.

March 18-25

The Atomic Energy Commission evaluated proposals by Radio Corporation of America and General Electric (GE) for an isotope generator for the Surveyor lunar roving vehicle, and assigned follow-on work to the latter firm. GE's concept, it was felt, was compatible with the possible requirement that the fuel source might have to be carried separately aboard the LEM. MSC's Propulsion and Power Division reported that the generator's "prospects . . . look[ed] very promising."

Ibid.

March 19

Bell Aerosystems Company reported that a study had been made to determine if it were practical to significantly increase simulation time without major changes to the Lunar Landing Research Vehicle (LLRV). This study had been made after MSC personnel had expressed an interest in increased simulation time for a trainer version of the LLRV. The current LLRV was capable of about 10 minutes of flight time and two minutes of lunar simulation with the lift rockets providing one-sixth of the lift. It was concluded that lunar simulation time approaching seven minutes could be obtained by doubling the 272-kg (600-lb) peroxide load and employing the jet engine to simulate one-half of the rocket lift needed for simulation.

A major limiting factor, however, was the normal weather conditions at Houston, where such a training vehicle would be located. A study showed that in order to use a maximum peroxide load of 544 kg (1,200 lbs), the temperature could not exceed 313K (40 degrees F); and at 332K (59 degrees F) the maximum load must be limited to 465 kg (1,025 lbs) of peroxide. On the basis of existing weather records it was determined there would be enough days on which flights could be made in Houston on the basis of 544 kg (1,200 lbs) peroxide at 313K (40 degrees F), 465 kg (1,025 lbs) at 332K (59 degrees F), and 354 kg (775 lbs) at 353K (80 degrees F) to make provisions for such loads.

Letter, John Ryken, Bell Aerosystems Company, to Ronald Decrevel, "Preliminary Study of Methods of Increasing LLRV Lunar Simulation Time," March 19, 1965; letter, Ryken to Decrevel, "Effect of Houston Temperatures on Allowable LLRV Weight and Flight Time," March 23, 1965.

March 21

NASA launched *Ranger IX*, last of the series, from Cape Kennedy aboard an Atlas-Agena vehicle. The target was Alphonsus, a large crater about 12 degrees south of the lunar equator. The probe was timed to arrive when lighting conditions would be at their best. The initial trajectory was highly accurate; uncorrected, the craft would have landed only 400 miles north of Alphonsus. On March 23, a midcourse correction increased *Ranger IX*'s speed and placed it on a near-perfect trajectory: the spacecraft impacted the following day only four miles from the original aiming point.

From 2,092 km (1,300 mi) out until it was destroyed on impact, *Ranger IX*'s six television cameras took 5,814 pictures of the lunar surface. These pictures were received at Jet Propulsion Laboratory's Goldstone, Calif., Tracking Laboratory, where they were recorded on tape and film for detailed analysis. They also were released to the nation's three major television networks in "real time," so millions of Americans followed the spacecraft's descent. The pictures showed the rim and floor of the crater in fine detail: in those just prior to impact, objects less than a foot in size were discernible.

A panel of scientists presented some preliminary conclusions from *Ranger IX* at a press conference that same afternoon. Crater rims and ridges inside the walls, they believed, were harder and smoother than the moon's dusty plains, and therefore were considered likely sites for future manned landings.

Generally, the panel was dubious about landing on crater floors however. Apparently, the floors were solidified volcanic material incapable of supporting a spacecraft. Investigators believed several types of craters were seen that were of nonmeteoric origin. These findings reinforced arguments that the moon at one time had experienced volcanic activity.

Aeronautics and Aeronautics, 1965, pp. 140, 142, 143, 146, 148-149; NASA News Release 65-25, "NASA Readies Two Ranger Spacecraft for Moon Missions," February 4, 1965; NASA News Release 65-96, "Ranger IX to Send World's First Live Moon Photos," March 23, 1965.

March 22

Glynn S. Lunney was named by MSC Director Robert R. Gilruth as Assistant Flight Director for Apollo missions 201 and 202. Lunney would continue to serve as Chief of the Flight Dynamics Branch, Flight Control Division, and as MSC Range Safety Coordinator with the U.S. Air Force Eastern Test Range.

MSC Announcement 65-33, "Appointment of Assistant Flight Director for Apollo 201 and 202 Missions," March 22, 1965.

March 22

The change from LEM fuel cells to batteries eliminated the need for a hard-line interstage umbilical for that system and the effort on a cryogenic umbilical disconnect was canceled. The entire LEM pyrotechnic effort was redefined during the program review and levels of effort and purchased parts cost were agreed upon.

MSC, "ASPO Weekly Management Report, March 18-25, 1965."

March 22

Jet Propulsion Laboratory scientists W. L. Sjogren and D. W. Trask reported that as a result of *Ranger VI* and *Ranger VII* tracking data, Deep Space Instrumentation Facility station locations could be determined to within 10 m (10.9 yds) in the radial direction normal to the earth's spin axis. Differences in the longitude between stations could be calculated to within 20 m (21.9 yds). The moon's radius had been found to be 3 km (1.86 mi) less than was thought, and knowledge of its mass had been improved by an order of magnitude.

Aeronautics and Aeronautics, 1965, p. 160.

March 22

ASPO summarized their requirements for entry monitoring and backup reentry range control:

- The flight crew would monitor the entry to detect a skip or excessive "g" trajectory early enough to allow manual takeover and safe reentry.
- The entry corridor should be verified and indications of too steep or shallow an entry displayed to the crew.
- The spacecraft guidance and control systems should provide manual range control capability after failures in the primary guidance and navigation system (PGNS) prior to reentry, and after discrete or catastrophic failures in the PGNS during reentry.

Memorandum, Joseph F. Shea, MSC, to Chief, Guidance and Control Division, "Requirements for Command Module entry monitoring and backup reentry ranging capability," March 22, 1965.

March 22

MSC ordered Grumman to halt development of linear-shaped charge cutters for the LEM's interstage umbilical separation system, and to concentrate instead on redundant explosive-driven guillotines. By eliminating this parallel approach, and by capitalizing on technology already worked out by North American on the CSM umbilical cutter, this decision promised to simplify hardware development and testing. Further, it promised to effect significant schedule improvements and reductions in cost.

Memorandum, W. F. Rector III, MSC, to Contracting Officer, LEM, "Request for PCCP-MDF Driven Guillotine," March 22, 1965.

March 23

A two-stage Titan II rocket boosted *Gemini III* and its crew, astronauts Virgil I. Grissom and John W. Young, into an elliptical orbit about the earth. After three orbits, the pair manually landed their spacecraft in the Atlantic Ocean, thus performing the first controlled reentry. Unfortunately, they landed much farther from the landing zone than anticipated, about 97 km (60 miles) from the aircraft carrier U. S.S. *Intrepid*. But otherwise the mission was highly successful. *Gemini III*, America's first two-manned space mission, also was the first manned vehicle that was maneuverable. Grissom used the vehicle's maneuvering rockets to effect orbital and plane changes.

NASA News Release 65-81, "NASA Schedules First Manned Gemini Flight from Cape Kennedy," March 17, 1965; James M. Grimwood and Barton C. Hacker, with Peter J. Vorzimmer, *Project Gemini Technology and Operations: A Chronology* (NASA SP-4002, 1969), pp. 189-191; *Astronautics and Aeronautics, 1965*, pp. 145-46; "MSC Fact Sheet 291-A, Gemini 3 Flight" [Ivan D. Ertel], April 1965.

March 23-24

Part I of the Critical Design Review of the crew compartment and the docking system in the Block II CM was held at North American. Systems Engineering (SED) and Structures and Mechanics (SMD) divisions, respectively, evaluated the two areas.

- Crew compartment:
 1. The restraint harness, acceptable in the Block I vehicle, interfered with attachments for the suit umbilicals. These attachments were critical for suit ventilation and mobility; the harness location was likewise critical for crew impact tolerances. Evaluation of alternate locations for the harness and umbilical fittings - or both - awaited the availability of a couch mockup. Manned sled tests might be needed to verify any harness changes.
 2. Restraints at the sleep station must be redesigned. At present, they did not allow sufficient room for a crewman in his pressure suit.
 3. To save weight, North American planned to strap crew equipment to shelves and bulkheads (rather than stowing such gear in compartments, as was done on the Block I vehicle).
 4. Most serious, in an earth landing, when the attenuator struts compressed, the couches would strike a portable life support system (PLSS). "No analysis has been made," SED reported, "to show that this is acceptable." For in such an occurrence, the crew could be injured or killed, the oxygen tank in the PLSS (under about 409 kg [900 lbs] of pressure) could explode, and the aft bulkhead might be ruptured. North American was scheduled to report on this problem on April 27.
- Docking system:
 1. SMD approved the probe and drogue concept, but recommended that fittings be standardized throughout (so that only one tool was needed).
 2. The division also approved North American's design for the outer side hatch (i.e., limiting its deployment to 90 degrees), pending MSC's final word on deployment requirements.
 3. The division recommended that the forward hatch mechanism be simplified. (North American warned of schedule delays.)

MSC, "ASPO Weekly Management Report, March 18-25, 1965"; MSC, "ASPO Weekly Management Report, March 25-April 1, 1965"; letter, H. G. Osbon, NAA, to NASA MSC, Attn: C. L. Taylor, "Contract NAS 9-150, R&D for Apollo Spacecraft Minutes of Critical Design Review No. 2, Phase I conducted on 23- 24 March, 1965," June 15, 1965.

March 24

Grumman ordered Space Technology Laboratories to increase the lifetime of the thrust chamber in the LEM's descent engine. This required substantial redesigning and was expected to delay the engine's qualification date about seven months.

MSC, "ASPO Weekly Management Report, April 1-8, 1965."

March 24

ASPO requested the Structures and Mechanics Division (SMD) to study the problem of corrosion in the

coolant loops of the CM's environmental control system, and to search for effective inhibitors. Current efforts at North American to lessen corrosion included improved hardware and operating procedures, but stopped short of extensive redesigning; and it would be some time before conclusive results could be expected. Early in May, Owen E. Maynard, chief of the Systems Engineering Division, directed SMD immediately to begin its search for inhibitors. If by July 1966 the corrosion problem remained unresolved, SMD could thus recommend stopgap measures for the early spacecraft.

Memorandum, Joseph N. Kotanchik, MSC, to Chief, Systems Engineering Division, "Water/glycol corrosion," March 24, 1965, with enclosure: "Detailed Plan of Investigation on Corrosion Effects of Water/ Glycol Mixtures on Spacecraft Radiators"; memorandum, Owen E. Maynard, MSC, to Chief, Structures and Mechanics Division, "Water/ Glycol Corrosion," May 4, 1965.

March 24

MSC contacted Grumman with reference to the LEM ascent engine environmental tests at Arnold Engineering Development Center (AEDC), scheduled for cell occupancy there from May 1, 1965, until September 1, 1965. It was MSC's understanding that the tests might begin without a baffled injector. It was pointed out, however, that the first test was expected to begin July 1, and since the recent baffle injector design selection had been made, time remained for the fabrication of the injector, checkout of the unit, and shipment to AEDC for use in the first test.

Since the baffled injector represented the final hardware configuration, it was highly desirable to use the design for these tests. MSC requested that availability of the injector constrain the tests and that Grumman take necessary action to ensure compliance.

TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, March 24, 1965.

March 24

ASPO Manager Joseph F. Shea said that the first major test of an Apollo spacecraft AFRM 009 tended to pace the CSM program and therefore had taken on a special program significance. Reflecting this significance, both MSC and North American had applied specific additional senior management and project engineering effort to that spacecraft. In the fall of 1965, Robert O. Piland, ASPO Deputy Manager, was assigned to give priority to AFRM 009 to complement and support the normal ASPO project engineering activities. North American simultaneously gave a special assignment regarding 009 to Assistant Program Manager Charles Feltz.

Recently North American had assigned a Chief Project Engineer to a full-time assignment on 009. ASPO's current management and project engineering plan for the spacecraft was: Piland would continue to give priority attention to 009, in addition to his normal duties, and would deal directly with Feltz. The ASPO Chief Project Engineer Rolf W. Lanzkron would be responsible for all ASPO project engineering activities for all spacecraft to be launched at KSC. He would give priority attention to all Block I

spacecraft, ensuring schedules through adequate planning, timely decisions, and rapid referral of problems to the Deputy Manager where appropriate. Lanzkron would coordinate with North American's Chief Project Engineer, Ray Pyle, on matters pertaining to 009. Lanzkron would be supported in the Block I project engineering effort by a group headed by William Petynia.

Memorandum, Joseph F. Shea, MSC, to Distribution, "MSC Management and Project Engineering for AFRM 009," March 24, 1965.

March 25-April 1

After further design studies following the M-5 mockup review (October 5-8, 1964), Grumman reconfigured the boarding ladder on the forward gear leg of the LEM. The structure was flattened, to fit closer to the strut. Two stirrup-type steps were being added to ease stepping from the top rung to the platform or "porch" in front of the hatch.

"ASPO Weekly Management Report, March 25-April 1, 1965"; letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Line Item 4-Lunar Excursion Module, M-5 Review, Chits 1-4 and 1-13," April 30, 1965.

March 25-April 1

North American completed negotiations with Ling-Temco-Vought for design support on the environmental control radiators for Block II CSMs.

"Apollo Monthly Progress Report," SID 62-300-36, p. 8; "ASPO Weekly Management Report, March 25-April 1, 1965."

March 25-April 1

Crew Systems Division confirmed the feasibility of commonality of personal communications equipment for the entire Apollo program.

"ASPO Weekly Management Report, March 25-April 1, 1965"; memorandum, Richard S. Johnston, MSC, to Chief, Systems Engineering Division, Attn: R. Williams, "Apollo space suit communications program definition," April 5, 1965.

March 26

North American began a series of water impact tests with boilerplate 1 to obtain pressure data on the upper portions of the CM. Data on the side walls and tunnel agreed fairly well with those obtained from 1/10 scale model drops; this was not the case with pressures on the top deck, however.

"Apollo Monthly Progress Report," SID 62-300-36, p. 3.

March 27

Test Series I on spacecraft 001 was completed at WSTF Propulsion Systems Development Facility. Vehicle and facility updating in progress consisted of activating the gimbal subsystem and installing a baffled injector and pneumatic engine propellant valve. The individual test operations were conducted satisfactorily, and data indicated that all subsystems operated normally. Total engine firing time was 765 seconds.

"Apollo Monthly Progress Report," SID 62-300-36, pp. 13, 18; memorandum, Spacecraft 001 Project Engineer, to Distribution, "Review of S/C 001 and TF-2 Test Results," April 19, 1965.

March 29

MSC decided upon a grid-type landing point designator for the LEM. Grumman would cooperate in the final design and would manufacture the device; MIT would ensure that the spacecraft's guidance equipment could accept data from the designator and thus change the landing point.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Item 3; LEM Landing Point Designator," March 29, 1965.

March 29

William F. Rector, the LEM Project Officer in ASPO, replied to Grumman's weight reduction study (submitted to MSC on December 15, 1964). Rector approved a number of the manufacturer's suggestions:

- Delete circuit redundancy in the pulse code modulation telemetry equipment
- Eliminate the VHF lunar stay antenna
- Delete one of two redundant buses in the electrical power system
- Move the batteries for the explosive devices (along with the relay and fuse box assembly) from the ascent to the descent stage
- Reduce "switchover" time (the length of time between switching from the oxygen and water systems in the descent stage to those in the ascent portion of the spacecraft and the actual liftoff from the moon's surface). Grumman had recommended that this span be reduced from 100 to 30 min; Rector urged Grumman to reduce it even further, if possible. He also ordered the firm to give "additional consideration" to the whole concept for the oxygen and water systems:
 1. in light of the decisions for an all-battery LEM during translunar coast; and
 2. possibility of transferring water from the CM to the LEM.

But ASPO vetoed other proposals to lighten the spacecraft:

- Delete the high intensity light. Because the rendezvous radar had been eliminated from the CSM, Rector stated flatly that the item could "no longer be considered as part of the weight reduction effort."
- Combine the redundant legs in the system that pressurized the reaction control propellants, to modularize" the system. MSC held that the parallel concept must be maintained.
- Delete the RCS propellant manifold.
- Abridge the spacecraft's hover time. Though the Center was reviewing velocity budgets and control weights for the spacecraft, for the present ASPO could offer "no relief."

And lastly, Rector responded to Grumman's proposals for staging components of the extravehicular mobility unit (EMU). These proposals had been made on the basis of a LEM crew integration systems meeting on January 27, at which staging had been explored. Those discussions were no longer valid, however. MSC had since required a capability for extravehicular transfer to the LEM. In light of this complicating factor, MSC engineers had reevaluated the entire staging concept. Although staging still offered "attractive" weight reductions, they determined that, at present, it was impractical. Accordingly, Rector informed Robert S. Mullaney, the LEM Program Manager at Grumman, that his firm must revert to the pre-January 27 position - i.e., the EMU and other assorted gear must be stored in the ascent stage of the spacecraft.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Weight Reduction Study Status," March 29, 1965.

March 29-April 4

Beech Aircraft Corporation stopped all end-item acceptance tests of hydrogen and oxygen tanks as a result of interim failure reports issued against three tanks undergoing tests. Failures ranged from exceeding specification tolerances and failure to meet heat leak requirements to weld failure on the H2 tank. Beech would resume testing when corrective action was established and approved by North American.

NAA, "Project Apollo Spacecraft Test Program Weekly Activity Report (Period 29 March 1965 through 4 April 1965)," p. 4; "Apollo Monthly Progress Report," SID 62-300-36, p. 12.

March 31

MSC requested that Grumman incorporate in the command list for LEMs 1, 2, and 3 the capability for turning the LEM transponder off and on by real-time radio command from the Manned Space Flight Network. Necessity for capability of radio command for turning the LEM transponder on after LEM separation resulted from ASPO's decision that the LEM and Saturn instrument unit S-band transponders would use the same transmission and reception frequencies.

TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, March 31, 1965.

During the Month

MSC directed Grumman to use supercritical helium only in the descent stage of the LEM; Grumman completed negotiations with AiResearch for the storage system.

"Monthly Progress Report No. 26," LPR-10-42, p. 1.

During the Month

Bell Aerosystems Company received Grumman's go-ahead to resume work on the thrust chamber of the LEM ascent engine. Bell conducted a dozen stability tests using an injector fitted with a 31.75 mm (1.25 in), Y-shaped baffle. Thus far, the design had recovered from every induced disturbance (including widely varied fuel-to-oxygen ratios). Also, to ease the thermal soakback problem, Bell planned to thicken the chamber wall.

"Monthly Progress Report No. 26," LPR-10-42, pp. 8, 17.

During the Month

Grumman recommended to MSC that the stroking gear pad be used on the LEM and that design effort to refine crushing performance should continue.

Ibid., p. 1.

During the Month

Grumman reported the status of their development program on the LEM landing gear. The firm was:

- Continuing hardware design on the 424-cm (167-in) gear.
- Testing honeycomb crushing characteristics at velocities up to 7.62 m per sec (25 fps).
- Studying high-density honeycomb materials that would still be compatible with a lightweight secondary strut.
- Studying the possibility of strengthening the rim of the fixed (non stroking) footpad.
- Designing a boilerplate footpad for use in drop tests.
- Planning drops of a 406-cm (160-in) gear.
- Continuing testing on primary and secondary struts.

Ibid., pp. 13-14.

During the Month

Space Technology Laboratories' major problems with the LEM descent engine, Grumman reported, were attaining high performance and good erosion characteristics over the entire throttling range.

Ibid., p. 19.

During the Month

Three flights were made with the Lunar Landing Research Vehicle (LLRV) for the purpose of checking the automatic systems that control the attitude of the jet engine and adjusting the throttle so the jet engine would support five-sixths of the vehicle weight.

On March 11 representatives of Flight Research Center (FRC) visited MSC to discuss future programs with Warren North and Dean Grimm of Flight Crew Support Division. A budget for operating the LLRV at FRC through fiscal year 1966 was presented. Consideration was being given to terminating the work at FRC on June 30, 1966, and moving the vehicles and equipment to MSC.

A contract was placed (on March 17) to erect a 12.19 x 12.19-m (40 x 40 ft) building at the south base area of FRC, where the LLRV was flown. Construction was expected to be complete in 60 days and the building should reduce LLRV interference with Air Force operations and enhance the preflight procedures.

Letter, Office of Director, FRC, to NASA Headquarters, "Lunar Landing Research Vehicle Progress Report No. 21 for period ending March 31, 1965,"sgd. De E. Beeler for Paul F. Bikle, April 7, 1965.

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Advanced Design, Fabrication, and Testing

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April 1

Grumman presented to MSC its recommendations for an all-battery electrical power system for the LEM:

- Two batteries in the ascent stage
- Four batteries in the descent stage
- A new power distribution system
- Active cooling for the descent batteries and electrical control assemblies

Following a review of cost and resources proposals, MSC approved Grumman's configuration, and on April 15 gave the LEM manufacturer a go-ahead.

MSC requested that Grumman evaluate the possibility of furnishing power for the pre-separation checkout of the LEM wholly from that module's power supply. This procedure would obviate the CSM's supplying that power during the initial 60 min of the checkout. This would simplify the electrical connections between the two spacecraft and eliminate the possible requirement for an additional battery charger in the CSM. The Center advised North American, however, that such a charger might still be needed on Block II CSMs.

GAEC, "Implementation of LEM All-Battery Configuration," April 1, 1965; letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Implementation of All-Battery LEM Configuration," April 15, 1965.

April 1

The first stage of the Saturn IB booster (the S-IB-1) underwent its first static firing at Huntsville, Alabama. The stage's eight uprated H-1 engines produced about 71,168-kilonewtons (1.6 million lbs) thrust. On April 23, Marshall and Rocketdyne announced that the uprated H-1 had passed qualification testing and was ready for flight.

Astronautics and Aeronautics, 1965, p. 162; *Space Business Daily*, April 7, 1965, p. 209.

April 1

Apollo Program Director Samuel C. Phillips told ASPO Manager Joseph F. Shea that Bellcomm, Inc., was conducting a systems engineering study of lunar landing dynamics to determine "functional compatibility of the navigation, guidance, control, crew, and landing gear systems involved in Apollo lunar landing." Phillips asked that he be advised of any specific assignments in these areas which would prove useful in support of the ASPO operation.

Shea replied, "We are currently evaluating the LEM lunar landing system with the Apollo contractors and the NASA Centers. We believe that the landing problem is being covered adequately by ourselves and these contractors." Shea added that a meeting would be held at Grumman April 21 and 22 to determine if there were any deficiencies in the program, and that he would be pleased to have Bellcomm attend the meeting and later make comments and recommendations.

Letter, Phillips to Shea, April 1, 1965; letter, Shea to Phillips, April 6, 1965.

April 1-7

H. I. Thompson Company's first combustion chamber with a tape-wrapped throat successfully withstood a series of four test firings. If further testing confirmed its performance, reported the resident Apollo office at Bethpage, N.Y., the design would be used in the LEM's ascent engine. (It would replace the current compression-molded throat, which suffered from excessive cracking.)

MSC, "Weekly Activity Report for Office of the Associate Administrator, Manned Space Flight, April 4-10, 1965," p. 2.

April 1-8

The thrust mount for the LEM ascent engine cracked during vibration testing. The mount would be strengthened.

During the same period, Bell tested the first one-piece ablative chamber for the ascent engine (designed to replace the molded-throat design, which developed cracks during testing). In firings that totaled over eight minutes, Bell engineers found that the unit suffered only negligible throat erosion and decay of chamber pressure.

"ASPO Weekly Management Report, April 1-8, 1965."

April 1-8

The cryoformed steel bottle for the portable life support system, manufactured by Arde-Portland, Inc.,

passed its first burst and cycling tests, which Crew Systems Division called a "major milestone" in its development.

Ibid.

April 1-8

MSC and Grumman reviewed the requirement for a backup mode of entering and leaving the LEM while on the moon. The new rectangular hatch was deemed "inherently highly reliable," and the only failure that was even "remotely possible" was one of the hatch mechanism. The proposal to use the top (or transfer) hatch was impractical, because it would cost 13.6 kg (30 lb) and would impose an undue hazard on both the crew and the spacecraft's thermal shield.

Ibid.

April 1-8

North American reviewed nondestructive techniques for testing honeycomb structures. The principal method involved ultrasonic testing, but this approach was highly dependent upon equipment and procedure. At best, ultrasonic testing could do no more than indicate faulty bond areas, and these could be confirmed only through destructive tests. A number of promising nondestructive methods were being investigated, but thus far none was satisfactory. The danger in this situation was that, if design allowables had to be lowered to meet the results of strength distribution tests, the weight advantage of honeycomb construction might be lost.

"ASPO Weekly Management Report, April 1-8, 1965"; memorandum, D. D. Few, RASPO-Downey, to R. H. Ridnour, "Recent Bonding Problems at NAA," May 12, 1965, with enclosures.

April 2

North American presented final results of their modification to the electrical power system for spacecraft 011 to solve the power and energy problem. This consisted of the addition of three batteries which would be mounted on the center platform and used to supply instrumentation and mission control programmer loads during flight. These batteries would be paralleled with the entry and landing batteries at impact to provide power for postlanding recovery loads. MSC concurred with this approach.

Memorandum, Owen E. Maynard, MSC, to Chief, Instrumentation and Electronic Systems Division, "S/C 011 circuit protection," April 8, 1965; TWX, C. L. Taylor, MSC, to NAA, Space and Information Systems Div., Attn: J. C. Cozad, April 13, 1965.

April 2

Following a presentation by North American on the status of the adapter, MSC spelled out specific and detailed design changes required.

Letter, J. B. Alldredge, MSC, to NAA, Space and Information Systems Div., Attn: J. C. Cozad, "Contract NAS 9-150, Spacecraft LEM Adapter (SLA) change status," April 2, 1965, with enclosure, "Technical Description of Proposed SLA Changes."

April 5-11

Rocketdyne completed qualification tests on two CM reaction control engines. These were successful. One of the nozzle extensions failed to seat, however, and was rejected. Its failure was being analyzed.

NAA, "Project Apollo Spacecraft Test Program Weekly Activity Report (Period 5 April 1965 through 11 April 1965)," p. 3.

April 5-16

To evaluate the Block 11 CSM's manual thrust vector control, five pilots, among them two astronauts, flew the Apollo simulator at Honeywell. These mock flights demonstrated that the manual control was sufficiently accurate for transearth injection. Also, researchers determined that the optical alignment sight provided the crewmen with attitude references adequate for midcourse maneuvers.

NAA, "Apollo Monthly Progress Report," SID 62-300-37, June 1, 1965, p. 6.

April 6

Quality verification vibration tests were completed on the command module of spacecraft 006.

Ibid., p. 1; memorandum, W. D. Graves, MSC, to Distr., "Quality Vibration Verification Testing (QVVT) Facility Validation," April 27, 1965.

April 7

A LEM/CSM interface meeting uncovered a number of design problems and referred them to the Systems Engineering Division (SED) for evaluation: the requirement for ground verification of panel deployment prior to LEM withdrawal; the requirement for panel deployment in earth orbit during the SA-206 flight; the absence of a backup to the command sequencer for jettisoning the CSM (Flight Projects Division [FPD] urged such a backup signal); and Grumman's opposition to a communications link with the LEM during withdrawal of the spacecraft (FPD felt that such a link was needed through verification of reaction control system ignition). SED's recommendations on these issues were anticipated by April 22.

MSC, "ASPO Weekly Management Report, April 8-15, 1965"; memorandum, R. W. Lanzkron, MSC, to Chief, Systems Engineering Division, "LEM-1 CSM Interface Meeting," April 19, 1965; memorandum, Lanzkron to Chief, Systems Engineering Division, "LEM-1 CSM Interface Meeting," April 15, 1965.

April 8

Goddard Space Flight Center awarded a \$4.6 million contract to RCA for a deep space tracking and data acquisition system. The equipment, to be installed on Cooper's Island, Bermuda, would support a variety of NASA space missions, including Apollo flights.

Astronautics and Aeronautics, 1965, pp. 174-175; *Space Business Daily*, April 12, 1965, p. 231.

April 8-15

The MSC Crew Performance Section evaluated the ability of two pressure-suited astronauts to put on and take off their external thermal garments and portable life support systems (PLSS). The subjects had considerable difficulty positioning the PLSS; also, though these modified thermal garments were much easier to don and doff, the subjects still experienced some trouble inserting the second arm.

MSC, "ASPO Weekly Management Report, April 8-15, 1965."

April 8-15

Bell Aerosystems tested a pressure transducer for the LEM's ascent propulsion system (the first time such a device was ever used with hypergolic fuels). The transducer proved extremely accurate at sensing pressure differences between the propellant lines.

Ibid.; "Monthly Progress Report No. 27," LPR-10-43, p. 13.

April 9

George E. Mueller, Associate Administrator for Manned Space Flight, announced the transfer of control over manned space flights from Cape Kennedy, Fla., to Houston, Texas. MSC's Mission Control Center would direct the flights from end of liftoff through recovery.

NASA News Release 65-119, "Mission Control Center at Houston to Handle GT-4, Subsequent Manned Flights," April 9, 1965.

April 9

Crew Systems Division (CSD) decided on a single garment for both thermal and micrometeoroid

protection for Apollo astronauts. CSD's Richard S. Johnston summarized factors underlying this decision:

- The integrated garment would be easier to don and thus would simplify preparations for leaving the LEM; it would fit better and afford greater visibility, mobility, and access to suit controls.
- The dual-purpose garment would weigh about 2.3 kg (5 lbs) less than would two separate protective covers. And because it would consume less storage space, the ascent stage of the spacecraft could be lightened by about three pounds. Involved here, also, was the abort weight of the LEM. It was assumed that the most adverse conditions would be encountered during an "immediate abort," before the crew could depressurize the cabin or jettison now-superfluous equipment (such as the thermal/meteoroid garment).
- Conversely, separate protective garments - and the "staging" procedure they entailed - would require modifications to the spacecraft and would shorten the astronauts' stay outside the LEM. Moreover, and perhaps even more important, separate garments would limit rescue possibilities and would lessen crew safety.

Johnston emphasized that, if for any reason the integration scheme proved impracticable, the division could still return to the concept of separate thermal and micrometeoroid garments.

Memorandum, Richard S. Johnston, MSC, to Chief, Systems Engineering Division, "Extravehicular Mobility Unit (EMU) thermal and meteoroid protection," April 9, 1965.

April 9

Systems Engineering Division (SED) reviewed the Flight Operations Directorate's recommendation for an up-data system in the LEM during manned missions. (Currently the LEM's guidance computer received data either from the computer in the CSM or from MSC.) SED concluded that, because the equipment was not essential for mission success, an up-data system did not warrant the cost and weight penalties (\$750,000 and 4.54 kg [10 lbs]) that it would entail.

Memorandum, Owen E. Maynard, MSC, to Manager, ASPO, "LEM up-data system," April 9, 1965.

April 12

The Apollo Program Director, Samuel C. Phillips, informed the Associate Administrator for Manned Space Flight, George E. Mueller, that action was underway by Grumman to terminate all Pratt & Whitney LEM fuel cell activity by June 30, 1965. Pratt & Whitney would complete testing of LEM fuel cell hardware already produced and one complete LEM fuel cell module plus spare parts would be sent to MSC for in-house testing.

North American's Space and Information Systems Division would continue development at Pratt & Whitney on the CSM fuel cell for 18 months at a cost not to exceed \$2.5 million, to ensure meeting the

400-hour lifetime requirement of the CSM system.

MSC would contract directly with Pratt & Whitney for CSM cell development followed by complete CSM module testing for a 1,000-hour CSM module at a cost of approximately \$2.5 million. Grumman was scheduled to propose to ASPO their battery contractor selection on April 29, 1965.

Memorandum, Phillips to Mueller, "Plans for LEM Fuel Cell Termination and Related Effort," sgd. John H. Disher, April 12, 1965.

April 12

MSC awarded MIT a new \$15,529,000 contract to design guidance and navigation equipment for Apollo spacecraft.

MSC, "Quarterly Activity Report for Office of the Associate Administrator, Manned Space Flight, for Period Ending April 30, 1965," p. 25.

April 13

Marshall Space Flight Center finalized a \$2,697,546 addition to an existing contract with Douglas Aircraft Company to provide for environmental testing of a full-scale S-IVB forward stage simulator, a full-scale test instrument unit, and an Apollo thermal simulator. Testing would be conducted in Douglas' 11.89-m- (39-ft-) diameter space simulator at Huntington Beach, California, and would simulate a typical Saturn V flight from launch to earth orbit and injection into lunar path.

Astronautics and Aeronautics, 1965, p. 182; *Space Business Daily*, April 27, 1965, p. 317.

April 14

Construction workers emplaced the final beam in the structural skeleton of the Vertical Assembly Building at Merritt Island (KSC), Florida. Scheduled for completion in 1966, the cavernous structure (160 m [525 ft] tall and comprising 10,968,476 cu m [129 million cu ft]) would provide a controlled environment for assembling Saturn V launch vehicles and mating them to Apollo spacecraft.

Astronautics and Aeronautics, 1965, p. 184.

April 15

The first firing of the LEM ascent engine test rig (HA-3) was successfully conducted at White Sands Missile Range, New Mexico. A second firing on April 23 lasted 14.45 sec instead of 10 sec as planned. A third firing, lasting 30 sec, completed the test series. A helium pressurization system would be

installed before additional testing could begin.

"Monthly Progress Report No. 27," LPR-10-43, pp. 1, 13; GAEC, "Monthly Progress Report No. 28," LPR- 10-44, June 10, 1965, p. 1.

April 15

ASPO informed North American that a meeting would be held at its Downey, California, plant April 20-23 to negotiate and have signed off all Block I and Block II suit interface control documents (ICDs) and the government furnished equipment ICDs. Hamilton Standard, Grumman, and David Clark were being instructed to have representation present to achieve the signed ICDs. North American was instructed to have the ICDs in final form to be signed or negotiated.

TWX, C. L. Taylor, MSC, to NAA, Attn: J. C. Cozad, April 15, 1965.

Mid month

Officials from North American and the three NASA centers most concerned (MSFC, KSC, and MSC) discussed the environmental umbilical arrangement for the CM. The current configuration hampered rapid crew egress and therefore did not meet emergency requirements. This group put forth several alternative designs, including lengthening the umbilical hood and relocating the door or hatch.

Internal Letter, E. P. Smith, NAA, to Distr., "Trip Report - MSFC - Command Module Environmental Umbilical Interface," April 15, 1965.

April 15-22

Grumman reviewed the engineering simulation program. The total cost was anticipated at \$9 million.

MSC, "ASPO Weekly Management Report, April 15-22, 1965."

April 15-22

At North American, ultrasonic inspection of the forward portion of airframe 007 disclosed only minor imperfections in the bonding, called "a dramatic demonstration of the improvement in the bonding process." (See April 1-8.)

Ibid.

April 15-22

MSC and Grumman reviewed the program for the LEM's reaction control system. The only issue outstanding was Grumman's in-house effort: MSC felt that that effort was "overestimated" and that the manufacturer alone should not handle support from subcontractors.

Ibid.; memorandum, W. F. Rector III, MSC, to Assistant Manager, ASPO, Attn: H. L. Reynolds, "LEM RCS Status," April 22, 1965.

April 15-22

North American began full-scale developmental testing on the CM's uprighting system.

"ASPO Weekly Management Report, April 15-22, 1965"; "Apollo Monthly Progress Report;" SID 62-300-37, p. 3.

April 16

MSFC conducted the first clustered firing of the Saturn V's first stage (the S-IC). The booster's five F-1 engines burned for about 6½ seconds and produced 33,360 kilonewtons (7.5 million lbs) thrust. George E. Mueller, Associate Administrator for Manned Space Flight, emphasized the significance of this test, calling it "one of the key milestones in the whole lunar landing program."

Eight days later, at its static facility in Santa Susana, California, North American first fired the S-II, intermediate stage of the Saturn V. The event was chronicled as the "second major Saturn V milestone" during April.

Astronautics and Aeronautics, 1965, pp. 188, 198; *Space Business Daily*, April 20, 1965, p. 276; *Ibid.*, April 28, 1965, p. 322.

April 16

Owen E. Maynard, Chief of MSC's Systems Engineering Division, announced that the ordering of objectives into first, second, and third order had been discontinued and replaced with two classifications: primary and secondary objectives. Primary objectives were defined as those which were mandatory. Malfunctions of spacecraft or launch vehicle systems, ground equipment, or instrumentation which would result in failure to achieve these objectives would be cause to hold or cancel the mission until the malfunction had been eliminated. Secondary objectives were those considered desirable but not mandatory. Malfunctions resulting in failure to achieve these objectives would be cause to hold or cancel the mission as indicated in Mission Rules.

Memorandum, Owen E. Maynard, MSC, to Distr., "Changes to objective classification," April 16, 1965.

April 16-May 15

Two CSM fuel cells failed qualification testing, the first failing after 101.75 hrs of the vacuum endurance test. Pratt and Whitney Aircraft determined that the failure was caused by a cleaning fluid which contaminated and plugged the oxygen lines and contaminated the oxygen gas at the electrodes. The fuel cell would be rebuilt for qualification testing and test preparation procedures were to be revised.

An internal short circuit occurred in the second fuel cell 16 hrs before the end of the 400-hour qualification test. In spite of the failure the fuel cell met the current Block I mission specification and did not need to be redesigned.

"Apollo Monthly Progress Report," SID 62-300-37, p. 10.

April 16-May 15

North American completed qualification testing on the fuel tanks for the SM's reaction control system.

Ibid., p. 11; NAA, "Project Apollo Spacecraft Test Program Weekly Activity Report (12 April 1965 through 18 April 1965)," p. 3.

April 16-May 15

On the basis of current systems reliabilities and the design reference mission, North American estimated at one in a hundred the possibility that returning Apollo crewmen would land on solid ground rather than on water. The contractor used this estimate in formulating test programs for boilerplate 28 and spacecraft 002A and 007.

"Apollo Monthly Progress Report," SID 62-300-37, p. 12.

April 16-May 15

North American halted testing on the hydrogen tanks for the CSM, produced by Beech, because of weld failures. Testing on a redesigned tank assembly began on May 8.

Ibid., p. 9; "Project Apollo Spacecraft Test Program Weekly Activity Report (12 April through 18 April 1965)," p. 5.

April 19-26

North American, Hamilton Standard, Grumman, David Clark, and MSC representatives, meeting in Downey, California, resolved all interfaces between the space suit and the two blocks of spacecraft. As a result of these agreements, MSC directed North American and Grumman to make some minor changes

(suggested by the Crew Systems Division) in the communications cables; to remove the portable life support systems from the CM; and to add a thermal-meteoroid garment - rather than one providing merely thermal protection - to the CM.

"ASPO Weekly Management Report, April 22-29, 1965"; memorandum, Richard S. Johnston, MSC, to Chief, Systems Engineering Division, "Extravehicular Mobility Unit (EMU) thermal and meteoroid protection," April 9, 1965; memorandum, Johnston to Asst. Chief, Program Control Division, Attn: G. J. Stoops, "Implementation of RECP's pertaining to Extravehicular Mobility Unit (EMU) thermal and meteoroid protection," April 21, 1965.

April 20

NASA and Boeing negotiated a contract modification. For an additional \$3,135,977, Boeing would furnish instrumentation equipment and engineering support for Marshall Space Flight Center's program for dynamic testing of the Saturn V.

Astronautics and Aeronautics, 1965, p. 191; *Space Business Daily*, April 22, 1965, p. 291.

April 20

At the initial design engineering inspection (DEI) of Spacecraft 009, held at Downey, California, MSC and North American officials reviewed the compatibility of the vehicle with SA-201 mission requirements. The DEI Review Board approved 11 hardware changes and assigned 26 others for further study.

Memorandum, Daniel A. Nebrig, MSC, to Distr., "Minutes of Houston Board Review for AFRM 009 DEI - Phase I," April 20, 1965; "Apollo Monthly Progress Report," SID 62-300-37, p. 3.

April 20

The ASPO CSM Project Officer, C. L. Taylor, said that immediate action must be taken to reduce the FY 1965 expenditures on the CSM program by \$5 million. Toward that end, he directed attention to a cost reduction program, "Project Squeeze," and said that a joint North American/NASA Project Squeeze had been in operation several months and had resulted in significant program reductions. However, the majority of items recommended for investigation were North American-oriented.

Taylor requested items for consideration be submitted no later than April 27, 1965, and pointed out some specifics which might be considered:

1. qualification programs, hardware quantities, tests, etc.,
2. component testing,
3. analytical effort,

4. design to excess,
5. documentation, and
6. changes.

Memorandum, C. L. Taylor, MSC, to Distr., "Project Squeeze," April 20, 1965.

April 20

MSC requested Grumman to make provisions for storage of two additional portable life support system (PLSS) batteries. This was an increase of two batteries over the previous requirement; requirement now was for two batteries in the PLSS and additional storage for six.

TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, April 20, 1965.

April 20

MSC's Systems Engineering Division requested that Grumman be advised to terminate the RCA systems engineering subcontract as soon as possible. It had been determined that this contract was no longer useful. Based on data presented by Grumman during a program review, an immediate and complete termination would save about \$45,000.

Memorandum, Owen E. Maynard, MSC, to Chief, Contract Engineering Branch, "LEM Program Review Contract NAS 9-1100, RCA Systems Engineering Sub-Contract," April 20, 1965.

April 21-22

Grumman and MSC engineers discussed the effect of landing impacts on the structure of the LEM. Based on analyses of critical loading conditions, Grumman reported that the present configuration was inadequate. Several possible solutions were being studied jointly by Grumman and the Structures and Mechanics Division (SMD):

- Strengthening the spacecraft's structure (which would increase the weight of the ascent and descent stages by 19 and 32 kg [42 and 70 lbs], respectively)
- Modifying the gear
- Reducing factors of safety and landing dynamics, including vertical velocity at touchdown

A decision was expected from SMD by June 1.

Also Grumman representatives summarized the company's study on the design of the footpads. They recommended that, rather than adopting a stroking-type design, the current rigid footpad should be modified. The modification, they said, would improve performance as much as would the stroking design, without entailing the latter's increased weight and complexity and lowered reliability. SMD was

evaluating Grumman's recommendations.

MSC, "ASPO Weekly Management Report, April 22-29, 1965."

April 22

MSC completed the program review on the electrical power system for the LEM and approved the cost through completion of the program (about \$23.2 million).

Ibid.

April 22

The MSC Systems Engineering Division published revisions to Apollo Mission 204A objectives and mission requirements. The principal difference between the revised version and the Initial Mission Directive for Mission 204 was the expansion of the secondary propulsion system performance objective, the radiation survey meter objective, which was deleted, and the don/doff of the Block I pressure garment and thermal blanket objectives which had also been deleted.

Memorandum, Owen E. Maynard, MSC, to Apollo Trajectory Support Office, "Revisions to Apollo Mission 204A objectives and mission requirements," sgd. C. H. Perrine, April 22, 1965.

April 22

The LEM Project Officer notified Grumman that the President's Scientific Advisory Committee (PSAC) had established sub-panels to work on specific technical areas, beyond the full PSAC briefings. One of the sub-panels was concerned with the environmental control subsystem, including space suits. This group desired representation from Hamilton Standard to discuss with regard to the LEM-ECS its interpretation of the reliability design requirements, its implementation through development and test phases, its demonstration of reliability, and its frank assessment of confidence in these measures. Briefing material should be available to the sub-panel by May 17, 1965, with a primary discussion meeting to be held at Hamilton Standard on May 24.

TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, April 22, 1965; TWX, W. L. Conn, MSC, to Hamilton Standard, Attn: E. V. Marshall, April 22, 1965.

April 22

Grumman was requested to ship ground support equipment and associated equipment to field test sites as soon as it was available.

TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, April 22, 1965.

April 22

Grumman was requested to attend a meeting at MSC and to present their reasons as to why the LEM reaction control system (RCS) propellant tanks could not be of common technology with the CSM RCS propellant tanks. Grumman was to also say why an additional development program was required for the LEM tanks.

TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, April 22, 1965.

April 22-23

North American conducted the final zero-g trials (part of developmental testing on the CM's waste management system) and reported good results for both urine and feces apparatus.

"Apollo Monthly Progress Report," SID 62-300-37, p. 4.

April 22-29

After reviewing the status of the LEM landing simulation program, the Guidance and Control Division reported that "significant data" from the Bell training vehicle were more than a year away.

"ASPO Weekly Management Report, April 22-29, 1965."

April 22-29

Allison Division of General Motors Corporation completed an analysis of failures in the LEM descent stage's propellant tanks. Investigators placed the blame on brittle forgings. MSC's Propulsion and Power Division reported that "efforts are continuing to insure [that] future forgings will be satisfactory."

Ibid.

April 22-29

Crews Systems Division reported that work on the suit visors was progressing well, and that operational mockups had been sent to North American for the upcoming critical design review. The visor could be attached and detached by a pressurized crewman; also, it afforded thermal protection and allowed a complete range of light attenuation.

Ibid.

April 22-29

North American updated the electrical power profile for spacecraft 011:

	Requirement (watt-hours)
Prelaunch	159
Ascent	4457
Entry	1032
Postlanding	2288

During the flight, the entry and landing batteries would supplement the spacecraft's fuel cells; three auxiliary batteries would power the mission control programmer and the instrumentation. At touchdown, all batteries would supply energy for postlanding requirements.

Ibid.

April 23

MSC and Grumman conducted the design engineering inspection on LEM test article 10. Structures and Mechanics Division called it "significant" that there were no requests for design changes. The vehicle was ready for shipment to Tulsa, Oklahoma, for static testing by North American, but, at the latter's request, delivery was delayed until May 28.

Ibid.; letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Minutes of the LTA-10 Development Engineering Inspection," April 29, 1965, with enclosure: "Minutes of LTA-10 Development Engineering Inspection, April 23, 1965."

April 26

North American received CM 009 forward and crew compartment heatshields from Avco Corporation. These heatshields were the first CM heatshields received by the contractor with complete ablative application.

"Apollo Monthly Progress Report," SID 62-300-37, p. 1.

April 26

Operating on a round-the-clock schedule, researchers at Langley Research Center began simulations of high-altitude aborts and CSM-active dockings. (See July 7-9.)

"ASPO Weekly Management Report, April 22-29, 1965."

April 26-May 2

Using boilerplate 14, North American simulated the mission for spacecraft 009. The test was conducted in two phases, with the vehicle on external and then internal power. All data showed satisfactory performance.

NAA, "Project Apollo Spacecraft Test Program Weekly Activity Report (Period 26 April 1965 through 2 May 1965),"

April 27

ASPO announced that a LEM Test Program Requirement Review would be held at Grumman during the first week in June. The purpose of the review would be to reach agreement with Grumman on an overall Test Program Plan and to consider planned allocation of hardware, test schedules, and test logic in relationship to flight missions.

The review would result in publication of a certification document which would define and catalog the program of testing, analysis, and rationalization which would form the basis for certification of flight spacecraft as capable of meeting requirements of flight missions. It would cover all formal qualification testing above the part level being done at subcontractors or vendors, component testing at Grumman, higher level of assembly testing conducted anywhere in support of a portion of test logic, and individual system test requirements to be conducted on integrated test vehicles such as LEM test article 1.

The format for the review would consist of individual subsystem test program reviews by the respective MSC and Grumman Subsystem Managers. MSC Subsystem Managers would be supported by RASPO, ASPO, and GE personnel where appropriate. After their initial meeting, the MSC and Grumman managers would summarize their findings to a MSC Grumman review board, emphasizing deficiencies in the program (to include inadequate tests, hardware availability problems, and schedules which were inconsistent with flight support requirements).

Memorandum, Owen E. Maynard, MSC, to Distribution, "LEM Test Program Requirements Review," April 27, 1965.

April 27

North American summarized its position on the design of the CM for earth impact in a letter to MSC. A number of meetings had taken place since the NASA North American Technical Management Meeting February 25, 1964, at which the decision was made to reorient Apollo impact to water as the primary landing site.

The letter reviewed the history of boilerplate 28 drop tests and a series of MSC North American meetings during the last two months of 1964 and the first two of 1965. On February 12, at a meeting at Downey, California, North American had recommended:

- Design for 0.99999 criteria.
- Retain the 27.5 degrees hang angle to eliminate the requirement for redesign of upper crew compartment side wall. The dual hang angle configuration should be eliminated for spacecraft 017 and subsequently through Block II.
- Allow plastic deformation of the aft heatshield.
- Continue investigation of possible upper deck and tunnel problems.
- Fly spacecraft 009 with a probability of success at water impact of 0.999, and continue boilerplate 28 testing to give assurance of meeting this criterion.

In a follow-up meeting on March 2, NASA gave concurrence to these recommendations in the form of signed meeting minutes.

At the time of the April 27 letter, North American was implementing the design changes defined in the Apollo CM design changes for water impact. The changes were based on North American's best understanding of agreements between it and MSC regarding criteria, loads, definition of the ultimate land envelope, structural analysis, and the requirement that no-leakage integrity within the ultimate load level be demonstrated by test.

Letter, J. G. Cozad, North American, to NASA MSC, Attn: J. B. Alldredge, "Contract NAS 9-150, R&D for Project Apollo Spacecraft Design of Apollo Command Module for Earth Impact," April 27, 1965.

April 27

LEM Project Officer W. F. Rector III, in a letter to Grumman, established the minimum acceptable NASA requirements for accomplishing the inspection, acceptance, and delivery operations at Bethpage, N.Y., on flight and major ground test vehicles.

Following manufacture, and prior to NASA acceptance, the spacecraft must undergo a thorough checkout by the contractor with MSC participating as an active member of a checkout team. Through experience in Projects Mercury and the CSM portion of Apollo, a team concept of operations had evolved for the aforementioned activities. The concept had proved highly successful in providing a balance of MSC and contractor personnel which assured that the evaluation of problems received proper attention and resulted in solutions acceptable to both NASA and the contractors. In addition, this "cross pollination" of skills provided a more complete evaluation of the spacecraft performance and systems anomalies.

Prior to starting acceptance testing, all systems should have completed a pre-installation acceptance check, been installed in the spacecraft, and the configuration verified. Acceptance checkout would begin

following complete installation of all subsystems and hook-up to the Acceptance Checkout Equipment (ACE). After ACE was installed, individual subsystems tests were to be performed. The hook-up of ACE to the spacecraft would constitute the point at which the checkout team would assume responsibility for the vehicle. At that time a documentation system must provide a means for authorizing and permanently recording all work and testing to be performed on the spacecraft.

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, NASA Requirements for Inspection, Acceptance and Delivery Operations at Bethpage," April 27, 1965.

April 27-30

Part II of the Critical Design Review of the crew compartment and docking system for the Block II CM was held at Downey, California, using mockups 28 and 27 A. (Part I had been held on March 23-24.)

- Systems Engineering Division reported 49 design changes were requested in the crew compartment, 45 of which were acted upon. The two most serious problems were:
 1. stowage of the portable life support systems;
 2. and the crewmen's knees striking the main display console at impact.
- Structures and Mechanics Division reported a number of minor changes to the docking system, primarily to simplify crew transfer and operation of the hatch mechanisms.
- Crew Systems Division (CSD) engineers evaluated the compatibility of the space suit and MSC's new in-house helmet with the Block II spacecraft. CSD reported that the suits were sufficiently mobile and afforded adequate visibility; problems with the shoulders, experienced in early versions of the suit, had been solved; and while the three crewmen still quite literally rubbed elbows, this problem also had been alleviated and no longer hampered the crew's performance.

MSC, "ASPO Weekly Management Report, April 29-May 6, 1965."

April 28

NASA Administrator James E. Webb, Deputy Administrator Hugh L. Dryden, and Associate Administrator Robert C. Seamans, Jr., decided that the announcement of any Apollo crew should be delayed as long as feasible without jeopardizing training schedules. They reasoned that as long as the entire astronaut group was undergoing generalized Apollo training, and until individual mission planning was complete, there should be no need to make even tentative crew selections.

Memorandum, Seamans to Associate Administrator for Manned Space Flight George E. Mueller, "Apollo Crew Selection," April 28, 1965.

April 28

Joseph F. Shea, ASPO Manager, approved Crew Systems Division's recommendation to retain the

"shirtsleeve" environment for the CM. The design was simpler and promised greater overall mission reliability; also, it would be more comfortable for the crewmen. Wearing part of the space suit would compound problems with humidity and condensation inside the cabin. Accordingly, the crew would be clad only in their constant-wear garments or would be fully suited. (MSC and North American had explored the feasibility of putting a water separator in the cabin heat exchanger for airframe 012. It was hoped that, through partially suited operations, the crew could gain confidence in the spacecraft's pressurization system. North American advised, however, that considerable cost and schedule impacts could be expected. Moreover, such a device would be only partly successful - condensation would still be a major problem, Shea therefore vetoed the water separator and the idea of partially suited operations during the first manned Apollo flight.)

Memorandum, Joseph F. Shea, MSC, to Distr., "Wear of space suits in C/M," April 28, 1965.

April 28-May 3

Under NASA contract, proton irradiation of primates tests were conducted on the Oak Ridge cyclotron by a team from Brooks AFB and Crew Systems Division. During this period, 136 monkeys and 900 mice were irradiated.

MSC, "ASPO Weekly Management Report, May 6-13, 1965."

April 29-May 6

Portable life support systems (PLSS) stowed against the aft bulkhead in the CM would prevent the crew couch from stroking fully. This condition would be aggravated if, at impact, the bulkhead was forced inward. North American spokesmen maintained that, in a water landing, the bulkhead would give only slightly and that the couch struts would not compress to their limits. They argued, therefore, that this condition would be of concern only in a land landing. On the contrary, said MSC. Center officials were adamant that any interference was absolutely unacceptable: it would lessen the attenuation capability of the couch (thereby jeopardizing crew safety); possibly, the bulkhead might even be ruptured (with obviously disastrous results). Because of this problem - and because the capability for extravehicular transfer from the CM to the LEM was required - MSC invited representatives from the three contractors involved to meet in Houston to deal with the question of PLSS stowage. (See May 12.)

"ASPO Weekly Management Report, April 29-May 6, 1965"; memorandum, Charles R. Haines, MSC, to Owen E. Maynard, "PLSS," May 25, 1965.

April 29-May 6

Grumman recommended redundant pyrotechnic or solenoid valves in the propellant system of the LEM's ascent stage. Thus the firm could meet NASA's ground rule that no single failure would cause the mission to be aborted.

"ASPO Weekly Management Report, April 29-May 6, 1965."

April 29-May 6

The Flight Projects Division (FPD) proposed a change in the checkout procedure at Merritt Island (KSC). The idea, drawn from Gemini, would eliminate checkout at the environmental control system (ECS) facility. Basically, FPD's plan was to transport the mated CSM directly from the Operations and Checkout Building to the altitude chamber, where the ECS would be tested. Officials at North American approved the new procedure, and FPD requested the Checkout and Test Division to study its feasibility.

Ibid.

April 30

Grumman advised MSC that it had selected the Eagle-Picher Company as vendor for batteries in both stages of the LEM. At the same time, because a proposal by Yardney Electric Company promised a sizable weight saving, this latter firm would produce "pre-production" models for the ascent stage.

Ibid.

April 30

North American announced an Apollo Engineering Reorganization, designed to improve operational efficiency and to be consistent with existing requirements of the Apollo program. The reorganization would: (1) increase the number of managers, but reduce the individual manager's scope and eliminate one level of management, making for clearer assignments and better communications; (2) incorporate certain checkout and ground support equipment systems engineering functions into Systems Engineering, strengthening the integration capabilities and simplifying operational procedures; and (3) basic functions of analytical engineering within Apollo Engineering were being transferred to the Research and Engineering Division, increasing the effective use of technical and management personnel.

NAA, Organization Announcement, Dale D. Myers, Apollo Program Manager, and H. G. Osbon, Chief Engineer, Apollo Engineering, to Apollo Engineering Supervision, "Apollo Engineering Reorganization," April 30, 1965.

April 30

A tentative agreement was reached between Grumman and MSC propulsion personnel concerning the Propulsion System Development Facility's test scheduling at White Sands operations in regard to stand occupancy times relating to the ascent and descent development rigs. The tentative schedule showed that the ascent LEM Test Article (LTA)-5 vehicle would not start testing until April 1967. The PA-1 rig

prototype ascent propulsion rig) would therefore be required to prove the final design and support early LEMs.

The PA-1 rig was designed and was being fabricated to accommodate small propellant tanks, and there were no plans to update it with larger ones. Therefore, advantages of flexibility, running tests of longer sustained durations, and with the final tank outlet configurations would not be realized. Grumman was requested to take immediate action to have the rig accommodate the larger tanks and install the smaller tanks by use of adapters or other methods.

TWX, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, April 30, 1965.

April 30

As a result of the decision for an all-battery LEM, MSC advised Grumman that power for the entire pre-separation checkout of the spacecraft would be drawn from that module's batteries (instead of only during the 30 minutes prior to separation). This change simplified the electrical mating between the two spacecraft and obviated an additional battery charger in the CSM. From docking until the start of the checkout, however, the CSM would still furnish power to the LEM.

TWX, James L. Neal, MSC, to GAEC, Attn: R. S. Mullaney. April 30, 1965.

During the Month

Grumman reported two major problems with the LEM's descent engine:

1. Space Technology Laboratories (STL) asked that the thrust chamber be lengthened by 13.9 cm (5.5 in). Weight penalty would be 11.3 kg (25 lbs).
2. STL concluded that, if used with Grumman's heatshield, the current nozzle extension would melt.

"Monthly Progress Report No. 27," LPR-10-43, pp. 3, 13.

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Advanced Design, Fabrication, and Testing

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May 1

North American and NASA officials conducted an engineering inspection on boilerplate 23A at White Sands Missile Range, New Mexico. The board approved four requests on minor structural changes; a fifth request, involving tolerances on the boost protective cover, was slated for further study.

Memorandum, Joe W. Dodson, MSC, to Distr., "Results of DEI on BP-23A," May 4, 1965, with enclosures.

May 3

Systems Engineering Division did not concur in use of the chamber technician's suit by test subjects in AFRM 008 tests. AFRM 008 represented the only integrated spacecraft test under a simulated thermal-vacuum environment and was therefore considered a significant step in man-rating the overall system. For that reason use of the flight configuration Block I suit was a firm requirement for the AFRM 008 tests.

The same rationale would be applicable to the LEM and Block II vehicle chamber tests. Only flight configured spacecraft hardware and extravehicular mobility unit garments would be used by test subjects.

Memorandum, Owen E. Maynard, MSC, to Chief, Crew Systems Division, "Utilization of a Flight Configured Block I Space Suit with AFRM 008," sgd. Robert W. Williams, May 3, 1965.

May 3

R. Wayne Young was appointed Chief of the LEM Contract Engineering Branch, ASPO, to perform the functions of Project Officer for the LEM, effective May 3. At the same time M. E. Dell was appointed Chief of the G&N/ACE Contract Engineering Branch, ASPO, and would be responsible for all functions of Project Officer for the guidance and navigation, automatic checkout equipment-spacecraft, and Little Joe II systems for the Apollo spacecraft, and for technical management of the General Electric Support Contract.

Memorandum, J. Thomas Markley, MSC, to Distr., "Assignment of Chief, LEM Contract Engineering Branch and Chief, G&N/ACE Contract Engineering Branch, Apollo Spacecraft Program Office," May 4, 1965.

May 4

Technical personnel at MSC became concerned over an RCS oxidizer tank failure that occurred in February 1965, during propellant exposure and creep tests. The failure had previously been explained as stress corrosion caused from a fingerprint on the tank shell before heat treat. NASA requested that the test be repeated under tighter controlled procedures.

TWX, C. L. Taylor, MSC, to NAA, Space and Information Division, Attn: J. C. Cozad, May 4, 1965.

May 4

A Panel Review Board (PRB) meeting was held at Office of Manned Space Flight (OMSF) in Washington and the MSC and MSFC Chairmen of the Flight Mechanics Panel attended.

Prior to the formal meeting, discussions with T. Thompson and B. Kaskey revealed that Bellcomm had recommended to Apollo Program Director Samuel C. Phillips that the contingency mission for AS 204 be an unmanned orbital flight and that no unmanned contingency mission be planned for 205. The reason for an unmanned contingency for 204 was to give MSFC an additional opportunity to obtain orbital data from the S-IVB stage.

PRB was informed that lack of specific requirements concerning contingency mission capability was hampering Flight Mechanics Panel in completion of interface control documents and associated mission development. Contingency capability was classified into two types: (1) contingency capability to provide for failures during the flight program or schedule adjustments of the hardware; and (2) in-flight contingencies due to malfunction of the launch vehicle.

Memorandum, C. H. Perrine, MSC, to Chief, Systems Engineering Division, "Trip Report on Panel Review Board Meeting at OMSF, May 4, 1965," May 7, 1965.

May 4

NASA Associate Administrator for Manned Space Flight George E. Mueller concurred with a plan of MSC Director Robert R. Gilruth to implement a three-station developmental Solar Particle Alert Network. Mueller said he understood that Gilruth would "review the necessity for the Guaymas station, and that you will examine having all data reduction related to this network carried out under contract," and adding that he felt the program would be enhanced if arrangement could be made to involve one or more academic institutions in the analysis of data.

Letter, Mueller to Gilruth, "Solar Particle Alert Network," May 4, 1965.

May 4

A preliminary flight readiness review was held in Houston on boilerplate (BP) 22. Several participants voiced serious doubts about the structural integrity of the boost protective cover, because of its sizable cutouts (required for pressure measurements and its poor fit. Structures and Mechanics Division representatives argued that the article not be modified, however. They stressed that BP-23's cover, which also fit poorly, endured greater dynamic pressures than were anticipated for BP-22. Final inspection of the cover would be made at WSMR. (See May 19, 1965.)

"ASPO Weekly Management Report, May 6-13, 1965."

May 4

Although North American was including real-time digital command equipment in Block II CSMs (as NASA had directed), the firm recommended that such equipment not be placed on Block I vehicles. North American based their contention on two factors:

1. the anticipated cost and schedule impacts; and
2. command capability was not essential during earth orbital flights.

Letter, E. E. Sack, NAA, to NASA MSC, Attn: J. B. Alldredge, "Contract NAS 9-150, Contract Change Proposal SID-150-370, Revision 1, Preliminary; Real Time Radio Command Requirements on Block I and Block II CSM's," May 4, 1965, with enclosure.

May 4

MSC directed North American to provide spacecraft 012, 014, 017, and 020 with a system to monitor combustion instability in the service propulsion engine. (On April 8, officials of ASPO, Propulsion and Power Division, and the Flight Operations Directorate had agreed on the desirability of such a system.) Should vibrations become excessive, the device would automatically shut down the engine. Manual controls would enable the astronauts to lock out the automatic system and to restart the engine.

Letter, J. B. Alldredge, MSC, to NAA, Space and Information Systems Division, "Contract Change Authorization No. 347," May 4, 1965; memorandum, Christopher C. Kraft, Jr., MSC, to Manager, ASPO, "Flight Combustion Stability Monitor (FCSM)," May 13, 1965.

May 5

In response to a query, Apollo Program Director Samuel C. Phillips told NASA Associate Administrator

for Manned Space Flight George E. Mueller that plans to use VHF communications between the CSM, LEM, and extravehicular astronauts and to use X-band radar for the CSM/LEM tracking were reviewed. Bellcomm reexamined the merits of using the Unified S-Band (USB) type which would be installed in the CSM and LEM for communication with and tracking by the earth.

It was found that no appreciable weight saving or weight penalty would result from an all USB system in the Apollo spacecraft. Also, it was determined there would be no significant advantage or disadvantage in using the system. It was noted, however, that implementation of an all S-band system at that stage of development of the design of the CSM, LEM, and astronaut equipment would incur an obvious cost and schedule penalty.

Memorandum, Phillips to Mueller, "Use of Only Unified S-Band Communication Equipment in Apollo Spacecraft," May 5, 1965.

May 6

After lengthy investigations of cost and schedule impacts, MSC directed North American to incorporate airlocks on CMs 008 and 014, 101 through 112, and 2H-1 and 2TV-1. The device would enable astronauts to conduct experiments in space without having to leave their vehicle. Initially, the standard hatches and those with airlocks were to be interchangeable on Block II spacecraft. During October, however, this concept was changed: the standard outer hatch would be structured to permit incorporation of an airlock through the use of a conversion kit (included as part of the airlock assembly); and when an airlock was installed, an interchangeable inner hatch would replace the standard one.

TWX, Samuel C. Phillips, NASA, to MSC, Attn: J. F. Shea, January 4, 1965; letters, J. B. Alldredge, MSC, to NAA, Space and Information Systems Division (S&ID), "Contract Change Authorization No. 348," May 6, 1965; Alldredge, MSC, to NAA, S&ID, "Contract Change Authorization No. 348, Revision 1," July 27, 1965; James Stroup, MSC, to NAA, S&ID, "Contract Change Authorization No. 348, Revision 2," August 4, 1965; Alldredge, MSC, to NAA, S&ID, "Contract Change Authorization No. 441," October 11, 1965.

May 6

ASPO overruled a recommendation by the Flight Operations Directorate for an up-data link in the LEM. Although an automated means of inserting data into the spacecraft's computer was deemed "highly desirable," there were prohibitive consequences:

- Weight - 7.25 kg (16 lbs) in the ascent stage
- Cost - \$1.7 million
- Schedule delay - five months

This last effect ASPO termed "flatly unacceptable."

Memorandum, William A. Lee, MSC, to Assistant Director for Flight Operations, "LEM Up-Data Link," May 6, 1965.

May 6

As a result of the Critical Design Review at North American during the previous month, Crew Systems Division (CSD) directed Hamilton Standard to fabricate an Apollo space suit with a pressure-sealing zipper. CSD would compare this concept with the current gusset design, which leaked excessively and hindered donning the suit.

TWX, Richard S. Johnston, MSC, to R. E. Breeding, Hamilton Standard Division, May 6, 1965; MSC, "ASPO Weekly Management Report, June 3-10, 1965."

May 6

The Apollo earth landing system (ELS) was tested in a drop of boilerplate (BP) 19 at El Centro, Calif. The drop removed constraints on the ELS for BP-22 (see May 19 ; also, it was a "prequalification" trial of the main parachutes before the start of the full qualification test program (see June 3).

"Apollo Monthly Progress Report," SID 62-300-37, p. 3.

May 6-13

Both General Electric and Radio Corporation of America studied the feasibility of using the spacecraft-LEM-adapter to dissipate heat from the radioisotope generator during initial phases of the mission. The generator would raise the temperature of the adapter about 30 degrees; radiation back to the spacecraft was not considered serious.

MSC, "ASPO Weekly Management Report, May 6-13, 1965."

May 6-13

Structures and Mechanics Division engineers determined that the spacecraft-LEM-adapter would not survive a service propulsion system abort immediately after jettisoning of the launch escape tower. North American planned to strengthen the upper hinges and fasteners and to resize the shock attenuators on spacecraft 009.

Ibid.

May 7

Launch escape system (LES) installation for CSM 009 was completed, marking the first LES completion. "Apollo Monthly Progress Report," SID 62-300-37, p. 1.

May 9

The U.S.S.R. launched a 1,476-kg (3,254-lb) scientific probe, called *Luna V*, on a trajectory to the moon. Western observers, among them England's Sir Bernard Lovell, speculated that the craft's mission was a soft landing. If that was indeed its goal, the attempt failed: *Luna V* crashed and all transmissions ceased. It was generally thought that the vehicle's retrorockets had malfunctioned.

Astronautics and Aeronautics, 1965, p. 222; *Space Business Daily*, May 11, 1965, pp. 49-50; M. K. Tikhonravov, B. V. Raushenbakh, G. A. Skuridin, and O. L. Vaysberg, Ten Years of Space Research in the USSR, NASA Technical Translation F-11, 500 of: "Desyat' let issledovaniya kosmosa v SSSR"; *Kosmicheskiye Issledovaniya*, Vol. 5, No. 5, pp. 643-679, 1967, p. 17.

May 10

ASPO reviewed Grumman's recommendation for a combination of supercritical and gaseous modes for storing oxygen in the LEM's environmental control system (ECS). MSC engineers determined that such an approach would save only about 14.96 kg (33 lbs) over a high-pressure, all-gaseous design. Mission objectives demanded only four repressurizations of the LEM's cabin. On the basis of this criterion, the weight differential was placed at less than nine pounds.

As a result of this analysis, MSC directed Grumman to design the LEM ECS with an all-gaseous oxygen storage system. (See June 11.)

Letter, W. F. Rector III, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Lunar Excursion Module - ECS Oxygen Storage Configuration," May 10, 1965, with enclosures.

May 10

Public Health Service (PHS) officials revealed that the Surgeon General had discussed the PHS/NASA relationships on back-contamination problems with the NASA Administrator. During this discussion, the Surgeon General proposed:

1. expansion of the space biology and contamination contract program in the PHS;
2. assignment by the PHS of a liaison officer to NASA; and
3. development by NASA of an interagency advisory committee on both outbound and inbound contamination problems with PHS participation.

The Administrator and Surgeon General were reported to have agreed that negotiations at staff level

were appropriate. As a result, NASA was drafting a proposal to go from the Administrator to the Surgeon General embodying not only the three items listed but also proposing a NASA organizational structure capable of implementing the objectives of the two agencies.

Memorandum, O. E. Reynolds, Director Bioscience Programs, NASA Headquarters, to Associate Administrator for Space Science and Applications, "Status of the Public Health Service - National Aeronautics and Space Administration negotiations on back contamination," May 10, 1965.

May 10

ASPO Assistant Manager William A. Lee heard a proposal to modify the LEM radar programs to reduce FY 1966 costs by \$7 million. It was his understanding that the proposal would be presented to the Configuration Control Board. Lee said he at first thought the change would be "tolerable," but later felt it was a poor idea.

The major points of the proposal were:

- Delete landing radars from LEMs 1 and 2: the landing radar was not essential to earth-orbital missions of these two vehicles. In fact, ASPO had planned to drop it on LEM-2 (AS-207) to save weight. Nevertheless the proposal was a violation of the "all-up" concept, and, if adopted, would set a precedent for further deletions.
- Delete the rendezvous radar on LEM 1.
- Use "qualifiable" but not qualified rendezvous radars on LEMs 2 and 3.
- Install the rendezvous radars for LEMs 2, 3, and 4 at KSC rather than at Grumman.

Lee opined that the violations of program ground rules inherent in these changes would establish a dangerous precedent and cut back existing margins too early in the program. It would also, he said, "open the door to a series of 'one-of-a-type' LEMs tailored to their specific development missions. . . . It is too early in the LEM program to consider compromising these requirements, and to do so for budgetary reasons almost certainly will prove to be false economy."

Memorandum, William A. Lee, MSC, to Manager, ASPO, "Proposed reduction in LEM radar expenditures," May 11, 1965.

May 11

Crew Systems Division let a contract to the Zaret Foundation to study effects of radiation on the lens of the human eye. The foundation would develop instruments that, by examining changes in the organ, would determine the precise dose that it had absorbed. Radiation could produce cataracts. Up to this time, however, the amount of radiation that could be absorbed safely was not known, nor could the initial damage be detected. It was generally thought that this damage was cumulative and that it was irreparable. For the crew's safety, the amount of radiation that the eye could sustain had to be known.

And, of course, some technique for measuring dosages was essential. (See July 2.)

"ASPO Weekly Management Report, June 3-10, 1965."

May 11

MSC instructed Grumman to negotiate award of a contract to supply batteries for the ascent and descent stages of the LEM with Eagle-Picher Company. Grumman had solicited and received proposals from Eagle-Picher and Yardney Electric Corporation. The bids, including fees, were: Eagle-Picher, \$1,945,222; and Yardney, \$1,101,673. Grumman evaluated the bids; made presentations to MSC personnel; and proposed on May 6 that they negotiate with Eagle-Picher for ascent and descent batteries; and with Yardney for development of a lighter ascent battery at a cost of approximately \$600,000. MSC instructed Grumman not to place the proposed development contract with Yardney, stating that such work could be more appropriately done by MSC work with Yardney or other battery vendors.

Memorandum of Conference, Apollo Program Management Office, "LEM Battery Procurement, MSC Comments on GAEC Recommendation for Contractor Selection," sgd. J. B. Trout, May 11, 1965.

May 12

Developmental testing began on a new landing device for the CM, one using rockets (mounted on the heatshield) that would be ignited immediately before impact. The current method for ensuring the integrity of the spacecraft during a landing in rough water involved strengthening of the aft structure. The new concept, should it prove practicable, would offer a twofold advantage: first, it would lighten the CM considerably; second, it would provide an improved emergency landing capability.

MSC, *Space News Roundup*, May 28, 1965, p. 8.

May 12

MSFC informed MSC that the thrust of the H-1 engine was being uprated to 1,000 kilonewtons (205,000 lbs), thus increasing the Saturn IB's payload capability.

Letter, Frederick E. Vreuls, MSFC, to O. E. Maynard, MSC, "Uprating the H-1 Engine in the Saturn IB Vehicle," May 12, 1965.

May 12-June 24

Representatives from North American, Grumman, Hamilton Standard, and MSC discussed the problem of stowing the portable life support systems (PLSS).



The space suit for the lunar landing mission was the only operational equipment designed to go all the way to the lunar surface and return to earth. Above is a photo of a subject in that suit as designed at that time, with the portable life support system strapped on.

Current specifications called for two PLSSs under the crew couch in the CM at launch, one of which would be brought back to earth. This location presented some serious problems, however. (See April 29-May 6.)

MSC officials laid down several ground rules for the discussions:

- The capability for extravehicular transfer must be maintained.
- During translunar flight, the capability must exist for general extravehicular activity from the CM.
- And upon landing, the PLSS must not interfere with the sweep of the crew couch.

The participants explored a number of stowage options (and the complications involved), even exploring the possibilities of staging and of using a Gemini Extravehicular Life Support System. As a result of these talks, Hamilton Standard began studying the feasibility of repackaging the PLSS to fit underneath the side hatch of the CM and to determine whether the reshaped system would be compatible with both spacecraft.

During the next few weeks, MSC concluded that, at earth launch, one PLSS would be stowed in each spacecraft. With the help of Hamilton Standard engineers, North American and Grumman designers worked out a stowage volume acceptable to all concerned. Hamilton Standard agreed to repackage the PLSS accordingly. MSC ordered North American to provide for stowage of one PLSS beneath the side hatch of the CM, again stressing that the system must not interfere with the crew couch during landing impact; also, the Center directed Grumman to plan for PLSS stowage in the LEM and to study ingress and egress with the reshaped backpack. (Studies by the Crew Systems Division had already indicated that, from the standpoints of compatibility and mobility, the new shape probably would be acceptable.)

TWX, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, May 17, 1965; memorandum, Charles R. Haines, MSC, to Owen E. Maynard, "PLSS," May 25, 1965; memorandum, Haines, to Record, "PLSS stowage study," May 25, 1965; "ASPO Weekly Management Report, May 27-June 3, 1965"; MSC, "ASPO Weekly Management Report, June 10-17, 1965"; memorandum, R. Wayne Young, MSC, to James L. Neal, "PLSS stowage in the LEM," June 21, 1965; letter, J. B. Alldredge, MSC, to NAA, Space and Information Systems Division, Attn: J. C. Cozad, "Contract NAS 9-150, Portable Life Support System (PLSS) Stowage in the Command Module," June 24, 1965.

May 13

Samuel C. Phillips, Apollo Program Director, issued the mission directive for Apollo-Saturn 201. The mission would flight-test the Saturn IB and the Apollo CSM.

NASA OMSF, "Apollo Program Flight Mission Directive for Apollo-Saturn 201 Mission," Program Directive M-D MA 2240.061, May 13, 1965.

May 13

AC Spark Plug officials presented to MSC their evaluation of bidders to design an optical rendezvous

sensor for the LEM. Because three different approaches were planned, AC gained Guidance and Control Division's approval to let three subcontracts. The firms chosen were Perkin-Elmer, Hughes Aircraft, and the Itek Corporation.

MSC, "ASPO Weekly Management Report, May 20-27, 1965."

May 13-20

Crew Systems Division (CSD) representatives contracted with Northrop Space Laboratories to study physiological effects of tailward g forces. (CSD believed these forces might be "very hazardous." Consequently, the lowest impact limits for Apollo missions were in that direction.) Northrop would study bradycardia (slow heart rate) in animals induced by such acceleration, and would apply these findings to humans. CSD hoped thereby to determine whether current limits were "ultraconservative."

MSC, "ASPO Weekly Management Report, June 3-10, 1965."

May 13-20

To broaden communications capabilities during near-earth phases of a mission, the S-band omnidirectional antennas on all Block II CMs were moved to the toroidal (doughnut-shaped) section of the forward heatshield.

MSC, "ASPO Weekly Management Report, May 27-June 3, 1965."

May 16-June 15

North American released a preliminary report, "Apollo Reliability Modeling Documentation," in response to an action item assigned to MSC by the President's Scientific Advisory Committee (PSAC) Space Technology Panel at an Apollo program reliability briefing for the panel in January. The expected crew safety reliability was assessed at 0.973 with a confidence level of 60 percent. Functional logic diagrams indicated the amount of redundancy in each CSM function. North American noted that a direct comparison should not be made between mission AS-506 lunar orbit rendezvous (LOR) crew safety reliability and the preliminary crew safety number 0.976 for spacecraft 012. The LOR assessment, while preliminary, was developed in greater depth than the assessment for the PSAC briefing. However, a real increase in reliability was indicated from spacecraft 012 to the LOR mission because the reliability values were about equal, and the complexity and number of required functions in the LOR were far greater.

NAA, "Apollo Monthly Progress Report," SID 62-300-38, July 1, 1965, p. 13.

May 16-June 15

North American conducted the third in a series of water impact tests on boilerplate 1 to measure pressures on forward portions of the spacecraft. Data from the series supported those from tests with one-tenth scale models of the CM. The manufacturer reported, therefore, that it planned no further full-scale testing.

Ibid., p. 3.

May 17

MSC informed Grumman it believed it would be beneficial to the LEM development program for MSC to participate in the manned environmental control system tests to be conducted in Grumman's Internal Environment Simulator. The following individuals were suggested to participate: Astronaut William A. Anders or an alternate to act as a test crewman for one or more manned runs; D. Owen Goons or an alternate to act as a medical monitor for the aforementioned astronaut; and John W. O'Neill or an alternate to monitor voice communications during the test and record astronaut comments.

Letter, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, MSC participation in Grumman manned environmental control system (ECS) tests," May 17, 1965.

May 18-20

Representatives from Motorola, RCA, Grumman, and MSC held the first design review on the S-band transponder for the LEM. Several areas were pointed out in which the equipment was deficient. Motorola was incorporating improved circuitry to ensure that the transponder met specifications.

Letter, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Rendezvous Radar Transponder Assembly Design," May 28, 1965; TWX, Young to Mullaney, "Communication Subsystem Input Voltage Levels," June 1, 1965; TWX, Young to Mullaney, "LEM S-Band Transponder," June 1, 1965.

May 19

Apollo mission A-003, a planned high-altitude abort test, was flown at WSMR. About 25 seconds after launch, and at an altitude of about three miles, the Little Joe II booster disintegrated as a result of violent - and unprogrammed - roll. The launch escape system (LES) functioned perfectly, however, and lifted the spacecraft (boilerplate 22) clear of the vehicle. ASPO Manager Joseph F. Shea, while acknowledging that A-003's "prime objectives . . . were not met," rightly observed that the LES nonetheless "proved its mettle in an actual emergency," (See mission objectives in Appendix 5.)

NASA News Release 54-145, "NASA to Test Apollo Escape System at High Altitude," May 9, 1965; memorandum, George E. Mueller, NASA, to Administrator, "Apollo Spacecraft Flight Abort Test, Mission A-003, Post Launch Report No. 1," May 24, 1965, with enclosure; MSC, *Space News Roundup*,

May 28, 1965; TWX, NASA, MSC/ WSO, to addressees, "Apollo Mission A-003 one hour report," sgd. J. F. Shea, May 19, 1965; General Dynamics, Convair Division, *Little Joe II Test Launch Vehicle, NASA Project Apollo: Final Report*, GDC-66-042 (May 1966), Vol. I, p. 1-18.

May 20-27

Engineers from General Electric and MSC's Crew Systems and Systems Engineering Divisions determined that transferring water from the CSM to the LEM involved a 5.4-kg (12-lb) increase in the latter's separation weight. Grumman had placed the penalty at only 1.8 kg (4 lbs). Because the LEM's weight was so critical, the water transfer scheme was canceled.

TWX, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, June 3, 1965.

May 20-27

To determine lunar touchdown velocity uncertainties, MIT studied radar-aided powered descent. From MIT's findings, Guidance and Control Division concluded that one or two sensors should provide velocity updates to the guidance system throughout the descent maneuver.

MSC, "ASPO Weekly Management Report, June 10-17, 1965."

May 21

Marquardt Corporation completed preliminary flight rating tests on the reaction control engine for the SM.

"Apollo Monthly Progress Report," SID 62-300-38, p. 10.

May 22

NASA launched another reentry heating experiment, Project Fire II, from Cape Kennedy, Fla. An Atlas D booster propelled the instrumented probe, called a "flying thermometer," into a ballistic trajectory over 805 km (500 mi) high. After 26 minutes of flight, when the spacecraft began its descent, a solid-fueled Antares rocket accelerated its fall.

The probe entered the atmosphere at a speed of 40,877 km (25,400 mph) and generated temperatures of about 11,206K (20,000 degrees F). Data on heating were transmitted to ground stations throughout the descent. Thirty-two minutes after the launch - and but six minutes after the Antares was fired - the device impacted in the Atlantic about 8,256 km (5,130 mi) southeast of the Cape.

NASA News Release 65-131, "NASA Schedules Project Fire Launch in May," April 28, 1965; NASA

News Release 65-179, "NASA Reports Project Fire Performed Well," May 27, 1965.

May 23

The Life Sciences Committee of the National Academy of Sciences' Space Science Board recommended to NASA that American astronauts returning from the moon and planets be kept in quarantine for at least three weeks to prevent possible contamination of the earth by extraterrestrial organisms, Howard Simons reported in the Washington Post. A report entitled "Potential Hazards of Back Contamination from the Planets" presented quarantine and other recommendations: the need to avoid decontamination of returning equipment until it had been subjected to biological study; the possible need for the astronauts to shed their outer garments on the moon and Mars before returning home; the need to conduct immediate research on any samples of extraterrestrial life brought to earth; and trial runs to acquaint astronauts with methods for minimizing chance of contamination.

Astronautics and Aeronautics, 1965, p. 246.

May 21-24

The Resident ASPO at Grumman approved three vendor selections by the LEM manufacturer:

1. Mechanical Products, Inc. - circuit breakers. (MSC concurred in the use of hermetically sealed breakers.)
2. Hartman Electric Co. - relays (also hermetically sealed).
3. Electronic Products Division of Hughes Aircraft Co. - rectangular connectors.

MSC, "ASPO Weekly Management Report, May 20-27, 1965"; memorandum, Ralph S. Sawyer, MSC, to Chief, Systems Engineering Division, "Common usage of Circuit Breakers," May 18, 1965.

May 24

MSC concurred in Grumman's selection of the RF tracking mode for the LEM's steerable antenna.

Letter, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, LEM high gain steerable antenna RF tracker," May 24, 1965.

May 24

At Wright-Patterson AFB, North American engineers conducted zero-g tests of crew transfer using mockup 27 A. The two subjects, astronauts Donn F. Eisele and Richard F. Gordon, had difficulty manipulating the forward hatches and the drogue assembly. North American reported that handles might be required on those pieces of hardware.

"Apollo Monthly Progress Report," SID 62-300-38, p. 5; memorandum, Donald K. Slayton, MSC, to Manager, ASPO, "CM/LEM Tunnel Hatches and Docking Hardware Zero Gravity Removal and Installation Test," June 18, 1965.

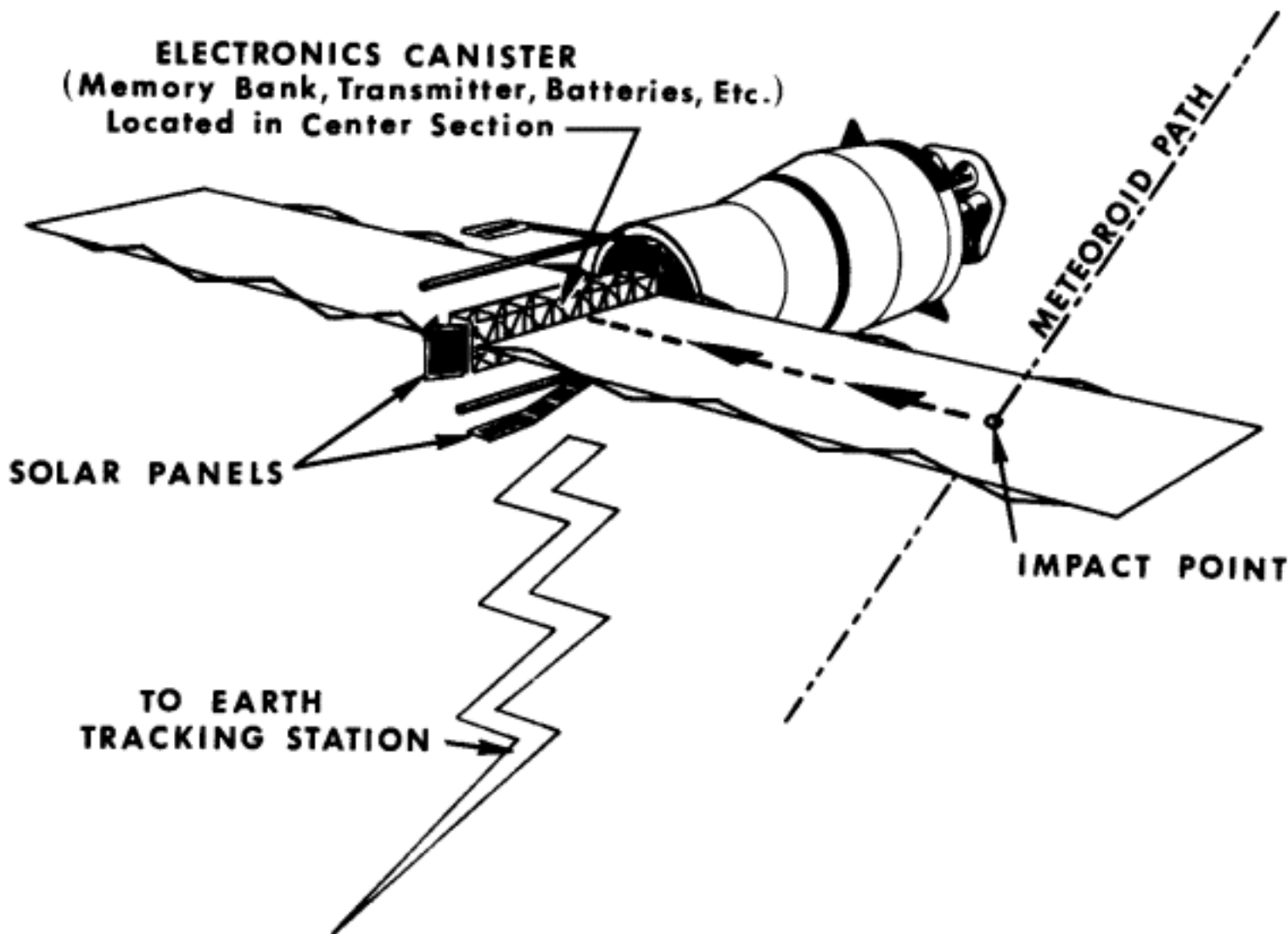
May 24

Donald K. Slayton, Assistant Director for Flight Crew Operations, described a potential hazard involved in crew procedures inside the LEM. Two sets of umbilicals linked the Block II space suit to the environmental control system (ECS) and to the portable life support system (PLSS). Though slight, the possibility existed that when a hose was disconnected, the valve inside the suit might not seat. In that event, gas would escape from the suit. Should this occur while the LEM was depressurized, the astronaut's life would be in jeopardy. Consequently, Slayton cautioned, it would be unwise to disconnect umbilicals while in a vacuum. This in turn imposed several mission constraints:

- PLSSs could not be recharged while the LEM was unpressurized.
- If the astronauts were planning to leave the spacecraft, they had to switch to the PLSSs and disconnect the ECS hoses before depressurizing their vehicle.
- Because the cooling circuit in the PLSS operated only in a vacuum, the crew must depressurize the LEM shortly after switching to their PLSSs.

Memorandum, Slayton, MSC, to Chief, Systems Engineering Division, "Apollo suit procedures inside the LEM," May 24, 1965.

May 25



Pegasus "finds" a meteoroid.

NASA launched *Pegasus II*, a meteoroid detection satellite, from Cape Kennedy. (See February 16, 1965.) The Saturn I launch vehicle (SA-8) placed the spacecraft, protected by a boilerplate CSM (BP-26), into a 740-by-509-km (460-by-316-mi) orbit. Once in orbit, the dummy CSM was jettisoned. *Pegasus II*, still attached to the second stage of the launch vehicle, then deployed its 29-m (96-ft) winglike panels. Within several hours, the device began registering meteoroid hits.

NASA News Release 65-151, "NASA to Launch Second Pegasus Meteoroid Satellite," May 17, 1965; NAA, "Project Apollo Spacecraft Test Program Weekly Activity Report (Period 24 May 1965 through 30 May 1965)," pp. 1-2; MSFC Historical Office, *History of the George C. Marshall Space Flight Center from January 1 through December 31, 1965* (MHM-11), Vol. I, p. 53.

May 25

MSC directed North American to install Block II-type, flush-mounted omni-directional S-band antennas on CMs 017 and 020. These antennas would survive reentry and thus would afford telemetry transmissions throughout the flight. On June 25, the Center ordered that they be installed in the toroidal (doughnut shaped) section of the aft heatshield.

Letters, James Stroup, MSC, to NAA, Space and Information Systems Division (S&ID), "Contract Change Authorization No. 357," May 25, 1965; J. B. Alldredge, MSC, to NAA, S&ID, "Contract Change Authorization No. 357, Revision 1," June 25, 1965.

May 25

ASPO pointed out to the Systems Engineering Division that planning of the manned Apollo missions had been constrained to maximize the Manned Space Flight Network support available for guidance and navigation (G&N) functions. While this was a desirable technique to maximize mission success probabilities, it led to a tendency to neglect onboard G&N capabilities.

"It is ASPO policy that, wherever feasible, both onboard and ground systems will be exercised fully during manned developmental missions. Spacecraft maneuvers should be computed both on the ground and in the flight vehicle, and the results of these computations recorded and compared. . . . It is requested that Apollo mission planning conform to this policy and that any tendency to omit full exercise of the onboard G&N capability be corrected."

Memorandum, William A. Lee, MSC, to Chief, Systems Engineering Division, "Utilization of onboard G&N capability during Apollo Manned Development Missions," May 25, 1965.

May 25

MSC completed contract negotiations with Westinghouse Electric Company on gear for the LEM's television camera (cables and connectors, stowage containers, and camera mockups). Because of technical requirements, the idea of using the same cable in both spacecraft was abandoned.

MSC, "ASPO Weekly Management Report, May 27-June 3, 1965."

May 26

To aid reacquisition and tracking of the high-gain antenna, MSC directed North American to study the feasibility of an inertial reference system on Block II spacecraft, one that would use rate signals from the CSM's stabilization and control system. Without this system, the astronauts would have to perform anywhere from 250 to 500 antenna reacquisitions during a single lunar mission. And during sleeping periods, when the CM pilot was alone in the vehicle, it was mandatory that the antenna automatically reacquire the earth.

Letters, James Stroup, MSC, to NAA, Space and Information Systems Division (S&ID), "Contract Change Authorization No. 358," May 26, 1965; J. B. Alldredge, MSC, to NAA, S&ID, "Contract Change Authorization No. 358, Revision 1," July 23, 1965.

May 26

ASPO requested the Apollo Program Director to revise the LEM control weight at translunar injection as follows:

- Ascent stage - 2,193kg (4,835lbs)
- Descent stage - 2,166kg (4,775lbs)
- Total LEM (fueled) - 14,515kg (32,000lbs)

The increase would be made possible by reductions of service propulsion system propellant requirements associated with the revised delta-V budget. ASPO pointed out that existing CSM and adapter control weight propellant requirements allowed a maximum LEM injected weight of 14,877 kg (32,800 lbs) with no increase in the launch vehicle payload requirement.

Letter, Joseph F. Shea, MSC, to NASA Headquarters, Attn: Director Apollo Program, "Revised LEM Control Weights," May 26, 1965.

May 26

William A. Lee, ASPO Assistant Manager, asked Systems Engineering Division to study the feasibility of an abbreviated mission, especially during the initial Apollo flights. Because of the uncertainties involved in landing, Lee emphasized, the first LEMs should have the greatest possible reserves. This could be accomplished, he suggested, by shortening stay time; removing surplus batteries and consumables; and reducing the scientific equipment. Theoretically, this would enable the LEM pilot to hover over the landing site for an additional minute; also, it would increase the velocity budgets both of the LEM's ascent stage and of the CSM. He asked that the spacecraft's specifications be changed to fly a shorter mission:

- Stay time - 10 hours
- Exploration time - six man-hours
- Scientific payload - 32 kg (70 lbs)
- Lunar samples returned - 36 kg (80 lbs)

Lee said that this modification would produce a spacecraft that could be adapted to short and long missions.

Memorandum, William A. Lee, MSC, to Chief, Systems Engineering Division, "Spacecraft capability

for short-duration lunar landing missions," May 26, 1965.

May 27

Because correspondence from Grumman and the Resident ASPO there hinted at deleting some equipment from the first LEM, MSC reaffirmed that LEM-1 would be an "all-up" spacecraft, as specified in the SA-206A mission requirements.

MSC Internal Note No. 65-PL-1 (Revision A), "Project Apollo Mission Requirements for Apollo Spacecraft Development Mission 206A (LEM 1)," May 11, 1965; TWX, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, "Mission Requirements for Apollo Spacecraft Development Mission 206A (LEM I) MSC Internal Note No. 65-PL-I (Rev. A) dated May 11, 1965," June 2, 1965.

May 27-June 3

MSC's Crew Systems Division (CSD) received from Hamilton Standard Division a liquid cooling garment which had been modified to include a comfort liner. Preliminary tests by the contractor showed a substantial increase in comfort with only a small decrement to cooling capacity. CSD scheduled tests to validate the performance.

MSC, "ASPO Weekly Management Report, May 27-June 3, 1965."

May 28

ASPO approved the use of common communications equipment in Block I and II space suits. The hardware would be procured from North American (under their contract with Pacific Plantronics), then furnished to the suit contractors (David Clark and Hamilton Standard).

TWX, James Stroup, MSC, to NAA, Space and Information Systems Division, Attn: J. C. Cozad, June 7, 1965.

May 30-June 5

ASPO Manager Joseph F. Shea reported the accomplishment of a number of important items:

- Boilerplate 23A command module and launch escape system were moved to the launch pad at WSMR and stacked; integrated ground support equipment checkout was in progress.
- North American was directed to stop all work on systems installation on CSM 006. Test objectives would be reassigned to boilerplate 14 and CSM 008.
- The first deliverable LEM attitude and translation control assembly had passed acceptance test at RCA and was delivered to Grumman.
- The Design Engineering Inspection on LEM descent propulsion test rig PD-1 was completed and

the rig shipped to WSMR/PSDF. The LEM ascent propulsion rig HA-4 was shipped to AEDC for ascent engine environmental tests.

- The LEM Technical Specification and the LEM Master End Item

Specification were incorporated into the Grumman contract on June 1, 1965. "Weekly Activity Report, May 30-June 5," sgd. Joseph F. Shea.

During the Month

Thiokol Chemical Company completed qualification testing on the tower jettison motor. An ignition delay on February 22 had necessitated a redesign of the igniter cartridge. Subsequently, Thiokol developed a modified pyrogen seal, which the firm tested during late August and early September.

"Apollo Monthly Progress Report," SID 62-300-38, pp. 2, 8, 11.

During the Month

Using one-third scale models, Grumman tested the LEM's antenna field at the extremes of the frequency range. Data evaluation showed that the range was adequate; errors were well within expected values.

"Monthly Progress Report No. 28," LPR-10-44, p. 16.

During the Month

Using improved restraint hardware, Grumman resumed tests simulating the shock of landing on the moon. Investigators reported better lateral stability - and they no longer bounced off the floor. Astronaut Donn F. Eisele, who took part, judged the system superior to those used in earlier trials.

Ibid., p. 14.

During the Month

Bell Aerosystems Company successfully cycled a LEM ascent engine propellant valve 500 times (double the specification requirement). Also, the company conducted a full-duration altitude firing with an ablative nozzle extension to verify heating characteristics.

Ibid., p. 1.

During the Month

MSC postponed the formal LEM program review (wherein spacecraft requirements would be redefined

and Grumman's contract converted to an incentive type). The Center directed the company to submit firm proposals for all contract change authorizations (CCA), which were promised by July 11. Grumman was preparing a revised estimate of total program cost. In the meantime, both parties were negotiating on all outstanding CCAs.

Also, Grumman described its continuing cost reduction effort. To keep expenditures within limits "suggested" by MSC, the firm was preparing detailed budgets both for itself and its subcontractors. The company had made a number of changes to strengthen its administrative structure and, with Houston's support, was reviewing possible schedule changes with an eye toward eliminating some test vehicles.

Ibid., p. 1.

During the Month

Three flights were made with the lunar landing research vehicle (LLRV) by FRC pilot Don Mallick for the purpose of checking the initial weighing, the thrust-to-weight, and the automatic throttle systems.

General Electric would update the LLRV CF-700 jet engines at their Edwards AFB facility rather than at Lynn, Mass. The change in work location would mean an earlier delivery date and a significant cost reduction. The updating would make the engines comparable to the production engines and would add an additional 890 newtons (200 lbs) of thrust.

Letter, Paul F. Bikle, FRC, to NASA Headquarters, "Lunar Landing Research Vehicle progress report No. 23 for the period ending May 31, 1965."

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Advanced Design, Fabrication, and Testing

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June 1

ASPO Manager Joseph F. Shea replied to a recommendation by the Assistant Director for Flight Operations to incorporate warning lights in Block I and II CMs to indicate failure of the gimbal actuator secondary drive motors. ASPO decided that no failure indication would be provided for the redundant drive motors in Block I spacecraft because:

1. in-flight checkout procedures would provide for exercising the gimbal actuators by the primary and secondary drive motors prior to service propulsion system burns; and
2. all manned Block I missions would be conducted in earth orbit and reaction control system deorbit capability was stipulated.

The warning lights would be incorporated in Block II spacecraft, and the in-flight checkout procedures would also apply to Block II lunar missions.

Memorandum, Joseph F. Shea, MSC, to Assistant Director for Flight Operations, "Service Propulsion System (SPS) Secondary Gimbal Motor Fail Indication," June 1, 1965.

June 2

In an attempt to reduce the overall preflight time in connection with lunar landing research vehicle (LLRV) activities, a meeting was held at Flight Research Center. Principal participants were Ray White, Leroy Frost, Leonard Ferrier, Joe Walker, Don Mallick, Cal Jarvis, Jim Adkins, Zeon Zwink, Wayne Ottinger, and Gene Matranga.

The session commenced with an estimate of time required to perform each of the functions on the preflight checklist. Review indicated that preflight might be shortened in several ways:

1. since the radar altimeter and doppler radar units did not affect safety of flights, it was suggested that radar checks on flight mornings be reduced to a minimum or be performed without inspection coverage;

2. addition of ac and dc voltmeters in the cockpit would eliminate need for power checks during the avionics preflight;
3. when the weight and drag computer had been properly checked in flight, the weight and drag preflight check could be streamlined down from the 30 minutes currently required; and
4. investigate the need to refill H2O2 after prime.

In general, though several operations were performed simultaneously during most of preflight, it appeared other operations could be performed in parallel and thereby reduce overall preflight time. Memorandum for Files, "LLRV Preflight Procedures," Gene J. Matranga, June 2, 1965.

June 2

ASPO advised North American that, at present, no unmanned flights were planned for the Block II CM. After the company concluded its own analysis of Apollo requirements, MSC would determine whether the heatshield must be verified prior to manned missions. But because of the long "lead time" involved, North American should continue securing the requisite instrumentation pending a final decision.

TWX, C. L. Taylor, MSC, to NAA, Space and Information Systems Division, Attn: J. C. Cozad, subject: "Requirements for Mission Programmers and Heat Shield Measurements in Block II CSM," June 2, 1965.

June 3

Northrop-Ventura began qualification testing of the earth landing system for Apollo with a drop of boilerplate 19 at El Centro, Calif. The entire landing sequence took place as planned; all parachutes performed well.

"Apollo Monthly Progress Report," SID 62-300-38, pp. 2-3.

June 6

NASA launched Gemini IV, America's second multi-manned space mission, piloted by astronauts James A. McDivitt and Edward H. White II, from Cape Kennedy. Gemini IV's primary objective was to evaluate the performance of man and machine during prolonged space flight. Also during this flight, White opened the hatch on his spacecraft and performed America's first "space walk." On June 7, after four days in space, McDivitt and White landed their vehicle in the Atlantic Ocean some 724 km (450 mi) east of the Cape.

James M. Grimwood and Barton C. Hacker with Peter J. Vorzimmer, *Project Gemini Technology and Operations: A Chronology* (NASA SP-4002, 1969), pp. 200-202.

June 3-10

MSC approved North American's recommendation that a programmer timer approach be used for earth reacquisition by the CSM's S-band high-gain antenna.

"ASPO Weekly Management Report, June 3-10, 1965."

June 5

ASPO Manager Joseph F. Shea concluded, after reviewing the boilerplate 22 mission, that all the test objectives would be met satisfactorily either in the flight of spacecraft 002 or in the ground qualification program. For that reason the boilerplate 22 flight would not be repeated. Memorandum, Shea to Distr., "Test Objectives," June 5, 1965.

June 6-12

ASPO reported a number of significant activities in its Weekly Activity Report.

- The CSM design engineering inspection was satisfactorily conducted at North American June 8-10.
- Qualification of the Apollo standard initiator was successfully completed by Space Ordnance Systems, Inc.
- The first full systems firing of the LEM ascent engine was accomplished at Bell Aerosystems using the heavyweight ascent (HA)-2 propulsion test rig.
- The LEM development program was revised and LEM test article (LTA)-4, LTA-5 ascent stage, flight test article (FTA)-1, and FTA-2 were eliminated.

"Weekly Activity Report, June 6-12, 1965,"sgd. Joseph F. Shea.

June 7

George E. Mueller, Associate Administrator for Manned Space Flight, approved procurement of the lunar surface experiments package (LSEP). The package, to be deployed on the moon by each LEM crew that landed there, would transmit geophysical and other scientific data back to earth. NASA's Office of Space Science and Applications would make the final selection of experiments. Mueller emphasized that the LSEP must be ready in time for the first lunar landing mission. Management responsibility for the project was assigned to MSC's Experiments Program Office.

Memorandum, George E. Mueller, NASA, to MSC, Attn: Dave Lang, "Request for Approval of Procurement Plan for Lunar Surface Experiments Package," June 7, 1965; NASA OMSF, Apollo Program Directive No. 3, "Management Assignment for the Lunar Surface Experiments Package (LSEP) Project," June 15, 1965.

June 7

Apollo Program Director Samuel C. Phillips approved MSC's request for revised velocity budgets for the two spacecraft. It was understood that these new values would:

1. still meet the free return trajectory constraint; and
2. increase (to at least two degrees) the LEM's out-of-plane launch capability. MPAD/FOD provided the analysis and recommendations leading to this decision.

Letter, Samuel C. Phillips, NASA, to MSC, Attn: Director, ASPO, "Revised Apollo Spacecraft Delta V Budget (U), per letter dated May 18, 1965, Reference PS8/L-82/65," June 7, 1965; Memorandum, Carl R. Huss, JSC, to JSC Historical Office, "Comments on Volume III of *The Apollo Spacecraft: A Chronology*," June 6, 1973.

June 7

MSC directed NAA to make a "pre-design" study of a rocket landing system for the Block II CM. (The Center had already studied the system's feasibility and had conducted full-scale drop tests.)

Letter, C. L. Taylor, MSC, to NAA, Space and Information Systems Division, Attn: J. C. Cozad, "Contract NAS 9-150, CM Rocket Landing System Study Meeting, 15 June 1965," June 22, 1965, with enclosure, "Minutes of Rocket Landing System Study Meeting," June 15, 1965; TWX, J. C. Ellis, NAA, to NASA Headquarters, Attn: Director, Procurement and Supply Division, July 15, 1965.

June 7-13

North American's Rocketdyne Division began qualification testing on the CM's reaction control system engines.

NAA, "Project Apollo Spacecraft Test Program Weekly Activity Report (Period 7 June 1965 through 13 June 1965)," p. 3.

June 8

Russia launched *Luna VI*, an instrumented moon probe. Tass reported that all onboard equipment was functioning normally. Two days into the flight, however, the spacecraft's engine failed to shut down following a midcourse correction. This failure caused *Luna VI* to miss its target by more than 160,000 km (99,419 mi).

Space Business Daily, June 11, 1965, p. 216; Tikhonravov, *et al.*, *Ten Years of Space Research in the USSR*, p. 17.

June 8-10

MSC reviewed a lighting mockup of the crew compartment in the Block II CM. The design concept, though needing further refinement, was deemed acceptable. Engineers from Crew Systems Division found that lights on the fingertips of the suit gloves worked quite well; optimum positioning was as yet undetermined, however. At the same time, MSC reviewed the design of the Block I side hatch (i.e., not modified to meet Block II extravehicular requirements). Reviewers found North American's major problems were warpage and crew ingress from space. Further, the design of both side hatches needed "additional coordination" with that of the umbilical access arm of the launch tower to ensure compatibility.

"ASPO Weekly Management Report, June 3-10, 1965"; "ASPO Weekly Management Report, June 10-17, 1965."

June 9

Crew Systems Division reported that MSC had ordered Hamilton Standard to integrate seven layers of thermal protection into the A5H pressure suit.

Memorandum, Francis J. DeVos and William C. Kincaide, MSC, to Record, "Meeting on June 9, 1965, to discuss thermal and meteoroid protection for the Apollo Extravehicular Mobility Unit," June 22, 1965.

June 10-17

Crew Systems Division reported that, as currently designed, the environmental control system (ECS) in the LEM would not afford adequate thermal control for an all-battery spacecraft. Grumman was investigating several methods for improving the ECS's thermal capability, and was to recommend a modified configuration for the coolant loop.

Memorandum, Owen E. Maynard, MSC, to Distr., "LEM battery thermal control problem," June 17, 1965.

June 10-17

NASA hired the U.S. Navy's Air Crew Equipment Laboratory (ACEL) to study several physiological aspects of pure-oxygen environments. Primarily, ACEL's study would try to determine: (1) whether known effects (such as lung collapse) could somehow be reversed; and (2) whether such environments enhanced respiratory infections.

"ASPO Weekly Management Report, June 10-17, 1965."

June 10-17

A list of materials that North American reported using in the CM's habitable area omitted more than 70 items that had appeared in earlier such reports. MSC ordered the company to determine why. This item could affect the course of backup toxicity testing. Materials listed as "used but not tested" were given highest priority in toxicity testing.

Ibid.

June 11

MSC ordered Grumman to propose a gaseous oxygen storage configuration for the LEM's environmental control system (ECS), including all oxygen requirements and system weights. Because no decision was yet made on simultaneous surface excursions by the crew, Grumman should design the LEM's ECS for either one-or two-man operations. And the Center further defined requirements for cabin repressurizations and replenishment of the portable life support systems. Oxygen quantities and pressures would be worked out on the basis of these ground rules. (See July 1-8.)

TWX, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, June 11, 1965.

June 11

The question of whether a data tape recorder would be installed on LEM-1 had been discussed at several Apollo 206 Mission Operations Plan meetings and there was a strong possibility it would not be installed.

In a memorandum to ASPO Manager Joseph F. Shea, Assistant Director for Flight Operations Christopher C. Kraft, Jr., pointed out that his Directorate had responsibility to ASPO of insuring "that all possible test objectives are accomplished. This is done not only by real-time conduct of the mission, but also through considerable premission planning which integrates the desired profile with the Manned Space Flight Network. The underlying purpose of all these operations activities is the accumulation of data, which for unmanned, nonrecoverable spacecraft such as LEM-1 can only be provided through the use of RE telemetry. The FOD (Flight Operations Directorate) does not believe the Apollo 206A Mission Objectives can be assured of being accomplished without the addition of a data tape recorder and associated playback transmitter. . . ."

Kraft said the tradeoff of weight and cost of a data recorder and dump transmitter versus possible loss of data for primary mission objectives, considering the cost of a Saturn IB launch vehicle, a fully functional LEM spacecraft, and the ground support required, seemed inequitable. He recommended that a data tape recorder and associated playback transmitter be installed on LEM-1 (and 2) to ensure that test objectives were achieved.

Memorandum, Kraft to Shea, "LEM-1 Mission 206A Data Tape Recorder," June 11, 1965.

June 11

ASPO Manager Joseph F. Shea, in a memorandum to Robert Williams, said that, confirming their discussion with Christopher C. Kraft, Jr., and Donald K. Slayton, both had agreed that HE orbital communications in the Block II Apollo spacecraft were not needed. Shea asked Williams to look into the implications of removing the requirement.

Memorandum, Shea to Williams, "Block II communication system," June 12, 1965.

June 11

MSC and North American discussed the brittleness of the boost protective cover and the possibility that, during tower jettison or abort, the cover might break up and cause damage to the spacecraft. Having investigated a number of various materials and construction techniques, North American recommended adding a nylon fabric to strengthen the structure. Company engineers believed that, thus reinforced, the cover would be less likely to tear apart in flight. Even though this would increase the weight of the cover by about 27 kg (60 lbs), MSC concurred. The change applied to both Block I and Block II CMs, and was effective for spacecraft 002, 009, and all subsequent vehicles.

Letter, C. L. Taylor, MSC, to NAA, Space and Information Systems Division, Attn: J. C. Cozad, "Contract NAS 9-150, Implementation of Actions Recommended at the NASA/NAA Boost Protective Cover Problem Area Review at MSC June 11, 1965," June 21, 1965, with enclosure: "Abstract of Proceedings, NASA/NAA Boost Protective Cover Problem Area Review, MSC, June 11, 1965," June 14, 1965; memorandum, Owen E. Maynard, MSC, to Chief, Structures and Mechanics Division, "Action Items resulting from Boost Protective Cover Problem Area Review at MSC, June 11, 1965," June 15, 1965; memorandum, Maynard, to Chief, C&SM Contract Engineering Branch, "CCA to NAA on backing material for Boost Protective Cover," June 24, 1965.

June 12

Apollo Program Director Samuel C. Phillips listed the RE communications systems envisioned by NASA Headquarters on the first three R&D LEMs and requested ASPO Manager Joseph F. Shea's comments.

The first three LEMs (LEM-1, LEM-2, and LEM-3) would be equipped with communications equipment in addition to that required in the LEM for lunar missions to provide:

1. transmission of required engineering (R&D) data;
2. redundant operational telemetry;
3. updating of spacecraft equipment via an up-data command link; and

4. redundant tracking capability.

The LEM R&D communications system was essentially independent from the operational communications systems. It would be housed primarily in the equipment bay (which on operational flights would house the scientific payload equipment).

Letter, Phillips to Shea, "R&D Communications and Tracking systems in LEMs 1, 2, 3," June 12, 1965.

June 12

Samuel C. Phillips, Apollo Program Director, noted MSC request for support from Goddard Space Flight Center on LEM battery development as well as Goddard's agreement to furnish limited support.

Phillips suggested to ASPO Manager Joseph F. Shea that since MSFC had much experience in the design, development, and operational aspects of battery systems, it was important to use their experience and recommended MSFC be contacted if such action had not already occurred.

Memorandum, Phillips to Shea, "LEM Battery Development," June 12, 1965.

June 14

MSC Director Robert R. Gilruth appointed a Technical Working Committee, headed by Edwin Samfield, to oversee the design of a Lunar Sample Receiving Laboratory at the Center.

Memorandum, Robert R. Gilruth, MSC, to Chief, Engineering Division, "Formation of a Technical Working Committee for the design of a Lunar Sample Receiving Laboratory and designation of consultants to assist in the selection of an architect-engineer firm," June 14, 1965.

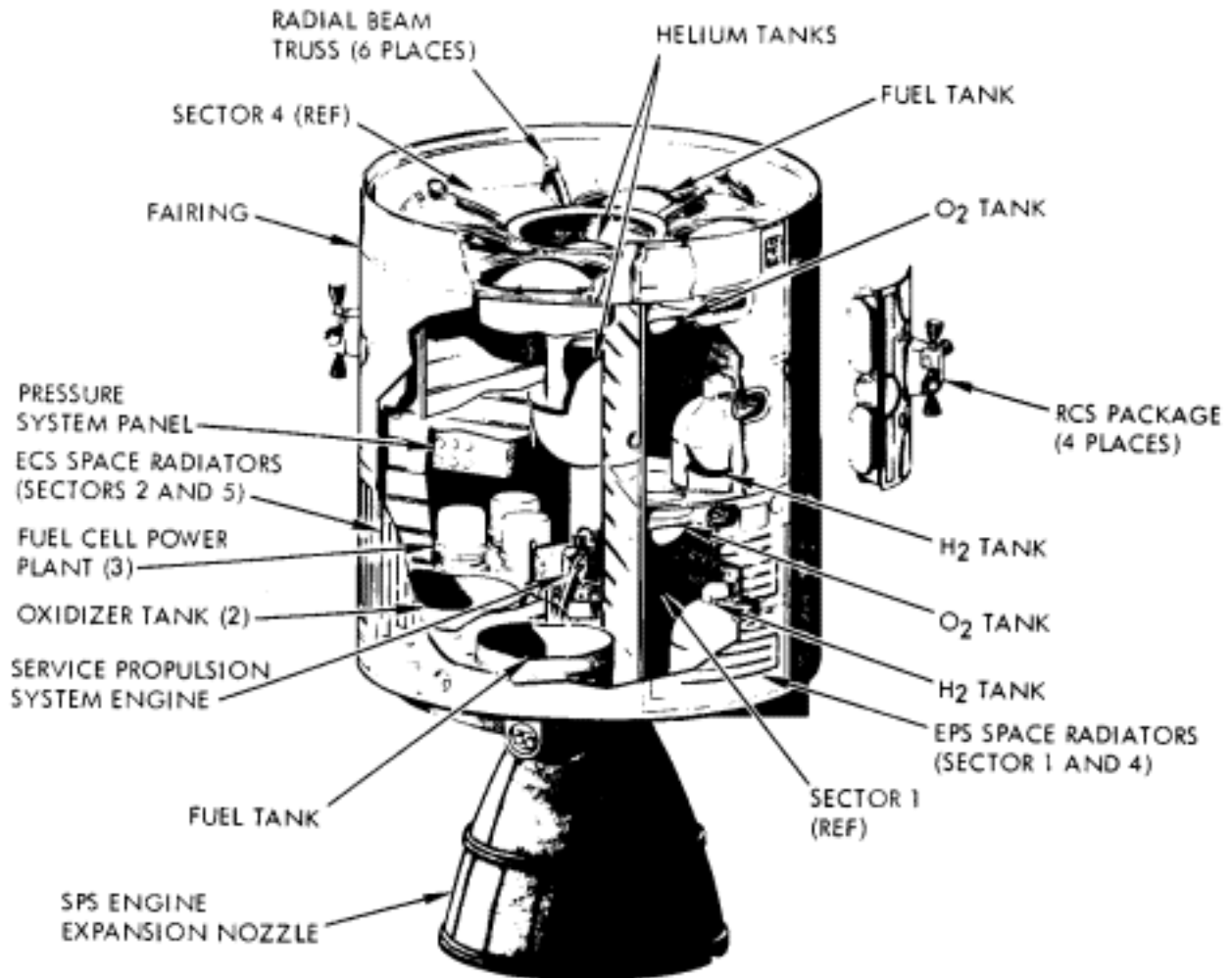
June 14-15

Using a LEM mockup at Grumman, and with the assistance of astronauts Roger B. Chaffee and Donn F. Eisele, engineers from Hamilton Standard performed mobility tests of the reconfigured portable life support system (PLSS). Crew Systems Division (CSD) reported that the reshaped back pack did not hinder entering or leaving the spacecraft; and while some interference problems were inescapable when the PLSSs were worn inside the spacecraft for any period of time, CSD believed that damage could be prevented through training and by limiting movement by the crew. Grumman, however, contended that the newer PLSSs had "serious implications" for mobility inside the LEM.

GAEC, "Monthly Progress Report No. 29," LPR-10-45, July 10, 1965, p. 3; "ASPO Weekly Management Report, June 10-17, 1965"; MSC, "ASPO Weekly Management Report, June 17-24, 1965."

June 15

Independent studies were made at MSC and North American to determine effects and impact of off-loading certain Block II service propulsion system components for Saturn IB missions. The contractor was requested to determine the weight change involved and schedule and cost impact of removing one oxidizer tank, one fuel tank, one helium tank and all associated hardware (fuel and oxidizer transfer lines, propellant quantity sensors and certain gaging wire harnesses) from CSM 101 and CSM 103. The MSC study was oriented toward determining technical problems associated with such a change and the effects on spacecraft operational requirements.



The service module.

The North American study indicated that removing the equipment would save about 690 000, along with a weight reduction of approximately 454 kg (1,000 lbs). Their report also indicated there would be no schedule impact provided go-ahead was given for CSM 101 prior to June 1, 1965, and for CSM 103 prior to November 1, 1965.

The MSC study indicated a maximum burn limitation of 280 seconds, due to excessive drop in helium temperature; and also pointed out that the change to the gaging system might not be as simple as North American stated because of the arrangement of the secondary sensing system. However, those problems did not appear insurmountable.

Memorandum, Owen E. Maynard, MSC, to Manager, ASPO, Attn: W. A. Lee, "OffLoading Block II SPS Components for Saturn IB Missions," June 15, 1965.

June 15-18

In a series of meetings at Downey, Calif., MSC, Grumman, and North American worked out most of the interface between the two spacecraft. Among the most significant items yet unresolved were: the thermal environment of the LEM during boost; and the structural loads and bending modes between the docked spacecraft.

Letter, C. L. Taylor, MSC, to NAA, Space and Information Systems Division, Attn: J. C. Cozad, "Contract NAS 9-150, Resolution of CSM/LEM Interfaces, MSC/NAA/GAEC Coordination Meetings No. 27 and 29, June 15-18 and June 24-25, 1965, respectively," July 28, 1965, with enclosure: "Minutes of Coordination Meeting . . .," June 24-25, 1965; "Monthly Progress Report No. 29," LPR-10-45, p. 1.

June 16

At Bethpage, N.Y., officials from Grumman and the Flight Projects Division (FPD) discussed the status of LEM-1. During early May, the company had agreed to devise a comprehensive development plan for the spacecraft, one that included hardware status; manufacturing and checkout sequences; requirements for facilities, ground support equipment, and software; and projected schedules. By mid-June, Grumman was still unprepared to discuss details, however, and requested another month to work on the plan. FPD could no longer remain patient: "It is the intention of this office," the division reported to ASPO, "to conduct a monthly LEM-1 status meeting . . . until the LEM-1 program plan is clearly defined."

Memorandum, J. Thomas Markley, MSC, to H. L. Reynolds, "Detailed LEM-1 working schedule," June 7, 1965; letter, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, LEM-1 Status Meeting," June 25, 1965; "ASPO Weekly Management Report, June 10-17, 1965."

June 16

To prevent the CSM's contacting the LEM's radar antenna (a problem disclosed during docking simulations), deviations in the CSM's roll attitude would be limited to eight degrees or less.

"ASPO Weekly Management Report, June 17-24, 1965."

June 16

MSC ordered North American to revise the deployment angles of the adapter panels: 45 degrees for separation, docking, and LEM withdrawal; and - at most - 60 degrees for abort separation. (See December 7, 1964.)

Letter, J. B. Alldredge, MSC, to NAA, Space and Information Systems Division, "Contract Change Authorization No. 275, Revision 1," June 16, 1965; letter, H. G. Osbon, NAA, to NASA MSC, Attn: C. L. Taylor, "Contract NAS 9-150, R&D for Project Apollo Spacecraft Results of Action Item from Eleventh Flight Mechanics, Dynamics, Guidance and Control Panel Meeting," June 29, 1965, with enclosure.

June 16

MSC directed Grumman to modify the LEM's pulse code modulation and timing electronics assembly to enable it to telemeter data from the abort electronics assembly (AEA). Thus, if data from the AEA disagreed with those from the spacecraft's guidance computer, the two sets could be reconciled on the ground (using inputs from the Manned Space Flight Network), relieving the astronauts of this chore.

Letter, James L. Neal, MSC, to GAEC, Attn: John C. Snedeker, "Contract NAS 9-1100, Contract Change Authorization No. 112, Provide Capability in PCMTEA to Telemeter AGS Computer Digital Data," June 16, 1965.

June 16

The net effect of a decision by ASPO Manager Joseph F. Shea in May was that the total fuel cell effort at both Pratt and Whitney and North American should be no more than \$9.7 million during FY 1966. The decision as to the distribution of the funds was left to the discretion of the fuel cell subsystem manager.

Memorandum for Record, J. Thomas Markley, "C&SM Fuel Cell Effort," June 16, 1965.

June 16-23

Structures and Mechanics Division (SMD) reported that Grumman had found two thermal problems with the LEM:

1. On the basis of current predictions, the spacecraft's skin and several antennas would overheat during the boost phase of the mission. SMD engineers, after analyzing the problem, believed that an "acceptable LEM environment" could be achieved by lessening the heat transferred from the inner panels of the adapter and by increasing that emitted by the outer panels.
2. Also, Grumman had reported that, when exposed to exhaust plumes from the SM's reaction

control engines, the LEM's skin would overheat in about five seconds. "Since the LEM withdrawal . . . requires 20 to 26 sec RCS firing," SMD understated, "it is apparent that a problem exists." One suggested solution involved improved insulation.

"ASPO Weekly Management Report, June 17-24, 1965"; memorandum, Joseph N. Kotanchik, MSC, "Review of requirement for Grumman Aircraft Engineering Corporation (GAEC) ground support equipment (GSE) Item LDW-410-12050, Thermal Control System," June 30, 1965.

June 16-July 15

North American submitted a design proposal for a scientific airlock for the CM (applicable to 014 and all Block II spacecraft). Structural design was scheduled to begin shortly.

NAA, "Apollo Monthly Progress Report," SID 62-300-39, August 1, 1965, p. 4.

June 16-July 15

North American reported two service propulsion engine failures at AEDC and a third at WSMR. At the first location, both failures were attributed to separation of the thrust chamber from the injector assembly; in the latter instance, weld deficiencies were the culprit. Analysis of all these failures was continuing.

Ibid., p. 11.

June 17

MSC directed Hamilton Standard Division to study the feasibility of incorporating a manual override in the current pressure relief valve. During lunar surface activity, a failed relief valve would prevent further operation of the suit.

TWX, Richard S. Johnston, MSC, to Hamilton Standard Division, Attn: R. E. Breeding, June 17, 1965.

June 17

Officials from Bellcomm, MSFC, and the Apollo offices in Houston and in Washington planned primary and alternate missions for the Saturn IB (applicable to SA-201 through SA-208). On July 16, the Office of Manned Space Flight specified launch vehicles (both Saturn IB and V hardware) for Apollo missions.

NASA OMSF, Apollo Program Directive No. 4, "Apollo Controlled Milestones and Hardware Quantities - Change Approval," July 16, 1965; memorandum, B. Kaskey, Bellcomm, to File, "Apollo Alternate Missions Meeting, Case 217 (U)," June 22, 1965.

June 17

A Development Engineering Inspection (DEI) was held on spacecraft 002 at North American, Downey, California. The NASA Board consisted of W. M. Bland, Jr., Chairman; R. H. Ridnour, J. Chamberlin, S. A. Sjoberg, F. J. Bailey, O. G. Morris, O. E. Maynard, and O. Tarango.

A total of 20 Request for Changes (RFCs) were submitted and reviewed; 12 of them resulted from the design review conducted at MSC prior to the DEI, and eight resulted from the inspection of the vehicle. The final disposition of the RFCs was: seven approved for immediate action; five approved for study; three rejected; and five determined not applicable.

Memorandum, W. M. Bland, Jr., MSC to Distr., "Results of Spacecraft 002 Development Engineering Inspection," sgd. E. M. Fields, June 23, 1965.

June 17

Crew Systems Division engineers evaluated various battery combinations for the portable life support system. The division recommended a three-hr main and a one-hr backup arrangement, which would save about 9 kg (20 lbs) in the total weight of the vehicle.

Memorandum, Richard S. Johnston, MSC, to Chief, Systems Engineering Division, "PLSS battery sizing," June 17, 1965.

June 17-24

NASA representatives briefed officials from the Atomic Energy Commission on the Apollo experiments program and discussed means of coordinating the Commission's work on a radioisotope generator to power those experiments.

"ASPO Weekly Management Report, June 17-24, 1965."

June 17-24

Crew Systems Division began evaluating space suits for the Apollo program (submitted by Hamilton Standard, David Clark, and International Latex. (See July 8-15.)

Ibid.

June 21

North American's Rocketdyne Division conducted the 1,000th test firing of the Saturn V's first-stage

engine, the F-1, MSFC.

Space Business Daily, June 23, 1965, p. 275; *History of Marshall. . . January 1-December 31, 1965*, p. 240.

June 21

Joseph F. Shea, ASPO Manager, established as a firm mission requirement the capability to connect the space suit to the LEM's environmental system and to the portable life support system while in a vacuum. This capability was essential for operational flexibility on the moon's surface.

Memorandum, Joseph F. Shea, MSC, to Chief, Crew Systems Division, "Suit Connections," June 21, 1965.

June 21

The following definitions were specified for use in evaluating design reliability, for design tradeoff studies, and in appropriate Interface Control Documentation:

Mission success

all primary mission objectives must have been accomplished and both the crew and command module safely recovered.

Alternate mission

if a contingency prevented completion of all primary mission objectives, but did not require immediate termination of the mission, an alternate mission plan would be followed but alternate missions would not be included in design reliability calculations.

Abort

the only objective after an abort decision was the safest recovery of the crew considering the contingency which caused the abort.

Memorandum, William A. Lee and Harry L. Reynolds, MSC, to Chief, Systems Engineering Division, "Mission success and crew safety definitions," June 21, 1965.

June 21-July 1

Crew Systems Division (CSD) conducted a series of flight tests to determine whether the cabin layout of the LEM was suitable for crew performance in zero and one-sixth g environments. Together with its report of satisfactory results, the division made several observations that it thought "appropriate":

- CSD suggested hand grips in a number of places to aid the crew
- Additional restraints were needed to supplement the Velcro pile on the cabin floor
- Some problems with crew performance and mobility, present during one-g simulations, were

absent in low- or zero-g environments (e.g., moving from one crew station to another).

MSC, "ASPO Weekly Management Report, July 8-15, 1965."

June 22

MSC advised Grumman of additional functions for the computer in the LEM's abort guidance section (to be added only if a part of its memory was left over after the basic requirements were digested). These functions, in order of priority, MSC listed as:

- Midcourse corrections
- Automatic abort from a coasting descent
- Display of CSM-LEM range and range rate
- Automatic terminal rendezvous (with manual velocity control).

Letter, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, LEM Abort Guidance Section Functional Requirements," June 22, 1965.

June 22

NASA Headquarters established an Ad Hoc Surveyor Orbiter Utilization Committee and MSC was requested to submit names of two proposed members. It was suggested that the nominees be familiar with the mission planning and constraints of the Apollo program. The first meeting was planned for late July.

On July 29, MSC Director Robert R. Gilruth submitted the names of William A. Lee and William E. Stoney, Jr. He noted that the same two individuals were being nominated to serve as MSC members on the Apollo Site Selection Board. Gilruth expressed a desire that the meetings of the two groups could be coordinated to the extent that travel would be minimized.

Letter, Homer E. Newell, Associate Administrator for Space Science and Applications, to MSC, Attn: Dr. Robert R. Gilruth, "Members of Ad Hoc Surveyor/Orbiter Utilization Committee," June 22, 1965; letter, Gilruth to Newell, "Members of Ad Hoc Surveyor/ Orbiter Utilization Committee," July 29, 1965.

June 23

In a memorandum concerning Configuration Control Panel and Configuration Control Board actions, J. Thomas Markley, Chief of ASPO's Program Control Division, pointed out that many proposals coming before the two groups were not being adequately evaluated for program impact by the responsible subsystem or technical area manager. He said, in part, "We must keep the number of changes to a minimum and incorporate only those that are necessary to meet program objectives. We are beyond the time when we can afford the luxury design improvement changes, unless they can show substantial

savings to the overall program. . . ."

Memorandum, Markley to Distr., "CCB/CCP Actions," June 23, 1965.

June 23

The operational requirement for Block I and Block II CSM HE orbital communications capability was investigated. ASPO requested that appropriate contract direction and specification change notices be submitted immediately to eliminate this capability from the Block II CSM and the practicality of eliminating the HE orbital capability from the Block I CSM be investigated.

Memorandum, William A. Lee, MSC, to Subsystem Manager, CSM Communications Subsystem, "Requirement for Block I and Block II CSM HF Orbital Communications Capability," June 23, 1965.

June 24-July 1

Dalmo-Victor submitted to MSC a report on modifications necessary to extend to lunar distances the operating range of the CSM's high-gain antenna. The Instrumentation and Electronic Systems Division was reviewing the report.

MSC, "ASPO Weekly Management Report, June 24-July 1, 1965."

June 24-July 1

MSC completed a cursory analysis of LEM landing gear load-stroke requirements at touchdown velocities of 2.43 m (8 ft) per sec vertical and 1.22 m (4 ft) per sec horizontal. This study was conducted to determine the lowest crush loads at 8-4 velocity to which the gear could be designed and still meet its landing performance requirements.

Ibid.; memorandum, William G. McMullen, MSC, to Manager, ASPO, "Elimination of TM-5 vehicle from the LEM Landing Gear Subsystem Test Program," July 7, 1965.

June 25

NASA announced the appointment of Col. C. H. Bolender as Mission Director for the first and second Apollo/Saturn IB flights. Bolender was assigned to the Mission Operations Organization in the Office of Manned Space Flight, NASA.

NASA News Release 65-211.

June 25

MSC approved North American's concept for thermal control of the valves in the CM's reaction control system (essential for long-duration missions). The crew could electrically heat the valves for about ten minutes before CSM separation and before the system was pressurized, thereby forestalling possible freezing of the oxidizer when it contacted the valve.

Letter, C. L. Taylor, MSC, to NAA, Space and Information Systems Division, Attn: J. C. Cozad, "Contract NAS 9-150, Effects of Spacecraft Venting Systems on RCS Propellant Requirements, Determination of," June 23, 1965.

June 25

Harry L. Reynolds, Assistant Manager of ASPO, said it was "becoming increasingly clear that we are going to have a difficult job keeping the LEM weight below the control weight." He said the Grumman effort was not adequate and suggested that R. Bullard of MSC be given LEM weight control as a full-time responsibility.

Memorandum, Reynolds to Chief, Systems Engineering Division, "LEM Weight Control," June 25, 1965.

June 25

ASPO informed Grumman, NAA, AC Spark Plug, and MIT that effective June 21, 1965, General Electric Company, Apollo Support Department, Daytona Beach, Fla., had assumed responsibility for the preparation and conduct of all automatic checkout equipment (ACE) training for NASA and its contractors.

To satisfy conditions of its contract, General Electric would:

- Survey NASA and contractor ACE training requirements and prepare for ASPO endorsement a standard set of lesson plans (course outlines) for three distinct ACE training courses -
 1. for ACE operators and operational checkout procedures writers,
 2. for personnel who had site assignments but were not operators, and
 3. for all other individuals who did not satisfy the aforementioned assignment considerations.
- Issue with ASPO approval a lesson plan for each ACE training course. These plans would be considered baseline documents and deviations would not be permitted without prior approval from ASPO.
- Prepare one study guide which would contain common reference information for all three ACE training courses.
- Issue coordinated ACE training schedules approved by ASPO.
- Distribute monthly status reports to each participating organization. "This report would contain a training schedule for the next three months as well as a discussion of achievements. To control established plans and implement changes, the coordinator for each participating organization

would be responsible for determining local training requirements and coordinating those needs with other contractors or NASA elements who desired training at that facility.

- Issue a citation which would acknowledge satisfactory course completion to those qualifying students.

Purpose of selection of a single ACE training contractor and establishment of a standard set of courses was to provide participating organizations a sufficient amount of training and a universal understanding of ACE.

Letters, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, ACE Training," June 25, 1965; M. E. Dell, MSC, to AC Spark Plug, Attn: Hugh Brady, "Contract NAS 9-497, ACE Training," June 28, 1965; M. E. Dell, MSC, to MIT, Attn: M. B. Trageser, "Contract NAS 9-4065, ACE Training," June 28, 1965; J. B. Aldredge, MSC, to NAA, Space and Information Systems Division, Attn: J. C. Cozad, "Contract NAS 9-150, ACE Training," June 29, 1965.

June 25

NASA announced negotiations with Douglas Aircraft Company for nine additional S-IVB stages to be used as the third stage of the Saturn V launch vehicle being developed at Marshall Space Flight Center. Work was to include related spares and launch support services. The S-IVB contract, presently valued at \$312 million, would be increased by \$150 million for the additional work.

NASA News Release 65-209, "NASA to Negotiate with Douglas for more S-IVB Stages," June 25, 1965; *Space Business Daily*, June 28, 1965, p.295.

June 25

MSC approved North American's proposed location of the antenna for the radar transponder in the CSM, as well as the transponder's coverage. This action followed a detailed review of the relative positions of the two spacecraft during those mission phases when radar tracking of the LEM was required.

Letter, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Radar Transponder Antenna Location on CSM," June 25, 1965.



The first ground-test version of the Saturn V's first stage is shown being removed from its vertical assembly tower at NASA's Michoud Operations Facility June 27, 1965. The stage was 10 m (33 ft) in diameter and 42 m (138 ft) tall.

June 28

Owen E. Maynard, Chief of the Systems Engineering Division, vetoed a demand by the Flight Control Division for redundancy in the LEM's pulse code modulation telemetry system. Two factors determined

Maynard's action:

1. cost and schedule impacts, and
2. the resultant weight and power increases that redundancy would impose. Also it would produce only a "marginal" increase in the total reliability of the spacecraft.

Memorandum, Owen E. Maynard, MSC, to Chief, Flight Control Division, "LEM PCM telemetry redundancy," June 28, 1965.

June 28

Systems Engineering Division chief, Owen E. Maynard, reported to the Instrumentation and Electronic Systems Division (IESD) the results of a study on a LEM communications problem (undertaken by his own group at IESD's request). During phases of powered descent to certain landing sites (those in excess of 20 degrees east or west longitude), the structure of the spacecraft would block the steerable antenna's line of sight with the earth. Communications with the ground would therefore be lost. Maynard concurred with IESD that the problem could best be solved by rotating the LEM about its thrust axis.

Memorandum, Owen E. Maynard, MSC, to Chief, Instrumentation and Electronic Systems Division, "Providing adequate earth coverage from the LEM S-band steerable antenna during lunar descent and ascent," June 28, 1965.

June 28

John H. Disher, Director of the OMSF Apollo Test Office, stressed two broad areas open to concern in the Apollo spacecraft heatshield development program:

1. structural integrity, and
2. flight-test confirmation of the Block II design.

The structural integrity question centered around the following problems: welding, ablative material integrity, and impact strength.

MSC had planned to qualify the Block II heatshield by flight tests of modified Block I spacecraft 017 and 020. Some of the Block II changes could not be incorporated into modified Block I spacecraft in time to meet the current schedule and limitations of facilities would not permit full evaluation of all modifications by ground testing.

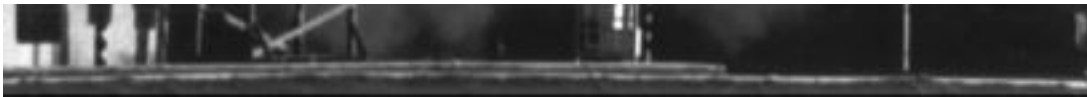
Disher suggested to Apollo Program Director Samuel C. Phillips that ASPO Manager Joseph Shea be asked to present physical descriptions of the Block I and Block II heatshields, and interim versions as applied to specific spacecraft, as well as the test plan that would ensure adequacy of heatshields to meet mission requirements. Memorandum, Disher to Phillips, "Apollo Spacecraft Heat Shield," June 28, 1965.

MSC directed North American to design the CM to store one integrated thermal meteoroid garment (TMG), rather than merely the thermal covering alone. The crewmen would carry the TMG into the LEM for use during extravehicular operations.

Letter, J. B. Alldredge, MSC, to NAA, Space and Information Systems Division, "Contract Change Authorization No. 371," June 29, 1965.

June 29





The launch of PA-2.

NASA launched Apollo mission PA-2, a test of the launch escape system (LES) simulating a pad abort at WSMR. All test objectives were met. The escape rocket lifted the spacecraft (boilerplate 23A) more than 1,524 m (5,000 ft) above the pad. The earth landing system functioned normally, lowering the vehicle back to earth. This flight was similar to the first pad abort test on November 7, 1963, except for the addition of canards to the LES (to orient the spacecraft blunt end forward after engine burnout) and a boost protective cover on the CM. PA-2 was the fifth of six scheduled flights to prove out the LES. [Mission objectives in Appendix 5.]

Memorandum, George E. Mueller, NASA, to Administrator, "Apollo Spacecraft Pad Abort Test, Mission PA-2, Post Launch Report No. 1," July 2, 1965; MSC, "Postlaunch Report for Apollo Mission PA-2 (BP-23A)," July 29, 1965, pp. 1-1, 2-1, 3-1, and 10-1.

June 29

North American reported to MSC that no structural changes to the spacecraft would be required for uprating the thrust of the Saturn IB's H-1 engine from 90,718 to 92,986 kg (200,000 to 205,000 lbs). Effects on the performance of the launch escape vehicle would be negligible.

Letter, H. G. Osbon, NAA, to NASA MSC, Attn: C. L. Taylor, "Contract NAS 9-150, R&D for Project Apollo Spacecraft; Spacecraft Structural Impact of Increase of H-1 Engine," June 29, 1965.

June 29

NASA formally announced the selection of six scientist-astronauts for the Apollo program, chosen from a group nominated by America's scientific community. Qualifications and recruiting procedures had been worked out earlier by NASA and the National Academy of Sciences' Ad Hoc Committee on Scientific Qualifications of Scientist-Astronauts. To be eligible, candidates must have been born on or after August 1, 1930; be citizens of the United States; be no more than 1.83 m (6 ft) tall; and have an educational level of a doctorate or the equivalent in experience. The six, only one of whom was on active military service, were Owen K. Garriott, Edward G. Gibson, Duane E. Graveline, Lt. Cdr. Joseph P. Kerwin (USN), Frank Curtis Michel, and Harrison Schmitt.

Letter, Homer E. Newell, NASA, to Robert R. Gilruth, MSC, August 19, 1964, with attachment, "Suggested Public Announcement of the Scientist-Astronaut Program," August 19, 1964; letter, Newell to Harry H. Hess, NAS, August 19, 1964; NASA News Release 64-315, "NASA Reports Some 900

Persons Interested in Scientist-Astronaut Program," December 16, 1964; MSC News Release 64-195, December 16, 1964; MSC News Release 65-63, June 29, 1965.

June 30

Langley Research Center put into operation its 3.5 million Lunar Landing Research Facility. The huge structure (76.2 m [250 ft] high and 121.9 m [400 ft] long) would be used to explore techniques and to forecast various problems of landing on the moon. The facility would enable a test vehicle to be operated under one-sixth g conditions.

Astronautics and Aeronautics, 1965, p. 303; Michael David Keller, *Fifty Years of Flight Research: A Chronology of the Langley Research Center, 1917-1966* (HHN-65), November 1966, p. 89.

June 30

In a memorandum to T. Tarbox, John Ryken, Bell Aerosystems Company LLRV Project Manager, said he understood that Dean Grimm of MSC believed that the LLRV was not configured to have the jet engine provide simulation of a constant-lift rocket thrust in addition to providing the 5/6th g lift. Ryken forwarded to Tarbox a copy of a report, "LLRV Automatic Control System Service and Maintenance Manual," plus notes on the system in the hope that these would help him and NASA personnel better understand the system. He also included suggestions about reducing aerodynamic moments which Grimm felt might interfere with LEM simulation.

Interoffice Memo, Bell Aerosystems Company, J. Ryken, Bell, to T. Tarbox, Bell, "LLRV," June 30, 1965.

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July 1

The Development Engineering Inspection (DEI) for Little Joe II 12-51-3 was satisfactorily conducted at General Dynamics Convair, San Diego, Calif. The vehicle had been assigned for Mission A-004, an abort mission in the power-on tumbling boundary region. The DEI was conducted with emphasis on changes which had been effected as a result of the malfunction encountered during the A-003 mission. The following served on the DEI Board: J. A. Chamberlin, Chairman, S. A. Sjoberg, R. F. Gordon, F. J. Bailey, R. C. Duncan, W. M. Bland, R. A. Gardiner, and L. P. Gallagher, Secretary.

Memorandum, Chief, Checkout and Test Division, MSC, to Distr., "Development Engineering Inspection for LJ II 12-51-3," sgd. James J. Shannon for W. M. Bland, June 25, 1965; "Weekly Activity Report, June 27-July 3, 1965," sgd. Joseph F. Shea.

July 1

On the basis of information from the two Apollo spacecraft manufacturers, the Systems Engineering Division (SED) reported a possible thermal problem with the Saturn V during ascent:

- On Saturns 501 and 502, the temperatures of the SM and the adapter would exceed design limits. (These limits were based on heating rates for 504, a heavier vehicle with a consequently cooler trajectory.)
- And on 504, heating rates on the adapter would create an "unacceptable thermal environment" for the spacecraft within.

SED laid down study procedures to determine the best solution to this problem (either by modifying the spacecraft or the launch trajectory - or both).

Memorandum, Owen E. Maynard, MSC, to Distr., "Saturn V ascent heating problem," July 1, 1965; memorandum, Aaron Cohen, MSC, to Chief, Systems Engineering Division, "Item 2.10, SESAME No. 2 Meeting Minutes, SM and SLA/LEM Potential Boost Heating Problems," July 26, 1965, with enclosure: "MSC/NAA Meeting, SM/SLA/LEM Boost Heating," July 15, 1965.

July 1

Within its Office of Manned Space Flight, NASA organized an Apollo Site Selection Board. As an advisory body to the Associate Administrator for Manned Space Flight, George E. Mueller, the group would recommend landing sites for Apollo.

Instruction, George E. Mueller, NASA, to Distr., "Establishment of Apollo Site Selection Board," July 1, 1965.

July 1

NASA Associate Administrator for Manned Space Flight George E. Mueller told MSC Director Robert R. Gilruth he was establishing an Operations Executive Group. This group would consist of senior executives whose organizations were carrying out the manned space flight operations.

It was Mueller's objective that the group meet on a regular basis and review program status, resource requirements, management, and flight operations to provide executive management with the background needed to make effective policy decisions. A second objective was to ensure that the executives in the operations area knew each other well enough to work directly in the rapid solution of time-critical problems.

Mueller planned that one-day meetings would be held at two to four month intervals at locations that would acquaint members with facilities and equipment.

Letter, Mueller to Gilruth, July 1, 1965.

July 1-8

Grumman completed its study of oxygen storage systems for the LEM (see June 11) and reviewed with MSC the company's recommendation (one 20,684-kilonewton per sq m [3,000 psi] tank in the descent stage, two 6,894-kilonewtons per sq m [1,000 psi] tanks in the ascent stage). One drawback to the design, which the Crew Systems Division termed an "apparently unavoidable bad feature," was that, by the time of the final cabin repressurization, the repressurization time would increase to about 12 minutes (though this was admittedly a conservative estimate). Although requesting more data from Grumman on temperatures and cabin pressures, the Center approved the configuration.

MSC, "ASPO Weekly Management Report, July 1-8, 1965."

July 2

The NASA Director of Bioscience Programs pointed out that the National Academy of Sciences' report

on back contamination placed emphasis on the potential hazard from the moon because of the short stay on the moon. From this report, it was evident that NASA had problems which must be solved in the very near future.

It was recommended that NASA accept the operational responsibility for back contamination and that there be a clear-cut assignment soon.

It was felt that failure of NASA to establish adequate authority to handle this problem and thus to satisfy the public, the press, the scientific community, and other regulatory agencies could result in direct control of back contamination by those agencies and cause unnecessary constraints upon the manned lunar and planetary missions.

Memorandum, Director of Bioscience Programs, NASA, to Associate Administrator for Space Science and Applications, "Responsibility for Space Quarantine," July 2, 1965.

July 2

ASPO Manager Joseph F. Shea ordered Crew Systems Division to develop some type of protective devices that the astronauts might use to shield their eyes during a solar flare. ASPO regarded the risk of cataracts during these solar events as extraordinarily high. Although not mandatory, it was desirable that the crew could still see while wearing the devices. Should a flare occur while the crew manned the LEM, mission ground rules called for an abort back to the safety of the CSM; therefore, such devices would be needed for the CM alone.

Memorandum, Joseph F. Shea, MSC, to Chief, Crew Systems Division, "Incidence of cataracts in Apollo crewmembers," July 2, 1965.

July 4-10

The Weekly Activity Report for the period indicated that

1. the CM 002 was transferred internally within North American from manufacturing to the test organization on July 8;
2. the CM 009 checkout at North American continued with the central timing equipment and signal conditioner checkout completed, and the new 40-ampere-hour batteries for CSM 009 and 011 were shipped to KSC and North American, respectively; and
3. the Grumman subcontract to Eagle-Picher for the LEM batteries was approved by NASA.

"Weekly Activity Report, July 4-10, 1965," sgd. J. Thomas Markley for Joseph F. Shea.

July 7-9

Langley Research Center completed CSM active docking simulations and lunar orbital docking runs.

Memorandum, Michael K. Lake, MSC, to Chief, Spacecraft Operations Branch, "Apollo Docking Simulation," July 23, 1965, with enclosure.

July 7-13

Illustrative of continuing design and managerial problems, MSC and North American representatives attempted to resolve thermal problems with the Block II environmental control system (ECS), primarily the ECS radiator. The week-long talks were fruitless. MSC's arguments and supportive evidence notwithstanding, the contractor steadfastly opposed the water-glycol approach, favoring a nonfreezing liquid (Freon). MSC, similarly, was hardly satisfied with North American's intransigence and less so with the company's effort and performance. "A pertinent observation," reported Crew Systems Division, "is that . . . it will be extremely difficult to complete any other development in support of Block II schedules unless their [North American's] attitude is changed."

"ASPO Weekly Management Report, July 8-15, 1965"; memorandum, Owen E. Maynard, MSC, to Chief, Crew Systems Division, "Design criteria for backup ECS radiator development program," July 6, 1965; memorandum, Frank H. Samonski, Jr., MSC, to Chief, Systems Engineering Division, "Viscosity data of RS-89A (water-glycol)," July 23, 1965.

July 8-9

At a design review on the VHF radio equipment for the LEM, conducted by RCA, Grumman refused to vote its approval. Grumman's most serious objection centered on thermal loads, which under extreme conditions could far exceed specification limits. RCA thereupon began exploring several approaches, including new materials, relocation of components, and redesigned heat sinks. Grumman was asked to keep MSC well informed on problems, corrective actions, and anticipated impacts.

TWXs, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, July 12, 16, 19, and 22, 1965.

July 11

An RCS oxidizer tank failed during a test to demonstrate propellant compatibility with titanium tanks. This was the first of seven tanks to fail from a group of ten tanks put into test to investigate a failure that occurred during February 1965. These results caused an intensive investigation to be undertaken.

Memorandum, Darrell Kendrick, MSC, to Chief, Propulsion and Power Division, "Trip to Bell Aerosystems Company (BAC) on July 14 and 15, 1965 regarding S/M F (S/N 26) RCS Tank Shell Failure," July 26, 1965.

July 11-17

During the period the NASA/Department of the Army agreement for use of Army helicopters to airlift LEM adapters was signed by both parties; the Apollo Block II space suit preliminary design review was successfully held by David Clark Company; and evaluation testing of the Apollo Block II space suits submitted by David Clark Company, Hamilton Standard Division and International Latex was completed, with data being reduced.

"Weekly Activity Report, July 11-17, 1965," sgd. J. Thomas Markley for Joseph F. Shea.

July 12

Joseph F. Shea, ASPO Manager, informed Flight Crew Operations that the capability had been firmly established for connecting and disconnecting the suit oxygen umbilicals in a vacuum. Crew Systems Division was modifying the connector (using a two-position release) to satisfy this requirement. This change would ensure safe umbilical operation while in an unpressurized spacecraft.

Memorandum, Donald K. Slayton, MSC, to Manager, ASPO, "Lunar Surface Operations," June 11, 1965; memorandum, Shea, MSC, to Asst. Dir. for Flight Crew Operations, "Lunar Surface Operations," July 12, 1965.

July 13

Crew Systems Division (CSD) completed its study on the feasibility of controlling the amount of bacteria vented from the LEM. Division researchers found that, by placing special filters in the environmental control system (ECS) of the spacecraft, emission levels could be greatly lowered. This reduction would be meaningless, however, in view of effluents from the extravehicular mobility unit (EMU) - the moon would still be contaminated by the space travelers. Because of weight penalties - and because of their dubious value - CSD recommended that bacteria filters not be added to the LEM's ECS. The Division further advised that, at present, neither the amount of bacteria emitted from the EMU nor a means of controlling this effluence was yet known.

Memorandum, Robert E. Smylie, MSC, to Chief, Systems Engineering Division, "Feasibility of controlling effluent bacteria from the LEM cabin and environmental control subsystem," July 13, 1965, with enclosure: "Control of Effluent Micro-Organisms from the LEM Cabin and Environmental Control System"

July 13

A Little Joe II failure investigation presentation was made at MSC July 13 in which General Dynamics/Convair (GD/C) and MSC's Engineering and Development (E&D) Directorate presented results of independent failure investigations of the mishap which occurred during Apollo Mission A-003 (Boilerplate 22) on June 22, 1965, at WSMR.

The GD/C investigation results were presented by J. B. Hurt, Little Joe II Program Manager, in the form of flight movies and a slide talk. The data made the following points:

- At approximately one second after liftoff, the Fin IV elevon moved in a direction to cause the observed clockwise rotation and at 2.5 seconds reached the fully deflected position where it remained until vehicle breakup.
- Although computer simulations of the flight with Fin IV fully deflected did not precisely duplicate the observed dynamic motions, sufficient correlation existed to conclude that Fins I, II, and III functioned normally while Fin IV alone caused loss of the mission.
- The complete attitude control system, exclusive of the Fin IV hydro-electrical servo loop, performed correctly as designed.
- The most probable cause for the failure was a malfunction in Fin IV hydro-electrical servo-loop due to an internal mechanical failure of the servo-valve.

The E&D investigation results were presented by O. P. Littleton of the Guidance and Control Division. In summary, results of the E&D investigation were stated to have confirmed the findings of GD/C although different computer methods were used. Littleton agreed with the conclusions of GD/C, but emphasized that an electrical malfunction within the Fin IV hydro-electrical servo-loop could not be discounted as a possible source of failure at that time.

Memorandum for Record, Bill J. McCarty, MSC, "Little Joe II Failure Investigation Presentation," July 20, 1965.

July 14

Structures and Mechanics Division (SMD) presented meteoroid protection figures for the Apollo CSM. (During April, General Electric [GE] had developed reliability estimates for the LEM, based on revised design criteria, for the 8.3-day reference mission. The probability for mission success, GE had found, was 0.9969.) SMD'S figures were:

	Block I (14-day earth orbital flight)	Block II (8.3-day lunar mission)
CM	0.99987	0.99989
SM	0.9943	0.9941

The division consequently placed the meteoroid protection for the entire mission at 0.99417 (Block I, CSM only) and 0.99089 (Block II, CSM and LEM). Apollo's goal was 0.99.

All of the above figures, both GE's and SMD's, were derived from the inherent protection afforded by the spacecraft's structure. Thus no additional meteoroid shielding was needed. (Meteoroid protection would still be required, of course, during extravehicular operations.)

"ASPO Weekly Management Report, July 8-15, 1965."

July 14

Willis B. Foster, NASA's Director of Manned Space Science Programs, informed MSC's Maxime A. Faget that he had asked the following persons to continue to serve as members of an Ad Hoc Committee as an advisory group to Foster with regard to the design and construction of the Lunar Sample Receiving Laboratory: E. C. T. Chao (Chairman), Lorin Clark (alternate chairman), James Arnold, Clifford Frondel, Briggs Phillips, P. R. Bell, and alternates Jonathan Klein and Larry Hall.

Letter, Foster to Faget, "Membership of the Headquarters Advisory Committee on Lunar Sample Receiving Laboratory," July 14, 1965.

July 15

North American began redesigning the side hatch mechanism in the CM to satisfy the requirement for extravehicular transfer from Block II spacecraft. Two basic modifications to the Block I mechanism were required: (1) enlarging it to overcome thermal warpage; and (2) adding some hinge retention device to secure the hatch once it was opened.

Memorandum, R. D. Langley, MSC, to Manager, ASPO, "Side Access Ablative Hatch," July 6, 1965; letter, C. L. Taylor, MSC, to NAA, Space and Information Systems Division, Attn: J. C. Cozad, "Contract NAS 9-150, Shipment of S/C 006 Side Access Ablative Hatch to MSC," July 15, 1965; memorandum, Owen E. Maynard, MSC, to Manager, ASPO, "Side access ablative hatch," July 23, 1965.

July 15

ASPO Manager Joseph F. Shea informed Grumman that a proposal they had made during the LEM Program Review on July 6 regarding broader qualification scheduling and parts deviations had been reviewed by NASA and it was considered "not in the best interests of the program to relax the requirements to the extent proposed by GAEC."

Shea cited a paragraph of the Contract Technical Specification which specified: "Qualification tests supporting a particular flight vehicle shall be completed prior to that vehicle being delivered from the Contractor."

It was NASA's desire that LEM program scheduling be such that all ground test logic constraints required in support of launch dates would be completed at least six weeks prior to scheduled launch dates. Shea pointed out that the LEM program schedules as presented by Grumman at the July 6 Review were not in complete accord with dates previously provided June 7 in a datafax signed by Shea.

Shea required the following delivery dates from Grumman: LEM-1, November 15, 1966; LEM-2,

February 15, 1967; LEM-3, April 15, 1967; LEM-4, July 15, 1967; LEM-5, October 15, 1967; LEM-6, December 15, 1967; LEM-7, February 15, 1968; LEM-8, April 15, 1968; LEM-9, June 15, 1968; LEM-10, August 15, 1968; and LEM-11, October 15, 1968.

Grumman was requested to provide NASA, no later than August 2, 1965, their plan for support of a LEM program development schedule which would incorporate these requirements.

Letter, Joseph F. Shea, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, LEM Development Program Requirements," July 15, 1965.

July 16

North American recommended to MSC that, for the time being, the present method for landing the CM (i.e., a passive water landing) be maintained. However, on the basis of a recent feasibility study, the contractor urged that a rocket landing system be developed for possible use later on. North American said that such a system would improve mission reliability through the increase in impact capability on both land and water.

TWX, C. L. Taylor, MSC, to NAA, Space and Information Systems Division, Attn: J. C. Cozad, July 9, 1965; NAA, "Apollo Monthly Progress Report," SID 62-300-40, September 1, 1965, pp. 12-13.

July 16

MSC directed Grumman to provide stowage within the LEM for those tools needed for transfer between the two spacecraft (either intra- or extravehicular). The tool kit, similar to that in the CM, would be stored in the LEM at earth launch.

Letters, James L. Neal, MSC, to GAEC, Attn: John C. Snedeker, "Contract NAS 9-1100, Contract Change Authorization No. 122, Extravehicular Crew Transfer Provisions," and "Contract NAS 9-1100, Contract Change Authorization No. 123, Stowage of Inflight Tools in the LEM," July 16, 1965.

July 16-August 15

On the basis of wind tunnel tests at Arnold Engineering Development Center (AEDC), North American now considered as negligible the effects of structural protuberances on the CM's rolling moment and on propellant consumption.

"Apollo Monthly Progress Report," SID 62-300-40, pp. 6-7.

July 16-August 15

In order to use the LEM as a backup for the service propulsion system (SPS) to abort the mission during the 15-hour period following translunar injection, Grumman informed North American that some redesign of the spacecraft's helium system would likely be required. This information prompted North American designers to undertake their own analysis of the situation. On the basis of their own findings, this latter group disagreed with the LEM manufacturer:

- Before transposition and docking, the two spacecraft would already be on a confirmed free-return trajectory.
- During the 15-hour interval, moreover, LEM propulsion would be required only in the event of failures in the SPS *and* some time- dependent, mission-critical system.

The probability of two such failures during the abort period, North American concluded, was not sufficient to warrant redesigning the helium system.

Ibid., pp. 12-13.

July 18

Russia launched *Zond III*, but neither its objectives nor its achievements were announced until some time later. About 36 hours after launch, the spacecraft began photographing the far side of the moon (at a range of between 11,600 and 10,000 km [7,217 and 6,217 mi]). After passing the moon, it entered a heliocentric orbit and thus became an artificial planet. On July 29, *Zond III* transmitted its pictures back to earth, as planned. Those pictures showed clearly the heavily cratered nature of the surface. This mission dramatized the advances in space photography that the U.S.S.R. had made since its first far-side effort six years earlier.

Astronautics and Aeronautics, 1965, pp. 337, 378-379, 392-393; Tikhonravov *et al.*, *Ten Years of Space Research in the USSR*, pp. 20-21.

July 19

NASA was acquiring eight KC-135 aircraft and three ships to help maintain communications during Apollo moon flights. In addition, two ships of the existing DOD instrumentation fleet were being remodeled for support of the Apollo lunar mission's reentry phase. The KC-135 jet transports would be used during reentry to combat the effects of the plasma sheath blackout which had drowned out communications on previous manned launchings. In addition, three primary ground stations were being prepared at Goldstone, Calif.; Canberra, Australia; and Madrid, Spain.

Astronautics and Aeronautics, 1965, p. 340; memorandum, Samuel C. Phillips, NASA, to Assoc. Admin. for Manned Space Flight, "Apollo Instrumentation Ship Schedules," July 23, 1965, with enclosures; memorandum, Arnold W. Frutkin, NASA, to Julian Scheer, "Designation of Spanish tracking station," July 23, 1965.

July 19

MSC directed Grumman to implement changes in weights of the LEM:

Total LEM	14,515 kg (32,000 lbs)
Ascent stage inert	2,193 kg (4,835 lbs)
Descent stage inert	2,166 kg (4,775 lbs)

Memorandum, James L. Neal, MSC, to GAEC, Attn: John C. Snedeker,

"Contract NAS 9-1100, Contract Change Authorization No. 124, Addition of Control Weights to Specification," July 19, 1965.

July 19-20

North American conducted zero-g tests at Wright-Patterson AFB to evaluate the design of the CM's unitized crew couch and restraint hardware.

"Apollo Monthly Progress Report," SID 62-300-40, p. 4.

July 19

NASA Headquarters authorized North American to subcontract the Block II CSM fuel cells to Pratt and Whitney. Estimates placed the cost at \$30 million.

TWX, George J. Vecchietti, NASA, to NASA Office, Downey, Calif., Attn: George A. Abbott, July 19, 1965.

July 21

At a LEM-1 review held at Bethpage, N.Y., Grumman briefed MSC officials on the status of design drawings and hardware procurement. Also, the company prepared a detailed schedule for manufacturing and installation of various systems on the spacecraft.

MSC, "ASPO Weekly Management Report, July 15-22, 1965"; letter, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, LEM I Status Meeting Number Two," August 6, 1965.

July 21

North American reported that qualification testing had been completed on two items of electrical hardware, the CSM battery charger and the pyrotechnic battery.

NAA, "Project Apollo Spacecraft Test Program Weekly Activity Report (Period 19 July 1965 through 25 July 1965)," p. 3.

July 21

MSC officially notified Grumman that, as part of the Apollo scientific program, an experiments package would be left on the moon by the crewmen of the LEM. The Center outlined weight and storage requirements for the package, which would be stored in the descent stage of the vehicle along with the lunar geological equipment. And MSC emphasized the need for dissipating waste heat given off by the system's radioisotope generator. (The radioisotope generator was a firm requirement, despite the fear voiced by many scientists that the radiation it gave off would disrupt the experiments.)

Letter, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Request for Preparation of Interface Control Documents for the Lunar Surface Experiments Package (LSEP), and the Lunar Geological Equipment," July 21, 1965; MSC, "ASPO Weekly Management Report, July 29-August 5, 1965."

July 21

Several lunar surface vehicles received national attention:

- NASA announced that it had dropped plans for developing a small rover to be carried to the moon aboard soft-landing Surveyor spacecraft. This action, the space agency said, stemmed from a desire to concentrate on the development of the spacecraft *per se* and on its scientific instrumentation.
- Bell Aerosystems Company announced that it had designed a rocket-propelled Lunar Flying Vehicle (LFV) to aid Apollo astronauts in their exploration of the moon. This work was the result of a year-long study that the company had conducted for MSFC. The LFV, nicknamed "Hopper," would be able to travel about 80 km (50 mi) without stopping. Bell announced also that it had received additional funds from NASA (almost a half million dollars) to continue work on another lunar vehicle, the so-called Manned Flying System. This latter craft, also primarily a tool for exploration, would be able to transport an astronaut and about 136 kg (300 lbs) of equipment (or two astronauts) for distances up to 24 km (15 mi) from the original landing site.

NASA News Release 54-245, "NASA Will Not Develop Surveyor Roving Vehicle." July 21, 1965; *Astronautics and Aeronautics*, 1965, p. 342.

July 22

MSC and Grumman discussed the LEM landing gear design and determined the landing velocity touchdown envelope.

TWX, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, subject: "Structural Design for Lunar Landing Dynamic Magnification Factor," July 22, 1965; TWXs, Young to Mullaney, July 30 and August 18, 1965; GAEC, "Monthly Progress Report No. 30," LPR-10-46, August 10, 1965, p. 8.

July 22

Agreements and decisions reached at the MSC briefing on the LEM optical tracker were:

- Development of the LEM rendezvous radar should be continued.
- One contractor should be selected for development of the optical tracker with schedules to support installation in early LEMs.
- A decision on the rendezvous radar versus the optical tracker was deferred.

TWX, Samuel C. Phillips, NASA, to MSC, Attn: Joseph F. Shea, subject: "LEM Optical Tracker," July 28, 1965.

July 23

MSC authorized North American to make a number of significant hardware changes:

- Delete hardware for transferring water from the CM to the LEM.
- Place filters in the propellant lines of the SM's reaction control system.
- Cease all work on an extravehicular probe (responsibility which MSC now assumed).
- Delete from the stabilization and control system (SCS) of all Block II CSMs the hybrid thrust vector control apparatus. (This change reduced the functional capability of the SCS and simplified the system's interface with the guidance and navigation system.)
- Delete the HE orbital antenna from CSMs 012, 014, and all Block II spacecraft.
- Change the propellant mixture in the service propulsion system of Block II spacecraft. The service propulsion engine would be modified, which would require additional developmental and qualification testing.
- Go ahead on thermal coating on the adapter (to achieve the desired thermal environment for the LEM during boost).

Letters, J. B. Alldredge, MSC, to NAA, Space and Information Systems Division, "Contract Change Authorizations, 384, 385, 387, 388, 390, 391, 392, and 393," July 23, 1965.

July 23

MSC defined for Grumman the functions that the LEM's abort guidance section (AGS) must perform

during earth orbital flights:

- When both spacecraft were unmanned, the AGS must be able to hold the LEM's attitude during coast or while thrusting; it would not, however, have to control thrusting itself.
- During manned missions, whether or not the LEM itself actually was manned, the AGS must afford closed-loop control of the vehicle, again both while coasting and thrusting. Thrusting phases of these flights would demonstrate the section's guidance and navigational capabilities.

The basic lunar mission program still would be used. False position, velocity, and gravity data would be inserted to make the AGS behave as if it were flying around the moon. Finally, MSC emphasized that neither the AGS hardware, its permanent or "hardwired" memory, nor delivery schedules must be altered to meet this earth orbital capability.

Letter, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Abort Guidance Section operational requirements during earth orbital missions," July 23, 1965.

July 26

During a news conference, Kenneth S. Kleinknecht, Deputy Manager of the Gemini Project Office at MSC, affirmed that, although no firm decisions had yet been made, the concept of a circumlunar flight using a Gemini spacecraft was being seriously studied. The mission would use Titan II and III-C launch vehicles and would require rendezvousing in earth orbit. NASA, Martin-Marietta Corporation (builder of the Titan), and Aerojet-General Corporation (which manufactured upper stages for the III-C) all were studying the feasibility of such a flight. Later in the year, NASA Administrator James E. Webb eliminated the possibility of a Gemini circumlunar mission, ". . . our main reliance for operating at lunar distances . . . is the large Saturn V/Apollo system."

Howard Benedict, *The Times-Picayune*, New Orleans, July 26, 1965; letter, U.S. Representative Olin E. Teague to James E. Webb, August 18, 1965; letter, Webb to Teague, September 10, 1965.

July 26

At North American's drop facility, a malfunction in the release mechanism caused boilerplate 1 to impact on land rather than water. After a recurrence of this accident on August 6, a team of investigators began looking into the problem. Drops were suspended pending their findings. These incidents aggravated delays in the test program, which already was seven weeks behind schedule.

MSC, "ASPO Weekly Management Report, August 5-12, 1965."

July 29

Failure of the Little Joe II launch vehicle on Mission A-003 and subsequent lack of positive failure cause

identification and corrective action led to a lower than desirable confidence level in the capability of the controlled version of Little Joe II to accomplish the planned A-004 mission. The test objectives for A-004 were set forth (see Appendix 5).

Memorandum, Owen E. Maynard, MSC, to ASPO Manager, "WSMR test requirements and their relations to the AFRM-002 Mission," sgd. R. W. Williams, July 29, 1965.

July 29

General Electric (GE) received a supplement to its ACE-S/C (Acceptance Checkout Equipment-Spacecraft) contract. Total cost and fee for the amendment, which covered a reliability program for Apollo parts and materials, was \$1,382,600. This brought the total value of GE's contract to \$85.6 million.

MSC, "Quarterly Activity Report for Office of the Associate Administrator, Manned Space Flight, for Period Ending July 31, 1965," pp. 25-26.

July 30

MSC advised Grumman that the altitude at which the LEM crewmen would switch from automatic to manual control of the spacecraft during Phase II of the landing approach would be 213 m (700 ft).

TWX, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, July 30, 1965.

July 30

NASA launched *Pegasus III*, third of the meteoroid detection satellites, as scheduled at 8:00 a.m. EST, from Cape Kennedy. (See February 16 and May 25.) As earlier, an Apollo spacecraft (boilerplate 9) served as the payload's shroud. This flight (SA-10) marked the end of the Saturn I program, which during its seven-year lifetime had achieved 10 straight successful launches and had contributed immeasurably to American rocket technology.

NASA News Release 65-232, "Pegasus C," July 21, 1965; NASA News Release 65-253, "Pegasus III Launch Caps NASA's Saturn I Program," July 30, 1965; memorandum, George E. Mueller, NASA, to Administrator, "Pegasus III/SA-10 Saturn I Flight Mission Post Launch Report No. 1," August 16, 1965, with enclosure: Mission Operation Report No. R-725-65-03 M-931-65-10; "Apollo Monthly Progress Report," SID 62-300-40, p. 1; TWX, KSC, to Distr., "SA-10 Apollo Flash Report No. 1," sgd. E. R. Mathews, July 30, 1965.

July 30

During the preceding six months, officials in ASPO and the Engineering and Development Directorate

evaluated the performance of the launch escape vehicle (LEV) during aborts on and near the launch pad. That performance, they had determined, was inadequate. To solve this problem, MSC ordered North American to incorporate a number of design changes in both the LEV and the spacecraft:

- provide the capability for manual override of the main parachute deployment timer and for manual deployment of those parachutes (for both Saturn IB and V flights)
- Provide for dumping helium from the CM's reaction control system (RCS) automatically
- Modify the CM RCS to permit rapid dumping of its fuel (similar to the existing oxidizer dump). But fuel and oxidizer must not be dumped simultaneously. (This change applied only to Block II CMs.)
- Provide the capability to cut out the LEV's pitch control motor on Block I vehicles (similar to that already in Block II spacecraft)
- Design a removable device that, while on the pad, would keep the launch escape motor's propellant temperature above 70 degrees.

Memoranda, Owen E. Maynard, MSC, to Distr., "LEV pad and near pad abort additional analysis and or testing required for implementation of a 609.6 m (2000 ft) constant altitude main chute deployment," April 23, 1965; John D. Hodge, MSC, to Asst. Dir. for Flight Operations, "Implementation of a 609.6 m (2000 ft) constant altitude main chute deployment," June 8, 1965; Christopher C. Kraft, Jr., MSC, to ASPO, Attn: O. E. Maynard, "Apollo Launch Escape Vehicle (LEV) pad and near-pad abort capability," July 16, 1965; letter, J. B. Alldredge, MSC, to NAA, Space and Information Systems Division, "Contract Change Authorization No. 397," July 30, 1965.

July 31

ASPO Manager Joseph F. Shea informed LEM Subsystems Managers that recent LEM schedule changes and program review activities had led to some confusion with regard to schedule requirements and policies. Shea pointed out that in some instances subsystem delivery schedules had been established which were inconsistent with the overall program. Where this had occurred, prompt action by the Subsystems Managers was required to recover lost ground. Shea then laid down specific ground rules to be followed, and requested that waivers of these ground rules be submitted no later than August 15, along with a demonstration that reasonable alternatives had been investigated. Only the ASPO Manager would approve any waivers.

Memorandum, Joseph F. Shea, MSC, to LEM Subsystems Managers, "Subsystem Qualification and Delivery Schedules," July 31, 1965.

July 31

At a meeting between representatives of NASA and Public Health Service representatives, it was agreed:

- That the PHS had responsibility for the health of the nation and for any potential threat to that

health from extraterrestrial life, particularly from back contamination.

- That the Office of the Surgeon General, PHS, would submit to the NASA Administrator a proposal for action deemed necessary.
- That the Department of Agriculture had a similar responsibility for the nation's crops and animals of economic importance and that the Department of Agriculture would probably accept arrangements made by PHS, and be brought into the matter at the point they considered action to be necessary.

James Goddard, Chief of the Communicable Disease Center of the PHS, stated he was prepared to staff any required quarantine activity at the Lunar Sample Receiving Laboratory but there was no discussion of the source of the personnel.

Memorandum for the Record, Orr E. Reynolds, NASA Headquarters, August 17, 1965.

During the Month

Two change orders were issued to Grumman under the LEM contract, which brought the total estimated cost and fixed fee to \$573,246,377.

"Quarterly Activity Report for Office of the Associate Administrator, Manned Space Flight, for Period Ending July 31, 1965," p. 25.

During the Month

Several astronauts participated in landing touchdown studies conducted in the LEM landing simulator to verify data collected in previous studies and to determine changes in controls and displays to improve the touchdown envelope. Studies involved landing runs from an altitude of 305 m (1,000 ft) with manual takeover at 213 m (700 ft), at which time the pilot could select a precise landing site.

"Monthly Progress Report No. 30," LPR-10-46, p. 4.

During the Month

Crew Systems Division completed evaluation of the three Block II space suits submitted by Hamilton Standard, David Clark, and International Latex. Also, the contractor presented to MSC the results of drop tests with the LEM's support and restraint system.

North American technicians began installing a CM mockup aboard a KC-135 at Wright-Patterson Air Force Base. The structure would be used in a zero-g flight test program (scheduled to begin within a week) to evaluate the Block I space suit *re* mobility, crew performance, and interfaces with the couch and restraints and with the guidance and navigation station. (See July 19.) *Ibid.*, p. 5; "ASPO Weekly Management Report, July 8-15, 1965."

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Advanced Design, Fabrication, and Testing

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August 2

NASA announced plans to install Apollo Unified S-Band System equipment at its Corpus Christi, Tex., tracking station. The Unified S-Band equipment included a 9-m (30-ft) diameter parabolic antenna and would enable handling of seven different types of communications with two different vehicles, the CM and the LEM. The communications would: track the spacecraft; command its operations and confirm that the command had been executed; provide two-way voice conversation with three astronauts; keep a continuous check on the astronauts' health; make continuous checks on the spacecraft and its functions; supply a continuous flow of information from the Apollo onboard experiments; and transmit television of the astronauts and the exploration of the moon.

NASA News Release 65-250, "NASA to Install Apollo Unified S-Band Tracking at Corpus Christi Station," August 2, 1965; *Space Business Daily*, August 3, 1965, p. 156.

August 2

NASA's office at Downey, Calif., approved the contract with the Marquardt Corporation for the procurement of Block II SM reaction control system engines. Estimated cost of the fixed price contract would be \$6.5 million. Marquardt was supplying the Block I SM engines.

TWX, Henry S. Smith, NASA-Downey, to NASA Headquarters, Attn: Director of Procurement and Supply Division, August 2, 1965.

August 2

Hamilton Standard shipped the first prototype portable life support system to Houston, where it would undergo testing by the Crew Systems Division.

MSC News Release 65-68, August 2, 1965; *Space Business Daily*, August 5, 1965, p. 172.

August 2

MSC informed Grumman of package dimensions and weight restrictions for the scientific equipment and packages to be stored in the LEM.

TWXs, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, August 2, 1965.

August 3

NASA named three firms, Bendix Systems Division, TRW Systems Group, and Space-General Corporation to design prototypes of the Apollo Lunar Surface Experiments Package (ALSEP). Each company received a \$500,000, six-month contract. After delivery of the prototypes, MSC would select one of the three to develop the ALSEP flight hardware.

NASA Headquarters Release No. 65-260, "Three Firms Selected to Design Apollo Lunar Surface Package," August 4, 1965; letter, Samuel C. Phillips, NASA, to Robert O. Piland, MSC, "Selection of Contractors for Apollo Lunar Surface Experiments Package," September 10, 1965.

August 3

Grumman reported the status of its effort to lighten the LEM. Despite some relief afforded by recent program changes (e.g., revised velocity budgets and the replacing of fuel cells with batteries), the contractor admitted that significant increases resulted as the design of the spacecraft matured. Grumman recommended, and MSC approved, a Super Weight Improvement Program (SWIP) similar to the one that the company had used in its F-111 aircraft program. By the end of the month, the company reported that SWIP had trimmed about 45 kg (100 lbs) from the ascent and about 25 kg (55 lbs) from the descent stages of the spacecraft. Grumman assured MSC that the SWIP team's attack on the complete vehicle, including its equipment, would be completed prior to the series of LEM design reviews scheduled for late in the year.

ASPO, "Minutes, NASA/GAEC Program Management Meeting, August 3, 1965"; GAEC, "Monthly Progress Report No. 31," LPR-10-47, September 10, 1965, p. 1.

August 4

During the next 10 months, 200 employees of MSFC would be transferred to MSC to augment the Houston staff for the operational phase of the Apollo program. Completion of the first phase of the Saturn program (with the successful launch of SA-10) made it possible for Marshall to release qualified personnel to satisfy MSC's needs.

Space Business Daily, August 9, 1965, p. 187; memorandum, Wernher von Braun, MSFC, to Distr., "Marshall's Changing Role in the Space Program," August 13, 1965.

August 5

During tests of the Apollo earth landing system (ELS) at El Centro, Calif., boilerplate (BP) 6A sustained considerable damage in a drop that was to have demonstrated ELS performance during a simulated apex-forward pad abort. Oscillating severely at the time the auxiliary brake parachute was opened, the spacecraft severed two of the electrical lines that were to have released that device. Although the ELS sequence took place as planned, the still-attached brake prevented proper operation of the drogues and full inflation of the mains. As a result, BP-6A landed at a speed of about 50 fps.

"ASPO Weekly Management Report, August 5-12, 1965."

August 5



The S-IC stage during static firing at MSFC.

The Saturn V's booster, the S-IC stage, made a "perfect" full-duration static firing by burning for the programmed 2.5 minutes at its full 33,360-kilonewton (7.5-million-lbs) thrust in a test conducted at MSFC. The test model demonstrated its steering capability on command from the blockhouse after 100 sec had elapsed; the firing consumed 2.133-million liters (537,000 gallons) of kerosene and liquid oxygen.

Space Business Daily, August 9, 1965, p. 185.

August 5-12

North American developed a plan to process NASA- and contractor-initiated design changes through a Change Control Board (CCB). Indications were that the contractor's Apollo Program Manager would implement the plan on August 19. Elevating the level of management on the CCB, together with a standard approach to processing changes, was expected to improve the technical definition and documentation of design changes. In addition, program baselines were being established to permit a more informed control of technical requirements.

"ASPO Weekly Management Report, August 5-12, 1965."

August 6

North American and MSC attended a design review at Ling-Temco-Vought on the environmental control system radiator for the Block II CSM. After reviewing design and performance analyses, the review team approved changes in testing and fabrication of test hardware.

Memorandum, Richard J. Gillen, MSC, to Chief, Crew Systems Division, "Trip to Ling-Temco-Vought, Dallas, Texas, on August 6, 1965, Block II ECS radiator," August 20, 1965; MSC, "ASPO Weekly Management Report, August 26-September 2, 1965."

August 6

Crew Systems Division (CSD) reported that changing the method for storing oxygen in the LEM (from cryogenic to gaseous) had complicated the interface between the spacecraft's environmental control system (ECS) and the portable life support system (PLSS). Very early, the maximum temperature for oxygen at the PLSS recharge station had been placed at 80 degrees. Recent analyses by Grumman disclosed that, in fact, the gas temperature might be double that figure. Oxygen supplied at 160 degrees, CSD said, would limit to 2½ hours the PLSS operating period. Modifying the PLSS, however, would revive the issue of its storage aboard both spacecraft.

Seeking some answer to this problem, CSD engineers began in-house studies of temperature changes in the spacecraft's oxygen. There was some optimism that Grumman's estimates would be proved much too high, and MSC thus far had made no changes either to the ECS or to the PLSS.

Memorandum, Richard E. Mayo, MSC, to Chief, Systems Engineering Division, "ECS thermal control configuration for 'battery' LEM," August 9, 1965; "ASPO Weekly Management Report, August 5-12, 1965."

August 9

Two Saturn milestones occurred on the same day. At Santa Susana, Calif., North American conducted the first full-duration captive firing of an S-II, second stage of the Saturn V. And at Sacramento, Douglas static-tested the first flight-model S-IVB, second stage for the Saturn IB. This latter marked the first time that a complete static test (encompassing vehicle checkout, loading, and firing) had been controlled entirely by computers.

TWX, Wernher von Braun, MSFC, to NASA Headquarters, Attn: George Mueller, August 11, 1965; *Space Business Daily*, August 12, 1965, p. 207.

August 10

MSC notified North American that, should one of the CM's postlanding batteries fail, the crew could lower the power requirements of the spacecraft during recovery and thus stay within the capabilities of the two remaining batteries.

TWX, C. L. Taylor, MSC, to NAA, Space and Information Systems Division, Attn: J. C. Cozad, August 10, 1965.

August 10

ASPO forwarded to Grumman the following schedule dates which should be used for submission of detailed vehicle test plans:

AS Mission	Vehicle Test Plan	Schedule Date
206	LEM-1	9-1-65
207	LEM-2	12-1-65
503	LEM-3	2-1-66
504	LEM-4	5-1-66
505	LEM-5	7-1-66
506	LEM-6	11-1-66

When determination of LEM test articles to be used on Missions 501 and 502 had been finalized, test plan dates would be forwarded. Current dates for 501 and 502 detailed vehicle test plans were 8-15-65

and 11-1-65, respectively.

TWX, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, "Vehicle Test Plan Schedule Dates," August 10, 1965.

August 12

Resident ASPO quality assurance officers at North American began investigating recent failures of titanium tanks at Bell Aerosystems. Concern about this problem had been expressed by the Apollo Test Directorate at NASA Hq in July and MSC started an investigation at that time. The eventual solution (a change in the nitrogen tetroxide specification) was contributed to by North American, Bell Aero Systems, the Boeing Company, MSFC, MSC, Langley Research Center, and a committee chaired by John Scheller of NASA Hq. The penstripe method to find cracks on the interior of the vessels was used to solve the problem. The quality assurance people viewed the failures as quite serious since Bell had already fabricated about 180 such tanks.

MSC, "Minutes of Senior Staff Meeting, August 6, 1965," John B. Lee, Recorder, p. 3; memorandum, L. E. Day, NASA to Melvyn Savage, "Apollo N2O4 Tank Problems," August 18, 1965; "ASPO Weekly Management Report, August 5-12, 1965"; memorandum, Director, Apollo Soyuz Test Project Engineering, NASA Hq, to Acting Director, NASA Historical Office, "Volume III of *The Apollo Spacecraft: A Chronology*," sgd. Charles H. King, Jr., May 7, 1973.

August 12

Samuel C. Phillips, Apollo Program Director, listed the six key checkpoints in the development of Apollo hardware:

1. **Preliminary Design Review (PDR)** - a review of the basic design conducted before or during the detailed design phase.
2. **Critical Design Review (CDR)** - a review of specifications and engineering drawings preceding, if possible, their release for manufacture.
3. **Flight Article Configuration Inspection (FACI)** - a comparison of hardware with specifications and drawings and the validation of acceptance testing. FACIs could be repeated to ensure that deficiencies had been corrected. Also, this inspection would be conducted on every configuration that departed significantly from the basic design. Items successfully passing the FACI were accepted, provided they met requirements in the Apollo Configuration Management Manual.
4. **Certification of Flight Worthiness (COFR)** - to certify that each vehicle stage or spacecraft module was a complete and qualified piece of hardware.
5. **Design Certification Review (DCR)** - to certify that the entire space vehicle was airworthy and safe for manned flight. DCRs would formally review the development and qualification of all stages, modules, and subsystems.
6. **Flight Readiness Review (FRR)** - a two-part review, scheduled for each flight, to determine that

both hardware and facilities were ready. Following a satisfactory ERR, and when decided upon by the mission director, the mission period would begin (which would commit deployment of support forces around the world).

NASA OMSF, Apollo Program Directive No. 6, "Sequence and Flow of Hardware Development and Key Inspection, Review, and Certification Checkpoints," August 12, 1965.

August 12

Grumman received approval from Houston for an all-gaseous oxygen supply system in the LEM. While not suggesting any design changes, MSC desired that portable life support systems (PLSS) be recharged with the cabin pressurized. And because the oxygen pressure in the descent stage tanks might be insufficient for the final recharge, the PLSSs could be "topped off" with oxygen from one of the tanks in the vehicle's ascent stage if necessary.

Letter, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Gaseous Oxygen Supply Configuration," August 12, 1965.

August 12-13

MSC rejected North American's second design concept for a panel retention system in the LEM adapter. (The contractor's first proposal had drawn an unsatisfactory verdict early in June.) These successive rejections, largely on the basis of weight and vibration factors, illustrated the company's continuing difficulties with the system. MSC "suggested" to North American that it circumvent these problems by attaching the retention cable directly to the skin of the adapter.

"Critical Design Review for the Block II Spacecraft/LEM Adapter, 12-13 August 1965."

August 18

At a third status meeting on LEM-1, Grumman put into effect "Operation Scrape," an effort to lighten that spacecraft by about 57 kg (125 lbs). "Scrape" involved an exchange of parts between LEM-1 and LTA-3. The former vehicle thus would be heavier than the latter; LTA-3, on the other hand, would have the same structural weight as LEMs 2 and forthcoming.

MSC, "ASPO Weekly Management Report, August 12-19, 1965"; letter, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, LEM I Status Meeting Number Three," August 30, 1965; "Monthly Progress Report No. 31," LPR10-47, pp. 28-29.

August 18

Owen E. Maynard, Chief of the Systems Engineering Division, asked that part of the LEM Mission

Programmer, the Program Reader Assembly, be deleted. The assembly was no longer needed, Maynard said, to meet Apollo mission requirements.

Memorandum, Owen E. Maynard, MSC, to Subsystem Manager, LEM SCS, "LEM Mission Programmer," August 18, 1965.

August 18-24

The preliminary Design Engineering Inspection (DEI) for CSM 011, Mission AS-202, was held. This was a major program milestone for the mission. The review board met on August 24 and the formal DEI was conducted August 30, 31, and September 1 (see entry for those dates).

Memorandum, Carl R. Huss, JSC, to JSC Historical Office, "Comments on Volume III of *The Apollo Spacecraft: A Chronology*," June 6, 1973.

August 19

The Apollo Resident Office at KSC was notified that it was ASPO Manager Joseph F. Shea's desire that a Configuration Control Panel be established and chaired at KSC to consider and process engineering changes to Apollo spacecraft and associated hardware undergoing checkout and test at KSC.

The ASPO Configuration Management Plan was being revised to reflect the action. The newly formed CCP's authority would be restricted to review of end item hardware (including ground support equipment configuration changes) to determine if the change was mandatory in the conduct of tests at KSC, and the approval of the contractor's plan for making the mandatory change to specific Apollo hardware end items at KSC.

Memorandum, William M. Bland, Jr., MSC, to Assistant Head of MSC Apollo Resident Office, KSC, "Apollo Spacecraft Configuration Control Panel at KSC," August 19, 1965.

August 19-26

MSC assigned two LEM test articles (numbers 10 and 2, respectively) to the SA-501 and SA-502 missions. Prior to flight, the spacecraft would be refurbished by Grumman, which would require four to five months' work on each vehicle.

MSC, "ASPO Weekly Management Report, August 19-26, 1965"; "Monthly Progress Report No. 31," LPR- 10-47, p. 38; memorandum, C. H. Perrine, MSC, to H. Davis, "Use of LTA-10 for Facilities Verification Vehicle," August 31, 1965.

August 20

Douglas Aircraft Company static-fired the S-IVB in a test at Sacramento, Calif., simulating the workload of a lunar mission. The stage was run for three minutes, shut down for half an hour, then reignited for almost six minutes.

Astronautics and Aeronautics, 1965, p. 386.

August 21

Gemini V, piloted by L. Gordon Cooper, Jr., and Charles Conrad, Jr., roared into space from Cape Kennedy. During their eight-day flight the astronauts performed a number of orbital and simulated rendezvous maneuvers to evaluate the spacecraft's rendezvous guidance and navigation equipment. A second principal objective of the mission was to evaluate the effects on the crew of prolonged exposure in space. *Gemini V* was significant as well for another reason: although the hardware experienced some troubles during the early part of the flight (which threatened to terminate the mission prematurely), *Gemini V* was the first spacecraft to use fuel cells as its primary source of electrical power. The operational feasibility of fuel cells would be essential for the success of long-distance (i.e., lunar) manned space flight.

Grimwood, *et al.*, *Project Gemini: A Chronology*, pp. 209-211.

August 23

MSC and Apollo spacecraft contractors were in process of planning and implementing an extensive ground-based test program to certify the spacecraft for flight. All possible efforts were being made to benefit from the experience of related spacecraft programs in planning the Apollo test program. In view of the similarities of the Surveyor mission and the LEM mission, Jet Propulsion Laboratory was asked to cooperate by providing: (1) background information concerning the manner in which their qualification test program had been performed, (2) the major complete vehicle and partial vehicles used in the ground test programs, and (3) significant results obtained from such programs.

Letter, Joseph F. Shea, MSC, to NASA Resident Office, JPL, "Surveyor ground test programs," August 23, 1965.

August 23

Joseph F. Shea, ASPO Manager, summarized ground rules on the schedules for qualifying and delivering equipment for Block II spacecraft:

- All components installed on the Block II test vehicle (2TV-1) and on Block II flight vehicles must be production hardware. (Prototype units were unacceptable.)
- Any changes from the configuration of CSM 103 in 2TV-1, 101, or 102 must be essential to the

specific mission requirements of those vehicles.

- Delivery schedules must be compatible with North American's needs. (North American was allowed some leeway in installing components, provided that such reordering was feasible and did not affect overall checkout and delivery schedules for the vehicle.)
- Qualification testing must be scheduled so that all equipment was qualified before February 15, 1967.
- Launch-constraining ground tests must be scheduled for completion at least six weeks before that launch.

Shea alone had authority to waive these schedule rules.

Memorandum, Shea, MSC, to Distr., "Subsystem qualification and delivery schedules for Block II," August 23, 1965.

August 24

MSC requested that Grumman review the current LEM landing and docking dynamic environments to assure: (1) no loss of the abort guidance system attitude reference due to angular motion exceeding its design limit of 25 degrees per second during indicated mission phases; and (2) a mission angular acceleration environment, exceeding the gyro structural tolerances, would not be realized.

TWX, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, August 24, 1965.

August 26-September 2

Grumman advised that prelaunch heat loads on LEM-1 exceeded the capability of the spacecraft's prelaunch Freon boiler. That boiler had originally been designed for loads anticipated from fuel-celled LEMs. When batteries replaced fuel cells, MSC had recommended deleting the boiler; Grumman had urged that the item be retained on LEM-1, however, because that spacecraft would have optional equipment onboard at launch. "It appears," Crew Systems Division (CSD) reported, "that the number of items of equipment required to be on [LEM-1] at earth launch has snowballed": the boiler's maximum capability was about 900 Btus per hour; the spacecraft's heat load was estimated at something like 6,000. "GAEC is presently investigating what can be done to reduce these loads," CSD said.

"ASPO Weekly Management Report, August 26-September 2, 1965."

August 26-September 2

Qualification testing was completed on the LEM's helium storage tank.

Ibid.; memorandum, Joseph G. Thibodaux, Jr., "Quantity gaging for the Descent Propulsion Supercritical Helium Pressurization System," August 19, 1965, with enclosure.

August 27

Owen E. Maynard, Chief of the Systems Engineering Division (SED), drafted a set of guidelines for Apollo developmental missions. While these guidelines pertained mostly to Block II development, and were so labeled, to some extent they dealt with Block I flights as well. These Development Mission Guidelines covered the overall mission, as well as specific phases, with one section devoted solely to the LEM. (Maynard was careful to distinguish these guidelines from "ground rules" in that, rather than being mandatory requirements, their intent was "to afford test planning a guide and somewhat of an envelope . . . and not hard and fast rules.")

SED was considering including these guidelines in the Apollo Spacecraft Master Test Plan when that document was next revised.

Memorandum, Maynard, MSC, to Distr., "Block II Development Mission Guidelines," August 27, 1965.

August 27

North American reported that ground testing of the service propulsion engine had been concluded. Also, changing the propellant ratio of the service propulsion system had improved the engine's performance and gimbaling angles and had reduced the weight of the Block II SM. (See July 23.)

Memorandum, Owen E. Maynard, MSC, to Asst. Manager, ASPO, "SPS engine gimbaling in stack," August 25, 1965; TWX, M. L. Raines, WSTF, to MSC, Attn: R. R. Gilruth and others, August 30, 1965; NAA, "Apollo Monthly Progress Report," SID 62-300-41, October 1, 1965, pp. 8, 10.

August 29-September 4

Several important activities were noted during the reporting period: (1) Qualification of the new reefing line cutters was progressing satisfactorily and scheduled for completion in October 1965. (The cutter had been used successfully on the last two earth landing system tests conducted at El Centro); (2) the helium storage tank for the LEM reaction control subsystem successfully passed qualification tests; and (3) the Aero Spacelines' new aircraft, "Super Guppy," made its maiden flight from Van Nuys, Calif., to Mojave Airfield, Calif. The new aircraft had the capability of airlifting the spacecraft-LEM-adaptor as well as providing vital backup for the "Pregnant Guppy" aircraft.

"Weekly Activity Report, August 29-September 4, 1965," Joseph F. Shea.

August 30

NASA's Associate Administrator for Manned Space Flight, George E. Mueller, informed MSC's Director Robert R. Gilruth that an official emblem had been adopted for the Apollo Program, a

composite based on the best proposals submitted by NASA and contractor personnel.

Letter, Mueller to Gilruth, August 30, 1965.

August 30-September 1

Spacecraft 011's design engineering inspection was held at North American. The review combined structures, mission (SA-202), and ground support. The Review Board approved 55 changes (53 of which were assigned to North American).

"Apollo Monthly Progress Report," SID 62-300-41, p. 4; memorandum, C. H. Bolender, NASA, to E. E. Christensen and S. C. Phillips, "Trip Report on Visit to NAA Downey," September 7, 1965.

August 31-September 1

At an implementation meeting at MSC on the LEM's guidance and control system, Grumman again made a pitch for its concept for the landing point designator (i.e., scale markings on the vehicle's window). On September 13, the company received MSC's go-ahead. Grumman was told to coordinate closely with both MSC and MIT on the designator's design to ensure that the scale markings would be compatible with the spacecraft's computer.

TWX, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, subject: "Action Item L52, Requirements for Landing Point Designator (LPD)," September 13, 1965.

During the Month

An explosion damaged a LEM reaction control system thruster being fired in an up attitude in altitude tests at MSC.

"Monthly Progress Report No. 31," LPR-10-47, p. 1.

During the Month

Grumman completed an analysis of radiation levels that would be encountered by the LEM-3 crew during their earth orbital mission. Grumman advised that doses would not be harmful. To lessen these levels even further, the contractor recommended that during some parts of the mission the two astronauts climb back into the CM; also, the planned orbit for the LEM (556 by 2,500 km [300 by 1,350 nm]) could be changed to avoid the worst part of the Van Allen Belt.

Ibid., p. 40.

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September 1

North American conducted another in their series of impact tests with boilerplate 28. This drop tested the toroidal section of the spacecraft (heatshield and equipment bay structure) in impact at high angle and maximum horizontal velocity. The spacecraft suffered no visible damage. Some water leaked into the vehicle, but this was blamed on the boilerplate structure itself and the apex-down attitude after impact.

"Apollo Monthly Progress Report," SID 62-300-41, p. 1; MSC, "ASPO Weekly Management Report, September 2-9, 1965."

September 1

A LEM ascent engine exploded during altitude firings at Arnold Engineering Development Center (AEDC). In subsequent investigations, Bell Aerosystems researchers concluded that the failure probably resulted from raw propellants being accidentally forced into the engine at the end of the second run, thus damaging the injector. The explosion, which occurred at the start of the third run, in turn followed an uncontrolled flow of propellants into the engine. As a result of this accident, Bell made several changes in hardware fabrication. Also, the company planned additional firings, under conditions similar to those at AEDC when the explosion occurred, to try to determine exactly the cause.

MSC, "Minutes of Senior Staff Meeting, September 10, 1965," p. 1; memorandum, A. L. Madyda, MSC, to Chief, Propulsion and Power Division, "Report on trip to Bell Aerosystems, September 13-14, 1965," September 16, 1965; memorandum, Madyda, to Chief, Propulsion and Power Division, "Trip to Bell on September 30, 1965," October 4, 1965.

September 1-8

MSC advised officials at North American's Tulsa Division that their concept for external panel retention cables on the adapter was unacceptable. While the Tulsa people agreed with Houston's objections, because of orders from Downey they had no authority to change the design. Structures and Mechanics

Division reported that North American's "continued apathy . . . to redesign the system" threatened a schedule delay.

"ASPO Weekly Management Report, September 2-9, 1965."

September 2-9

MSC's Flight Operations Division requested an investigation of the feasibility of performing an abort from an inoperative S-IVB booster on the AS-206 unmanned LEM mission.

Ibid.; memorandum, R. W. Lanzkron, MSC, to Chief, Systems Engineering Division, "AS-206 Preliminary Abort Requirements," September 10, 1965.

September 3

NASA Associate Administrator for Manned Space Flight George E. Mueller summarized for Administrator James E. Webb the status of the LEM tracking systems. The LEM rendezvous radar system, which had been under development since 1963, was expected to be available when needed for flight missions. Technical studies had shown that an Optical Tracker System offered weight and reliability advantages with no reduction in LEM performance. Hughes Aircraft Company was developing an Optical Tracking System as a back-up to the rendezvous radar.

Memorandum, Mueller to Webb, "LEM Tracking Systems," September 3, 1965.

September 3

To aid in defining abort limits for the emergency detection system, MSC authorized North American to determine the ultimate strength of the spacecraft based on failure trajectories of the Saturn IB and Saturn V vehicles.

Letter, J. B. Alldredge, MSC, to NAA, Space and Information Systems Division, "Contract Change Authorization No. 407," September 3, 1965; memorandum, Owen E. Maynard, MSC, to Chief, Flight Control Division, "Range Safety Destruct Time Delay for Saturn IB & V," September 27, 1965.

September 3

MSC requested Grumman to review the following ascent and descent pressurization system components in the propulsion subsystem for materials compatibility with certain propellants:

1. helium explosive valve;
2. pressure regulator;

3. latching solenoid valve;
4. pressure relief and burst disc; and
5. quad check valve.

Recent reports from various programs had shown that propellant vapors had seeped into mid-portions of their pressurization systems, causing corrosion and leakage problems. The SM and LEM had recently revised portions of their programs to incorporate this compatibility requirement.

Letter, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Internal compatibility of LEM Ascent and Descent Propulsion Subsystem pressurization system components with fuel and oxidizer propellant vaporizer, Hydrazine-Unsymmetrical Dimethyl Hydrazine and Nitrogen Tetroxide, respectively," September 3, 1965.

September 8

William A. Lee, ASPO, pointed out to the MSC Thermo-Structures Branch that Grumman was engaged in a strenuous weight reduction effort and that, when feasible, MSC should accept the proposed changes. In the area of thermal control, Grumman was investigating the use of etched aluminum surfaces to replace thermal paint. It was expected that the change was feasible and that approximately 11 kg (24 lbs) of inert weight would be saved on each stage of the LEM. In addition, Grumman was investigating the applicability of this technique to the landing gear components.

Grumman was also studying substitution of an aluminum-mylar nonrigid outer heatshield with plastic standoffs for current rigid ascent and descent heatshields. The potential inert weight saving would be about 84 kg (185 lbs). Lee requested that Thermo-Structures Branch stay in close contact with these developments.

Memorandum, William A. Lee, MSC, to Thermo-structures Branch, Attn: J. A. Smith, Jr., "LEM weight reductions in the area of thermal control," September 8, 1965.

September 8

Assistant ASPO Manager William A. Lee told the General Instrumentation Branch of the Instrumentation and Electronic Systems Division Grumman was preparing a proposal for use of the LEM vehicle as an electrical ground. The plan was to adopt a single wire system selectively for those circuits not susceptible to electrical transients. Lee said Grumman estimated a weight savings of 27 kg (60 lbs) in the ascent stage and 9 kg (20 lbs) in the descent stage. The proposal was expected to be available to NASA by October 1 and Lee had committed NASA to a decision within three weeks of receipt of the plan.

Memorandum, William A. Lee, MSC, to General Instrumentation Branch, Attn: A. H. Campos, "Use of LEM vehicle structure as electrical ground return," September 8, 1965.

September 9-10

MSC requested Grumman and North American to study the possibility of taking the guillotine that Grumman had developed for the LEM's interstage umbilical and using it as well to sever the two umbilicals linking the LEM to the adapter. In this manner, North American's effort to develop these cutters might be eliminated; LEM-adapter interface would be simplified; and a significant monetary savings could be effected without schedule impact.

MSC, "ASPO Weekly Management Report, September 9-16, 1965"; ASPO, "Abstract of Proceedings, Ground Test Requirements Meeting No. 4, September 9 and 10, 1965," September 16, 1965.

September 9-16

Northrop-Ventura canceled a parachute test because of problems with the reefing line rings and the main parachute bags. North American was looking into these problems which, it was anticipated, would affect both blocks of spacecraft.

MSC, "ASPO Weekly Management Report, September 9-16, 1965."

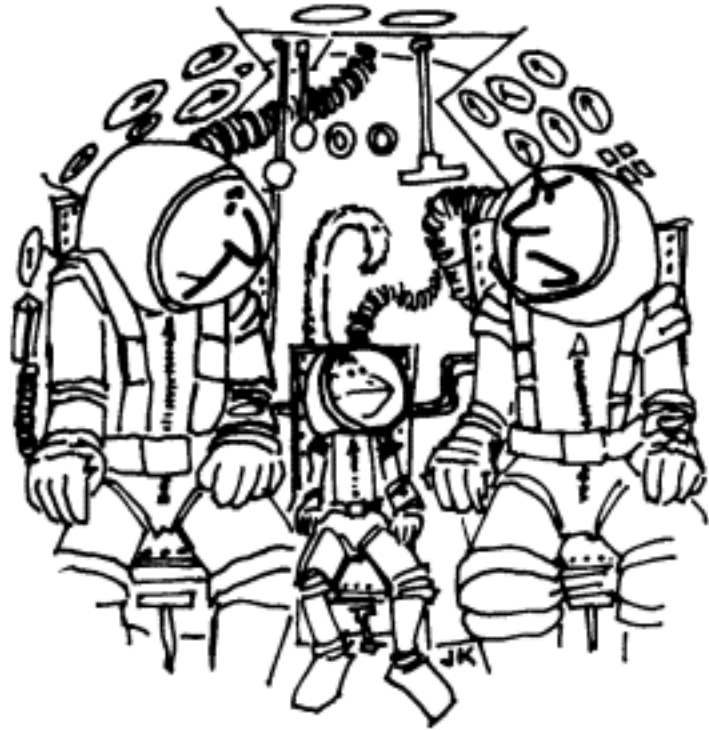
September 10

Because of recent changes in the design of the space suit, Motorola, under its contract for suit communications antennas, began concentrating on the development of antennas for the back pack rather than on the helmet.

Letter, Richard S. Johnston, MSC, to R. E. Breeding, Hamilton Standard Division, "Technical directive on SSC helmet mounted antenna," September 10, 1965; MSC, "ASPO Weekly Management Report, September 16-23, 1965."

September 10

**" I KNOW
WE HAVE A
WEIGHT
PROBLEM... "**



With the continued frustrations of fighting the weight problem on both the CM and LEM it was necessary that both NASA and contracting personnel maintain a sense of humor. The above was used in slide form at a meeting at MSC.

Owen E. Maynard, Chief of Systems Engineering Division, advised ASPO Manager Joseph F. Shea of the major technical problems currently plaguing Apollo designers:

Spacecraft weight growths

these, Maynard said, exceeded predictions "by a serious margin." Pessimistically, he added that the performance of many systems was but "marginally acceptable."

Lunar landing criteria

the unknowns involved precluded conservative thinking on the LEM.

Integration of scientific experiments

Maynard blamed the "piece-meal" integration of experiments for the lack of comprehensive planning and for many late hardware changes.

Water landing criteria

because of the range of variables, present design margins were questionable.

Land landing

i.e., development of the landing rockets.

Thermal design

conflicts existed between temperature control and attitude constraints for the spacecraft.

Propulsion performance

no unit, Maynard reported, had yet achieved the specific impulse which was required of it.

Space suit development

design of the suit, and of the thermal-meteoroid garment and the portable life support system, Maynard said, had "gyrated violently, resulting in spacecraft design compromises to accommodate questionable space suit performance."

Memorandum, Maynard, MSC, to Manager, ASPO, "Apollo principal technical problems," September 10, 1965.

September 10

NASA began recruiting additional pilot-astronauts, to begin training the following summer.

MSC News Release 65-79, "NASA to Select Additional Pilot-Astronauts," September 10, 1965.

September 12

Hurricane Betsy hit the United States and Apollo Program Director Samuel C. Phillips presented an interim report to NASA Associate Administrator Robert C. Seamans, Jr., concerning the effects of the storm on NASA property and programs:

Michoud (La.) Plant

all of the buildings suffered moderate to severe damage. So far as could be determined, Saturn hardware in process was not damaged to any appreciable extent. Damage was estimated at between \$2 and \$4 million. Time lost by the storm and due to cleanup and repairs would probably affect program schedules by two or more weeks.

Transportation

the barge *Promise* tied up at the Michoud dock broke free and was beached. Externally, no damages were visible. The dock area was heavily damaged.

Production of Liquid Hydrogen

Air Products, Inc., plant under construction across the canal from Michoud was reported to be under nine feet of water. Extent of the damage was unknown.

Reentry Ships *Huntsville* and *Watertown*

these vessels were under modification at the Avondale Shipyard, New Orleans. Both broke loose and were hard aground. The *Watertown* was battered but the holds were dry; it looked like it could be salvaged. The *Huntsville* had a 9-m (30-ft) gash in the side plus three other holes. The engine rooms were flooded. Navy salvage crews did not think the vessel was salvageable.

Cape Kennedy

damage from the storm was minor. The storm did cause a shutdown of site activation activities on Complex 34, costing four critical days.

Memorandum, Phillips to Seamans, "Impact of Hurricane Betsy on Apollo," September 13, 1965.

September 13

ASPO Manager Joseph F. Shea announced a new plan for controlling the weight of Apollo spacecraft. Every week, subsystem managers would report to a Weight Control Board (WCB), headed by Shea, which would rule on their proposals for meeting the target weight for their systems. Three task forces also would report to the WCB on the way to lighten the spacecraft:

1. weight reduction task force;
2. requirements reduction task force; and
3. an operations task force.

Memorandum, Shea, MSC, to Distr., "Apollo Weight Control Program," September 13, 1965, with enclosure: "Apollo Weight Control Plan."

September 14

As a result of discussions with North American and Aerojet-General, MSC ordered several changes to the service propulsion engine:

1. redesign of the ablation chamber seals and the flange mountings
2. modifications to permit ground purging
3. redesign of the injection hub
4. doubling of the nominal valve opening time (from 0.3 to 0.6 sec).

These changes applied to all qualification test and all flight hardware.

TWX, J. B. Alldredge, MSC, to NAA, Space and Information Systems Division, Attn: J. C. Cozad, subject: "SPS Engine Changes and Checkout," September 14, 1965.

September 14

At a status meeting at Grumman on LEM-1, MSC learned that, as a result of welding problems, the vehicle's ascent stage was about four weeks behind schedule.

Memorandum, R. A. Newlander to W. J. Gaylor, RASPO-Bethpage, "LEM-1 Status Meeting, 9/14/65," September 17, 1965; letter, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, LEM-1 Status Meeting Number Four," September 21, 1965.

September 15

Flight Crew Support Division defined the minimum time required to assure adequate crew training in the Apollo Mission Simulators. Individual part task training in the simulators required 36 hrs for each of six astronauts (prime and backup crews), a total of 216 hrs; each of the two crews would require 40 hrs of crew mission task training, 120 hrs of crew specific mission training, and nine hrs each of crew integrated mission (with ground crews) training, a total of 169 hrs per crew or a total of 338 hrs.

It was estimated that the simulator would be operational on an average of 30 hours a week, based on experience in other programs. Thus, eight months of simulator availability would be required prior to the AS-204 launch date - one month of training verification plus 29 weeks for crew training.

The needed dates for simulators were: Apollo Mission Simulator No. 1, fully operational January 15, 1966, with spacecraft 012 modification kit delivery complete on March 18, 1966; Apollo Mission Simulator No. 2 delivery in 012 configuration April 15, 1966, to be fully operational June 6, 1966.

Memorandum, Warren J. North, MSC, to Chief, Systems Engineering Division, "Simulator training requirements to support the Apollo missions," September 15, 1965.

September 16

MSC's Assistant Director for Flight Operations, Christopher C. Kraft, Jr., told ASPO Manager Joseph F. Shea that postlanding operational procedures require that recovery force personnel have the capability of gaining access into the interior of the CM through the main crew hatch. This was necessary, he said, so recovery force swimmers could provide immediate aid to the crew, if required, and for normal postlanding operations by recovery engineers such as spacecraft shutdown, crew removal, data retrieval, etc.

Kraft said the crew compartment heatshield might char upon reentry in such a manner as to make it difficult to distinguish the outline of the main egress hatch. This potential problem and the necessity of applying a force outward to free the hatch might demand use of a "crow bar" tool to chip the ablator and apply a prying force on the hatch.

Since this would be a special tool, it would have to be distributed to recovery forces on a worldwide basis or be carried aboard the spacecraft. Kraft requested that the tool be mounted onboard the spacecraft in a manner to be readily accessible. He requested that the design incorporate a method to preclude loss of the tool - either by designing the tool to float or by attaching it to the spacecraft by a lanyard.

Memorandum, Kraft to Shea, "Apollo Crew Hatch Tool," September 16, 1965.

September 16

The Assistant Chief for Electronic Systems notified ASPO that the proposed Grumman plan to

repackage the LEM pulse command modulated and timing electronic assembly (PCMTEA) had been discussed and investigated and that the Instrumentation and Electronic Systems Division (IESD) concurred with the proposal.

Following is the impact to the PCMTEA as a result of Grumman's proposed changes:

1. weight of the PCMTEA would be reduced 1.4 kg (3 lbs) and a further reduction of 4.99 kg (11 lbs) would result from repackaging;
2. volume of the PCMTEA would be reduced by approximately 8,123 milliliters (500 cu in);
3. there would be no schedule impact to LEM-1, LT A-8, or the PCMTEA qualification test program because of the proposed changes; and
4. no firm cost estimates were available but IESD estimated repackaging cost would be about \$100,000.

Memorandum, Leonard E. Packham, MSC, to Assistant Manager, ASPO, "GAEC plan to repackage the LEM PCMTEA," September 16, 1965.

September 16-17

North American and its subcontractor, LTV, conducted a design review on the environmental control system radiator for the Block II CSM. Both parties agreed upon a backup effort (i.e., a narrower selective stagnation panel), which would be more responsive to thermal changes in the spacecraft. Testing of this backup design could follow that of the prototype and still meet the design release.

Memorandum, Frank H. Samonski, Jr., MSC, to Gary G. Metz, "Environmental control system (ECS) attitude constraints for Spacecraft 012," September 14, 1965; "ASPO Weekly Management Report, September 16-23, 1965."

September 16-17

A design review on the attitude controller for the LEM was held at Honeywell. Flight Crew Support Division reported that the device seemed "highly optimized functionally, operationally, and weight wise."

"ASPO Weekly Management Report, September 16-23, 1965"; GAEC, "Monthly Progress Report No. 32," LPR-10-48, October 10, 1965, p. 14; TWX, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, October 14, 1965.

September 16-23

Systems Engineering Division (SED) reported that, on the basis of data from SA-4, 8, and 9 flights, the thermal coating of the spacecraft suffered considerable damage. This degradation was caused by the S-

IV retro motor and/or the tower jettison motor. SED advised that a thorough analysis was scheduled shortly at TRW to look into the entire area of thermal factors and the performance of ablative coating. However, North American refused to acknowledge the existence of any such thermal problem, SED said. The firm's "continued inactivity" was described as a "major obstacle" to solving the problem.

"ASPO Weekly Management Report, September 16-23, 1965"; memorandum, James A. Smith, MSC, to Project Officer, C and SM, ASPO, "Technical Evaluation, Justification, and Plan of Action for Instrumentation to determine effects of TJM Impingement, RECP 461," September 27, 1965.

September 16-23

NASA and the Atomic Energy Commission (AEC) agreed that AEC would provide radioisotope thermoelectric generators which would power each Apollo Lunar Surface Experiments Package for an operating period of one year on the lunar surface.

"ASPO Weekly Management Report, September 16-23, 1965"; memorandum, Robert E. Vale, MSC, to Chief, Systems Engineering Division, "Radioisotope Thermoelectric Generator," September 27, 1965.

September 16-23

Grumman established the final design parameters for the landing gear of the LEM (both primary and secondary struts). It was anticipated that this newer design would be between 9 and 14 kg (20 and 30 lbs) lighter than the earlier gear.

"ASPO Weekly Management Report, September 16-23, 1965"; "Monthly Progress Report No. 32," LPR-10-48, pp. 10, 12.

September 16-October 15

North American evaluated the compatibility of spacecraft 012 with its mission, AS-204, the first manned Apollo flight. The manufacturer determined that, by using roll-stabilized attitude during most of the flight, the vehicle could remain aloft for about 13½ days. The only onboard expendables termed marginal were cryogenics and the propellant supply in the SM's reaction control system (which, for added safety, would offer a redundant means of braking the vehicle out of orbit).

NAA, "Apollo Monthly Progress Report," SID 62-300-42, November 1, 1965, p. 3; memorandum, Robert V. Battey, MSC, to Chief, Apollo Trajectory Support Office, "Spacecraft systems and attitude constraints for mission AS-204," September 14, 1965.

September 17

The basic structure of Apollo CM simulator "A," around which a full-scale mockup of the CM crew

stations would be built, was delivered to MSC. Flight Crew Support Division would use the mockup for crew familiarization, procedures training, and equipment evaluation.

"ASPO Weekly Management Report, September 16-23, 1965."

September 20

MSC's Director, Robert R. Gilruth, sent a detailed history of actions taken in regard to development of the Apollo Extravehicular Mobility Unit, and recommended three changes not consistent with the overall procurement plan previously approved by NASA Headquarters:

- Amend the existing Hamilton Standard contract to provide for the development, qualification, and fabrication of the portable life support system and associated equipment only. This contract would cover delivery of all flight equipment for the Apollo flight program.
- Award a separate contract to International Latex Corporation for the development and fabrication of test and flight space suits and associated equipment.
- MSC would assume responsibility for total program management, systems integration, and space suit qualification.

Basis for the recommendations was

1. a comparative suit evaluation of space suits submitted by International Latex, Hamilton Standard, and David Clark Company in June 1965;
2. a reassessment of the capabilities of International Latex; and
3. previous difficulties of Hamilton Standard in adequate total system development but recognizing their competence in the portable life support systems work.

MSC planned to establish a resident engineer at International Latex to provide on-contractor-site management of the contractor.

Letter, Gilruth to NASA Headquarters, Attn: George E. Mueller, "Procurement plan for the Apollo Extravehicular Mobility Unit and EMU ground support equipment development and fabrication," sgd. George M. Low, September 20, 1965.

September 20

On the basis of studies by both MSC and Grumman on LEM landing criteria, Engineering and Development Directorate determined that contractor and customer alike favored reducing landing velocity requirements for the spacecraft. The two did not see eye to eye on how far these requirements should be reduced, however, and MSC would study the problem further.

Memorandum, James A. Chamberlin, MSC, to Distr., "Status of LEM landing studies," September 20,

1965.

September 21

ASPO Manager Joseph F. Shea decided that no device to indicate a failure of the secondary gimbal motor in the service propulsion system (SPS) was necessary on Block I spacecraft. Two factors shaped Shea's decision:

1. procedures for inflight checkout of the vehicle called for gimbaling the service propulsion engine with both primary and secondary drive motors prior to SPS burns;
2. furthermore, all Block I (i.e., earth orbital) spacecraft would be capable of returning to earth by means of the SM's reaction control system.

This decision did not alter the requirement for such devices on Block II spacecraft, however, and North American was incorporating warning lights on those vehicles to indicate such gimbal motor failures.

Memorandum, Shea, MSC, to Assistant Director for Flight Operations, "Service Propulsion System (SPS) Secondary Gimbal Motor Fail Indication," September 21, 1965.

September 27

NASA's Administrator James E. Webb, Deputy Administrator Hugh L. Dryden, and Associate Administrator Robert C. Seamans, Jr., selected Ling-Temco-Vought from a total of 17 proposers for contract negotiations for a one-year cost-plus-award-fee contract with options to extend for two one-year periods, to provide operational laboratory support services for the Apollo spacecraft program at the White Sands (N. Mex.) Test Facility. The selection was based upon the presentation of a source evaluation board and comments of key officials concerned. The Associate Administrator for Manned Space Flight was asked to issue appropriate instructions to ensure that the contract negotiating team follow the negotiation objectives as presented to them.

Memorandum, Deputy Associate Administrator, NASA, to Associate Administrator for Manned Space Flight, "Selection of Contractor to Provide Operational Laboratory Support Services for the Apollo Spacecraft Program at the White Sands Test Facility," sgd. Earl D. Hilburn, September 27, 1965.

September 22-29

North American proposed an additional pane of glass for the windows on Block II CMs. Currently, both blocks of spacecraft had one pane. Should meteoroids pit this pane, the window could fail during reentry at lunar velocities. The meteoroid protection group in Structures and Mechanics Division were evaluating North American's proposal, which would add about 10.43 kg (23 lbs) to the vehicle's weight. No such added protection was required on Block I spacecraft.

MSC, "ASPO Weekly Management Report, September 23-30, 1965"; "Apollo Monthly Progress Report," SID 62-300-41, p. 5.

September 24

The Critical Design Review (CDR) of the LEM, tentatively planned during the week of September 27, 1965, at Grumman, was rescheduled as a series of reviews beginning in November 1965 and ending in January 1966. The schedule was to apply with five teams participating as follows: Structures and Propulsion, November 8-11, Team Captain: H. Byington; Communications, Instrumentation, and Electrical Power, December 6-9, Team Captain: W. Speier; Stabilization and Control, Navigation and Guidance, and Radar, January 10-13, Team Captain: A. Cohen; Crew Systems, January 10-13, Team Captain: J. Loftus; and Mission Compatibility and Operations, January 24-27, Team Captain: R. Battey.

Memorandum, Owen E. Maynard, MSC, to Distr., "Critical Design Review of LEM," September 24, 1965.



MSFC marked completion of its first Saturn V S-IC booster September 26, 1965, with a brief ceremony in

front of the assembly shop. A wide-angle camera caught this view as the ceremony was about to start with MSFC Director Wernher von Braun at the microphone (left).

September 27

MSC directed Grumman to draw up a complete list of all nonmetallic materials used in the habitable area of the LEM, including type, use, location, weight, and source of all such materials.

Letter, James L. Neal, MSC, to GAEC, Attn: John C. Snedeker, "Contract NAS 9-1100, Contract Change Authorization No. 136, Exhibit E, Nonmetallic Materials in Habitable Area," September 27, 1965.

September 27

Officials from the U.S. Public Health Service (PHS) and the Department of Agriculture met at MSC to discuss informally the problem of back contamination. They listened to briefings on the mission profile for Apollo; reentry heating rates; present thinking at the Center on the design of the Lunar Sample Receiving Station (LSRS); and MSC's plans (none) for quarantining the astronauts.

James Goddard, Assistant Surgeon General in PHS, presented three broad areas of concern:

1. quarantine procedures and accommodations inside the LSRS for both astronauts and technicians;
2. quarantine facilities aboard the recovery ships; and
3. the need to gather samples before the moon's surface was contaminated by the astronauts or the LEM's atmosphere.

These matters were discussed in some detail. MSC's failure to plan for the astronauts' return, and Goddard's ideas on what procedures were needed, provoked "very extended and somewhat heated" discussions. It was generally agreed that Apollo astronauts could not entirely avoid lunar contaminants: the level of contamination inside the spacecraft's cabin, although low, nonetheless would be "significant." MSC then asked, hypothetically, what PHS's reaction would be if Apollo astronauts were recovered and returned in much the same manner that Gemini crews were. The representative from PHS's Foreign Quarantine Division replied "emphatically" that, in such a case, those crews would not be allowed back in the country.

On October 15, Lawrence B. Hall, Planetary Quarantine Officer in NASA's Office of Space Science and Applications, summarized for Deputy Administrator Hugh L. Dryden the September 27 meeting, and recommended that such informal discussions continue. "I believe," he told Dryden, "that . . . the Manned Spacecraft Center is more fully aware of the point of view of the regulatory agencies on this matter. Unfortunately, the regulatory agencies still do not understand the reasons for the Manned Spacecraft

Center's reluctance to face this problem." [To appreciate MSC's "reluctance," see October 29, 1965.]

Memorandum, Hall, NASA, to Deputy Administrator, "Informal conference on back contamination problems," October 15, 1965, with enclosure: "Summary, Informal Conference on Back Contamination Problems," undated.

September 27

North American evaluated the CSM's communications capability with the unified S-band system using attitude data published with the AS-501 (spacecraft 017) preliminary reference trajectory. The trajectory selected to achieve the desired entry conditions had a maximum altitude at apogee of about 16,668 km (9,000 nm). At this altitude, the maximum range to a Manned Spacecraft Flight Network (MSFN) station was about 20,372 km (11,000 nmi). Since a high-gain antenna was not installed on spacecraft 017, communications depended on the S-band omnidirectional antennas. In order to verify their adequacy, directions to the MSFN stations were computed and system circuit margins were derived. North American concluded that the margins were inadequate to support high-bit-rate telemetry for about three hours of the mission. Modification of the planned CSM attitude produced significant improvement (about 17 decibels) in communications. The contractor also proposed a relocation of range ships to improve performance.

"Apollo Monthly Progress Report," SID 62-300-42, p. 3; TWX, C. L. Taylor, MSC, to NAA, Space and Information Systems Division, Attn: J. C. Cozad, subject: "Mission 501/Spacecraft 017 Compatibility Evaluation," September 27, 1965.

September 28-30

Representatives from MSC, David Clark, Hamilton Standard, and Westinghouse met at North American, where they negotiated and signed most of the interface control documents (ICD) for the space suit and associated equipment. Of the ICD's yet unresolved, only two involved problems that could have a significant effect on hardware design:

1. The current design of the CM environmental control system, because it could not accept waste water from the portable life support system (PLSS), was therefore incapable of recharging the PLSS. ASPO must decide if the recharge requirement was to be kept or eliminated.
2. The CM's waste management system was not compatible with the capacity of the urine bag in the space suit. This problem was assigned to Crew Systems Division.

MSC, "ASPO Weekly Management Report, September 30-October 7, 1965"; letter, C. L. Taylor, MSC, to NAA, Space and Information Systems Division, Attn: J. C. Cozad, "Contract NAS 9-150, Portable life support system (PLSS) water recharge (functional) ICD No. MH01-06153-416," October 12, 1965.

September 29

Ralph S. Sawyer, Chief of the Instrumentation and Electronic Systems Division, advised ASPO Manager Shea of current problems with antennas for the Apollo spacecraft:

CSM high gain antenna

the infrared (IR) earth tracker originally proposed would not satisfy mission requirements. On September 23, Sawyer reported, North American had ordered Dalmo-Victor to halt development of IR systems and to proceed with work on an RE tracker.

CSM S-band omnidirectional antennas

release of specifications was delaying subcontract award. North American might be unable to meet delivery for CSMs 017 and 020.

North American's in-house development program

because of a lack of qualified personnel in California, North American proposed to develop VHF scimitar, S-band flush mounted, and C-band antennas at its Columbus, Ohio, facility.

LEM S-band high-gain antenna

Dalmo-Victor predicted that preproduction models would weigh 11 kg (25.33 lbs), 3 kg (6.83 lbs) more than the specification weight. Grumman already had ordered Dalmo-Victor to study ways of lightening the antenna.

Memorandum, Sawyer, MSC, to Manager, ASPO, "Apollo antenna problem areas," September 29, 1965.

September 29

Apollo Program Director Samuel C. Phillips issued the flight directive for the AS-202 mission, which spelled out the general flight plan, objectives, and configuration of both spacecraft and launch vehicle.

OMSF Directive M-D MA 1400.011, "Apollo Program Flight Mission Directive for Apollo-Saturn 202 Mission," September 29, 1965.

September 29

The Critical Design Review (CDR) of the Block II CSM was scheduled to be conducted in November and December 1965, with the first phase being held November 15-18, and the second phase December 13-17.

The first phase activity would be a review of drawings, schematics, procurement specifications, weight status, interface control drawings, failure analysis, proposed specification change notices, and specification waivers and deviations. The second phase of the review would be a physical inspection of the mockup of the Block II CSM.

The review would be conducted by review teams organized in the several areas and headed by team captains, as follows: Structures and Propulsion, O. Ohlsson; Communications, Instrumentation, and

Electrical Power, W. Speier; Stabilization and Control, Guidance and Navigation, A. Cohen; Crew Systems, J. Loftus; and Mission Compatibility and Operations, R. Battey.

Memorandum, Chief, Systems Engineering Division, MSC, to Distr., "Critical Design Review of Block II CSM," sgd. Harry W. Byington, September 29, 1965.

September 29-30

The Mission Operations Organization had been under continued review and discussion and on September 29 and 30 in New Orleans, La., a meeting was held between George E. Mueller, James C. Elms, Robert R. Gilruth, and George M. Low. General agreement was reached on a method of operation: The Mission Operations Director would represent the Associate Administrator for Manned Space Flight in all operational areas and would be responsible to the Associate Administrator for Manned Space Flight for the execution of all NASA manned spaceflight missions.

The people responsive to the Missions Operations Director (in the same sense as Center Program Managers are responsible to Headquarters Program Directors) are:

The Director of Launch Operations of the Kennedy Space Center,
who is responsible for the preparation, checkout, countdown and launch of the space vehicle. In two of these areas, preparation and checkout, he is responsive to the Program Managers and Program Directors; whereas in the other two areas, countdown and launch, he is responsive to the Mission Operations Director.

The Assistant Director for Flight Operations at the Manned Spacecraft Center,
who represents the Director of MSC in all operational areas. These areas include flight operations and the flight operational aspects of flight crew and medical operations.

The DOD Representative for Manned Space Flight,
who is responsible for the National Ranges and the recovery forces.

The Program Directors,
who are responsive to the Mission Operations Director insofar as the readiness of flight hardware is concerned.

It was pointed out that there were multiple and sometimes divergent inputs from the Program Offices and the Mission Operations organization in OMSF to various elements at the Manned Spacecraft Center.

It was agreed that a better definition of responsibility between Program Office and Mission Operations Directorate in OMSF was required. It was also agreed that for all flight operational areas MSC would prefer to have the Assistant Director for Flight Operations act as its single point of contact. The Assistant Director for Flight Operations would represent Flight Crew Operations and Medical Operations in the mission operations area.

Memorandum, George M. Low, "Mission Operations Discussions," October 4, 1965; Informal

Memorandum, George M. Low to Distr., October 15, 1965, with enclosure.

September 30-October 7

Pressure loading and thermal tests were completed on the types of windows in the Block I CM. The pressure tests demonstrated their ability to withstand the ultimate stresses (both inward and outward) that the CM might encounter during an atmospheric abort. The thermal simulations qualified the windows for maximum temperatures anticipated during reentry at lunar velocities.

"ASPO Weekly Management Report, September 30-October 7, 1965."

September 30-October 7

Flight Projects Division advised that, on the basis of current weight studies, the aft heatshield on Block I CMs must be thinned. North American had said that this change would not affect schedules, but felt some concern about the heat sensors. Accordingly, Structures and Mechanics Division (SMD) ordered North American to proceed with this weight reduction on the hardware for spacecraft 011, 012, and 014 (but ensuring that the orbital decay required for Block I manned missions would still be met). The sensors on 011's heatshield would be adapted to the new thickness. SMD anticipated that these changes would cost about \$500,000 and would probably delay by about four weeks delivery of the 011 heatshield from Avco.

"ASPO Weekly Management Report, September 23-30, 1965"; "ASPO Weekly Management Report, September 30-October 7, 1965"; memorandum, R. W. Lanzkron and O. E. Maynard, MSC, to Manager, ASPO, "Weight Reduction for Block I Aft Heat Shield," October 8, 1965; memorandum, Joseph N. Kotanchik, MSC, to Manager, ASPO, "Flight Configuration of SC 011," October 18, 1965.

September 30

Crew Systems Division defined the survival equipment that MSC would procure for Apollo spacecraft. Fifteen survival sets would be needed for Block I and 30 for Block II CMs.

Memorandum, R. E. Smylie, MSC, to Chief, Crew Systems Division, "Apollo Block I and Block II survival equipment procurement," September 30, 1965.

During the Month

Bell Aerosystems reported on stability and ablative compatibility testing of the first bipropellant-cooled injector baffle for the ascent engine of the LEM. Combustion was stable; however, streaking on the injector face forced Bell to halt ablative testing after only 60 seconds of operation.

"Monthly Progress Report No. 32," LPR-10-48, pp. 1, 11.

During the Month

Thirteen flights were made with the lunar landing research vehicle. Two of those flights were devoted to mulling the lunar simulation system; the remaining 11 flights were devoted to research with the attitude control system in the rate command mode. Nine landings were made in the lunar simulation mode.

On flight 1-34-94F the lunar simulation mode worked perfectly and no drift was encountered during more than one minute of hovering flight. The landing was made in the simulation mode for the first time on this flight.

Letter, Office of Director, Flight Research Center, to NASA Headquarters, "Lunar Landing Research Vehicle progress report No.27 for the period ending September 30, 1965," sgd. Paul F. Bikle, October 14, 1965.

September-October

Grumman advised MSC of major troubles plaguing development of the LEM's descent engine. These included problems of weight, chamber erosion, mixtures, valves, combustion instability, and throttle mechanisms (which Grumman said could delay delivery of LEM 1 and the start of qualification testing).

"Monthly Progress Report No. 32," LPR-10-48, pp. 3, 11; GAEC, "Monthly Progress Report No. 33," LPR- 10-49, November 10, 1965, p. 3.

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Advanced Design, Fabrication, and Testing

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October 1

At a Customer Acceptance Readiness Review at North American, NASA formally accepted spacecraft 002. The vehicle was then demated and shipped to White Sands.

"Apollo Monthly Progress Report," SID 62-300-42, p. 1.

October 1

Homer E. Newell, Associate Administrator for Space Science and Applications, notified Houston of the first two experiments selected for early Apollo landing flights:

1. a lunar gravimeter, which would measure variations in the moon's gravitational field; and
2. a seismic experiment. MSC informed Newell on November 2 that negotiations were being initiated.

Letter, Newell, NASA, to Director, MSC, "Selection of Scientific Investigations for Early Apollo Lunar Landing Missions," October 1, 1965; letter, Director, MSC, to Newell, NASA Headquarters, November 2, 1965.

October 1

MSC informed Grumman that the Center had awarded a contract to AC Electronics for the development of an optical tracking system for the LEM (as a possible alternative to the rendezvous radar). Until MSC reached a final decision on which mode to use, Grumman should continue building the LEM to accept either of these navigational devices. Flight Crew Operations Directorate requested the decision be deferred pending evaluation of an operational paper.

Letter, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Item 3; Selection of Rendezvous Radar or Optical Tracker for LEM Navigation Requirement," October 1, 1965; memorandum, Donald K. Slayton, MSC, to Manager, ASPO, "LEM Optical Tracker," October 1, 1965.

October 1

In the absence of a firm requirement, and because of limited utility, reported Robert C. Duncan, Chief of the Guidance and Control Division, the horizon photometer and star tracker were being deleted from the primary guidance system in Block I CSMs. (Block II guidance systems would still contain the devices.)

Memorandum, Robert C. Duncan, MSC, to Distr., "Apollo primary guidance system star tracker and horizon photometer," October 1, 1965.

October 3-9

The U.S. Geological Survey cooperated with Crew Systems Division (CSD) in testing the extravehicular mobility unit under simulated lunar conditions at Flagstaff, Arizona. As a result, CSD technicians determined a number of deficiencies in the thermal meteoroid garment, and recommended a number of changes to make the garment more functional and more durable, as well as better fitting and more comfortable.

Memorandum, James H. O'Kane, MSC, to Chief, Crew Systems Division, "Report of trip for USGS Apollo support in Arizona," November 1, 1965.

October 4

MSC ordered Grumman to halt work on both linear-shaped charges and gas-driven guillotines as a method for severing the LEM's interstage umbilical. Instead, the contractor should use two mild-detonation guillotines or one dual-blade device.

Letter, James L. Neal, MSC, to GAEC, Attn: John C. Snedeker, "Contract NAS 9-1100, Contract Change Authorization No. 142, Mild Detonating Fuse Driven Guillotine," October 4, 1965.

October 5

As a result of a design meeting on September 2, MSC ordered North American to make a number of detailed hardware changes in the CM uprighting system for Block I spacecraft.

TWX, C. L. Taylor, MSC, to NAA, Space and Information Systems Division, Attn: J. C. Cozad, subject: "Flotation Uprighting System Meeting Conducted at NAA September 2, 1965," October 5, 1965.

October 5

ASPO Manager Joseph F. Shea recommended to Apollo Program Manager Samuel C. Phillips that experiment M-5A (Bioassays Body Fluids) not be incorporated on mission AS-204, based on schedule

impact resulting from structural modifications necessary to support the Urine Volume Measuring System. Redesign and rework of existing spacecraft hardware would have a schedule impact of two to four weeks.

Letter, Shea to Phillips, "Apollo In-Flight Experiments, Flight AS-204," October 5, 1965.

October 6

MSC requested that Grumman study the feasibility of a "fire-till- touchdown" landing procedure for the LEM. Grumman was to investigate especially performance factors surrounding crushing of the descent engine skirt, or possibly jettisoning the skirt, and was to recommend hardware modifications required for this landing mode.

TWX, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, October 6, 1965.

October 7-14

MSC's Reliability and Quality Assurance Division reported in August that, because beryllium would corrode in the humid environment of the spacecraft's cabin, the metal thus posed a toxicological hazard to the crew of the CM. During subsequent meetings with the Health and Physics Group, and Guidance and Control and Structures and Mechanics Divisions, it was agreed that, because of crew safety, beryllium surfaces in the guidance and control system must be coated to protect the metal from the humid atmosphere inside the cabin of the spacecraft.

"ASPO Weekly Management Report, August 12-19, 1965"; MSC, "Minutes of Senior Staff Meeting, October 1, 1965," p. 1; MSC, "ASPO Weekly Management Report, October 7-14, 1965"; memorandum, Joseph N. Kotanchik, MSC, to Chief, Guidance and Control Division, "Protective coating to prevent beryllium corrosion inside the Apollo Command Module," November 4, 1965.

October 7-14

The Instrumentation and Electronic Systems Division (IESD) proposed that the LEM's inflight VHF antenna might be used as a link to astronauts on the surface of the moon as well. (LEM communications had to provide VHF contact with the crew outside the spacecraft at ranges up to three nautical miles. The VHF antenna, however, had been designed only for the flight portions of the mission, and to meet this communications requirement another antenna was being added to the LEM at a cost of between 1.36 and 2.26 kg [3 and 5 lbs].) IESD offered to study the coverage and range of the inflight antenna while on the lunar surface, and suggested that the three-mile range requirement might be relaxed. The additional VHF antenna might thereby be obviated.

Also, IESD attended a preliminary design review at Autonetics on the signal conditioning equipment (SCE) for the Block II CSM. IESD concurred in several modifications to the Block I design (adding a

redundant power supply; hermetic sealing of equipment; and repackaging to fit the equipment bay in Block II CMs). These changes reduced the SCE's weight from 22 to 19 kg (47.5 to 41 lbs) and, because of more efficient power supply, lowered its power consumption from 65 to 35 watts. North American was studying ways of perhaps lightening the SCE even further.

"ASPO Weekly Management Report, October 7-14, 1965."

October 7-14

Crew Systems Division (CSD) established vibration limits for the crew of the LEM. This action followed the final LEM vibration test with human subjects at Wright-Patterson AFB and a review of the test program by CSD and Grumman engineers.

Also, in what CSD described as "the start of a long range program for familiarizing Apollo suit technicians with field and launch operations," the Division reported that it had sent an Apollo suit technician to Cape Kennedy to take part in the forthcoming Gemini VI mission.

Ibid.

October 8

A drop in the boilerplate 6A series, using flight-qualifiable earth landing system (ELS) components, failed because the braking parachute (not a part of the ELS) did not adequately stabilize the vehicle. MSC invited North American and Northrop-Ventura to Houston to explain the failure and to recommend corrective measures.

Ibid.

October 8

Because of the less-than-perfect firing of its retrorockets, *Luna VII*, another Russian moon probe, was destroyed on impact. The craft, launched four days earlier, was thus the third failure, Western observers believed, in Russia's attempt to soft-land a spacecraft on the moon.

Space Business Daily, October 11, 1965, pp. 190, 194; *Astronautics and Aeronautics*, 1965, pp. 460, 463, 464-465, 467.

October 8

A test model of the Lunar Landing Research Vehicle, designed to simulate lunar landings, was flown by former NASA X-15 pilot Joseph Walker to an altitude of 91 m (300 ft). Built by Bell Aerosystems

Company under contract to NASA, the research craft had a jet engine that supported five-sixths of its weight. The pilot manipulated solid-fuel lift rockets that supported the remaining one-sixth, and the craft's attitude was controlled with jets of hydrogen peroxide.

Astronautics and Aeronautics, 1965, p. 465.

October 12

On August 26, the attachments for the pilot parachute mortar had failed during static testing on CM 006. The fittings had been redesigned and the test was not repeated. This test, the final one in the limit load series for the earth landing system, certified the structural interface between the CM and the earth landing system for the 009 flight.

Memorandum, Joseph N. Kotanchik, MSC, to Manager, ASPO, "Launch configuration of SC 009," October 19, 1965; MSC, "ASPO Weekly Management Report, October 21-28, 1965."

October 12

To ensure compatibility with the spacecraft, MSC specified weight and storage details for the extravehicular visors. The devices, two of which would be carried on each mission and transferred from the CM to the LEM, would afford impact, thermal, and ultraviolet protection for the crew during operations in space or on the lunar surface.

Letter, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, EMU EV Visor Assembly," October 12, 1965.

October 14

NASA was negotiating with General Electric Company to provide 56-watt isotopic power generators for the Apollo Lunar Surface Experiment Packages. The Atomic Energy Commission would manage detailed design and development of the unit based on MSC studies of prototypes.

Astronautics and Aeronautics, 1965, p. 476.

October 15

Owen E. Maynard, Systems Engineering Division chief, summarized for ASPO Manager Joseph F. Shea the recovery requirements for Apollo spacecraft. The CM must float in a stable, apex-up attitude, and all of the vehicle's recovery aids (uprighting system, communications, etc.) must be operable for 48 hrs after landing. In any water landing within 40 degrees north or south latitude, the Landing and Recovery Division had determined, the crew either would be rescued or recovery personnel would be in the water with the CM within this 48-hr period. Thereafter, Maynard said, the spacecraft had but to remain afloat

until a recovery ship arrived - at most, five days.

Memorandum, Maynard, MSC, to Manager, ASPO, "Post-landing flotation requirements," October 15, 1965.

October 15

NASA announced that it had selected Lockheed Electronics Company of Houston, Texas, to provide broad data-handling support at MSC. Negotiations on the contract (valued at more than \$3 million) began shortly thereafter.

MSC News Release 65-93, "NASA to Negotiate with Lockheed Electronics Co. for Computer Programming Support," October 15, 1965; letter, George E. Mueller, NASA, to Robert R. Gilruth, MSC, October 29, 1965.

October 18

MSC ordered Grumman to discontinue use of zinc and cadmium on all production LEMs. This action followed performance studies by the Reliability and Quality Assurance Division that showed a deleterious effect of space environments upon these metals.

Letter, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, The use of Cadmium or Zinc Plate in the Apollo Spacecraft," October 18, 1965.

October 18

To solve the problem of controlling bacteria in the LEM's waste management system (WMS), Crew Systems Division (CSD) recommended some type of passive control rather than periodically adding a germicide to the system. CSD described two such passive techniques, both of which relied on chemicals upstream from the WMS (i.e., in the urine collection device in the space suit). MSC began studying the feasibility of this approach, and ordered Grumman also to evaluate passive control in the contractor's own investigation of the bacteriological problem.

Letter, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Bacteriological Control for LEM Waste Management Subsystem," October 18, 1965, with enclosure.

October 19-22

A meeting was held at Flight Research Center to discuss several items relating to the Lunar Landing Research Vehicle (LLRV) and Lunar Landing Training Vehicle (LLTV). Attending were Dean Grimm, Robert Hutchins, Warren North, and Joseph Algranti of MSC; Robert Brown, John Ryken, and Ron

Decrevel of Bell Aerosystems Company; and Gene Matranga, Wayne Ottinger, and Arlene Johnson of Flight Research Center.

The discussions centered around MSC's needs for two LLRVs and two LLTVs and the critical nature of the proposed schedules; alternatives of assembling a second LLRV ; clarifying the elements of the work statement; and preliminary talks about writing specifications for the LLTV.

From a schedule standpoint, it was decided that both LLRVs would be delivered to MSC on September 1, 1966. MSC planned to check out and fly the second LLRV (which needed additional systems checkout) with their crew and pilot on a noninterference basis with LLRV No. 1, the primary training vehicle.

NASA Internal Memorandum for those concerned, Gene J. Matranga, LLRV Project Manager, "Meetings held during the week of October 17 relating to the LLRV," October 26, 1965.

October 20

The MSC Mission Constraints Control Panel (MCCP) held its initial meeting. The panel's function was to resolve all conflicts between launch vehicle, spacecraft, and operational constraints. Also, once the preliminary reference trajectory was issued, the MCCP must approve all constraint changes. These would then be included in the mission requirements.

Memorandum, Robert V. Battey, MSC, to Distr., "Minutes of 1st Mission Constraints Control Panel Meeting," October 26, 1965, with enclosure.

October 20

To save weight, Crew Systems Division was studying the feasibility of using three one-man liferafts and a composite set of survival gear in Block I CMs.

Memorandum, R. E. Smylie, MSC, to Chief, Crew Integration Branch, Attn: J. Marshall, "Block I composite kit study," October 20, 1965,

October 20

Apollo spacecraft 009, first of the type that would carry three astronauts to the moon and back, was accepted by NASA during informal ceremonies at North American. Spacecraft 009 included a CM, SM, launch escape system, and adapter.

Astronautics and Aeronautics, 1965, p. 485.

October 20-21

To support studies on equipment stowage, North American agreed to maintain mockups of the crew compartments in the two blocks of CMs. The contractor's effort would be geared for the first manned flight for each series of vehicles (spacecraft 012 and 101).

"ASPO Weekly Management Report, October 21-28, 1965."

October 21

Samuel C. Phillips, Apollo Program Director, notified the Center directors and Apollo program managers in Houston, Huntsville, and Cape Kennedy that OMSF's launch schedule for Apollo-Saturn IB flights had been revised, based on delivery of CSMs 009 and 011:

- AS-201 - January 1966
- AS-202 - June 1966

Schedules for AS-203 through 205 (July and October 1966, and January 1967) were unchanged.

TWX, Phillips, NASA, to Kurt Debus, KSC, Robert Gilruth, MSC, and Wernher von Braun, MSFC, subject: "Saturn IB Launch Schedules," October 21, 1965.

October 21

MSC announced that the bubble-type helmet, designed by Crew Systems Division (CSD) engineers Robert L. Jones and James O'Kane, had been adopted for use in the Apollo extravehicular mobility unit. The new helmet was smaller and lighter than earlier types; extensive studies by CSD had demonstrated its superior comfort, visibility, and don/doff characteristics.

MSC News Release 65-96, October 21, 1965.

October 21

To enable MSC's Mission Control Center (MCC) to handle Apollo flights, MSC announced that NASA's contract with IBM for computer systems would be extended. For an additional \$80 million, IBM would convert the MCC to newer equipment and would use more advanced support techniques. The contract would contain provisions for conversion to an incentive fee type.

MSC News Release 65-97, October 21, 1965.

October 21

North American completed static structural tests on the forward heatshield for the Block I CM (part of the certification test network for airframes 009, 011, and 012), thus demonstrating the heatshield's structural integrity when jettisoned (at the start of the earth landing system sequence).

"ASPO Weekly Management Report, October 21-28, 1965."

October 22

NASA announced that it had selected 10 areas on the moon as subjects for Lunar Orbiter's cameras during 1966. These areas encompassed most major types of lunar terrain. Most were suitable - and potential - landing sites for Surveyor and Apollo spacecraft.

NASA News Release 65-335, "NASA Selects 10 Potential Photo Areas for Lunar Orbiter," October 22, 1965.

October 23-26



The Pregnant Guppy aircraft, which was used extensively by NASA to transport spacecraft during all phases of the Apollo program.

While delivering Apollo SM 009, the Pregnant Guppy aircraft was delayed at Ellington Air Force Base, Texas, for three-and-a-half days while waiting for an engine change. In view of the delay of the SM, the incident was reviewed during the succeeding weeks, and Aero Spacelines was requested to place spare engines not only at Houston, but also at other strategic locations on the normal air route from Long Beach, Calif., to KSC.

Letter, Edmund F. O'Connor, MSFC, to MSC, Attn: Joseph F. Shea, "Pregnant Guppy emergency engine change, October 23-26, 1965," November 18, 1965.

October 26

MSC authorized North American to modify the Block II CSM design to provide for installation of a luminous beacon compatible with the LEM tracking system. The CSM beacon could replace the rendezvous radar and transponder.

Letter, J. B. Alldredge, MSC, to NAA, Space and Information Systems Division, "Contract Change Authorization No. 455," October 26, 1965; memo, Owen E. Maynard, MSC, to Project Officer, CSM, "Deletion of automatic actuation capability of VHF recovery beacon (Block II)," October 8, 1965.

October 27

At a meeting with Grumman, MSC agreed with the contractor's basic design of the LEM's descent-stage base heatshield and its installation and access. MSC asked Grumman to demonstrate accessibility, installation, and removal of the heatshield on the M-4 mockup.

Letter, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Implementation of Action Items," November 3, 1965, with enclosure, "Abstract of LEM Base Heat Shield Review," undated.

October 29

Owen E. Maynard, Systems Engineering Division chief, advised his branch managers of the U.S. Public Health Service's (PHS) growing concern that Apollo spacecraft and crews might bring organisms back from the moon. (See September 27.) PHS feared that such organisms would be "capable of multiplying in the earth environment and [that] precautionary measures must be undertaken to prevent global exposure." Therefore, Maynard told his group, PHS believed that the CM, its environment, and its crew must not be allowed to contact the earth's environment. Maynard further advised that efforts were already underway to define the design of an isolation facility, and isolation facilities for the recovery ships were being contemplated.

As a result of this strong stand by PHS, Maynard said, "It appears that ASPO will soon be requested to

show what spacecraft measures are being taken to assure that the CM environment will not be exposed to the earth atmosphere. The spacecraft," Maynard told his group - who already knew as much - "has not been designed to preclude CM environment exposure." Actually, much the opposite had long been assumed to be part of normal operating procedures. Maynard therefore ordered subsystem managers to review their individual systems to determine:

- If their system was potentially a carrier of moon germs
- What could be done to confine such organisms
- If a "strict no contamination edict" would affect the life and operation of systems
- How postlanding procedures could be changed to prevent release of organisms from the spacecraft

Maynard cautioned systems managers to "assume that ASPO is morally obligated to prevent any possible contamination of the earth," and not to reply with "the standard answer that no changes can be made within present weight, cost, and schedule limitations. Admittedly," he said, "our first look may prove to be insurmountable." Nonetheless, review must be performed so that recommendations can be made concerning all such systems.

Memorandum, Maynard, MSC, to PHS Branches, "Earth contamination from lunar surface organisms," October 29, 1965.

During the Month

Seven flights were made with the Lunar Landing Research Vehicle at Flight Research Center during October. The first three were in support of X-15 conference activities, and the last four were for attitude control research. Five of the landings were made in the lunar simulation mode.

Letter, Office of Director, Flight Research Center, to NASA Headquarters, "Lunar Landing Research Vehicle progress report No. 28 for the period ending October 31, 1965," sgd. Paul F. Bikle, November 2, 1965.

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November 1

MSC's Engineering and Development Directorate established the Lunar Sample Receiving Laboratory Office as an interim organizational element pending development of a permanent organization for operation of the laboratory.

MSC Announcement 65-140, "Establishment of the E&D Lunar Sample Receiving Laboratory Office," November 1, 1965.

November 2

Bell Aerosystems Company reported that the LEM ascent engine bipropellant cooled injector baffle met all basic specification requirements, including those for combustion efficiency, ablatives compatibility, and stability. Bell conducted a successful firing with an engine that had previously been vibrated to simulate launch boost and lunar descent. The contractor also completed a duty cycle firing at AEDC with hardware conditions set to the maximum temperatures believed attainable during a lunar mission.

GAEC, "Monthly Progress Report No. 34," LPR-10-50, December 10, 1965, pp. 1, 13; letter, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Bell Aerosystems Contamination Problems," December 9, 1965.

November 4

MSC management gave Grumman the go-ahead to implement the LEM Certification Test Plan effective October 25.

Memorandum, Owen E. Maynard, MSC, to Distr., "LEM Certification Test Program Implementation," November 4, 1965.

November 4

In a letter to the Director of Flight Research Center, MSC Director Robert R. Gilruth said that recent Lunar Landing Research Vehicle LLRV flight results and problems with the handling qualities of the LEM had focused high interest on the LLRV activities at FRC.

Gilruth concurred with the recent decision to assemble the second LLRV and said MSC planned to support the assembly and checkout of the second vehicle with engineering and contractor personnel assigned to the Flight Crew Operations Directorate.

Gilruth expressed appreciation for the effort expended by FRC in initiating a three-month study contract with Bell Aerosystems to provide drawings for a follow-on vehicle and indicated MSC planned to contract for Lunar Landing Training Vehicles in June 1966.

Letter, Gilruth to Director, FRC, "Lunar Landing Research and Training Vehicles," November 4, 1965.

November 4

MSC's Configuration Control Board approved the reduction of maximum translunar flight time from 110 hrs to 100 hrs.

Memorandum, Robert V. Battey, to Manager, ASPO, "Response to your question on reduction of translunar flight time," November 1, 1965; MSC, "Minutes, Configuration Control Board Meeting No. 24, November 4, 1965."

November 4-12

The design of the Block I space suit helmet ear cup and attachment was finalized. Based on evaluation of AFRM 007 acoustic test data, it was determined that existing Gemini-type "soft" ear cups were adequate for Block I flights. North American and David Clark Company specifications would be changed to reflect revised requirements. The majority of drawings for the suit had been reviewed and approved by MSC's Crew Systems Division. Remaining to be resolved and approved were selection of helmet visor material, installation of helmet microphones and earphones, communications harness, and fingertip glove lighting systems.

MSC, "ASPO Weekly Management Report, November 4-12, 1965"; NAA, "Apollo Monthly Progress Report," SID 62-300-44, January 1, 1966, p. 6.

November 5

NASA announced that it would negotiate with International Latex Corporation for an estimated \$10 million contract to fabricate the Apollo space suit consisting of the liquid-cooled undergarment, constant wear garment, pressure garment assembly, and thermo-micrometeoroid protective overgarment. At the same time an estimated \$20 million contract was negotiated with Hamilton Standard Division of United

Aircraft Corporation for continued development and manufacture of the portable life support system with a four-hour main power supply subjected to a maximum stowage soak temperature of 328K (130 degrees F).

MSC News Release 65-102, November 5, 1965; TWX, Richard S. Johnston, MSC, to R. E. Breeding, Hamilton Standard Division, subject: "PLSS Power Supply Concept," November 8, 1965; NASA News Release 65-346, "NASA to Negotiate for Apollo Suit, Support System," November 5, 1965; "ASPO Weekly Management Report, November 4-12, 1965."

November 8

The development mission planning panel met to discuss the general constraints for missions AS-206 and AS-207. AS-206 spacecraft and operational constraints and mission rules were checked for compatibility. An investigation of the AS-207 preliminary mission profile showed that the ascent power requirements far exceeded the capacity of the ascent stage batteries. A modification to the mission profile was developed which would enable the mission objectives to be accomplished within the LEM battery capabilities. A tentative procedure for negotiating MSFC launch vehicle constraints was established between MSC and MSFC.

"ASPO Weekly Management Report, November 4-12, 1965"; memorandum, Robert V. Battey, MSC, "Minutes of the Mission Constraints Panel Meeting #4," November 23, 1965, with enclosure; memorandum, Owen E. Maynard, MSC, to Distr., "Official Method for Negotiating Mission Constraints with MSFC," November 16, 1965.

November 9-12

Upon examination of the airlock gas connectors at the Portable Life Support System Emergency Oxygen System Preliminary Design Review, ASPO representatives discovered a possible catastrophic failure. If an astronaut unhooked the PLSS supply umbilical before the exhaust line was disconnected the suit would vent through the PLSS. A request for change was rejected by the preliminary design review board in spite of this situation. ASPO recommended to the Crew Systems Division that the connectors be modified or that the problem be solved another way to preserve crew safety.

Memorandum, Owen E. Maynard, Systems Engineering Division, ASPO, to Apollo Support Office, Crew Systems Division, "RFC 111-1, Preliminary Design Review, PLSS/EOS, 9-12 November 1965," December 7, 1965.

November 10

North American conducted an Apollo Program Review for key subcontractors to convey the current status of the program and to discuss the subcontractors' specific participation and support to the program.

NAA, "Apollo Monthly Progress Report," SID 62-300-43, December 1, 1965, p. 3.

November 10

A North American layout of the volume swept by the CM couch and crewmen during landing impact attenuation showed several areas where the couch and or crewmen struck the CM structure or stowed equipment. One area of such interference was that the center crewman's helmet could overlap about four inches into the volume occupied by the portable life support system (PLSS) stowed beneath the side access hatch. The PLSS stowage was recently changed to this position at North American's recommendation because the original stowage position on the aft bulkhead interfered with the couch attenuation envelope. The contractor was directed by MSC to explain this situation.

"ASPO Weekly Management Report, November 4-12, 1965"; TWX, C. L. Taylor, MSC, to NAA Space and Information Systems Division, Attn: J. C. Cozad, subject: "Impact Attenuation System Interference," November 10, 1965.

November 11

The Block I service propulsion system engine successfully completed the first altitude qualification tests at AEDC.

MSC, "ASPO Weekly Management Report, November 12-18, 1965."

November 11

A manned lunar mission metabolic profile test was run in the Hamilton Standard Division altitude chamber using the development liquid-cooled portable life support system (PLSS). The system was started at a chamber altitude of over 60,906 m (200,000 ft), and the subject adjusted the liquid bypass valve to accommodate the programmed metabolic rates which were achieved by use of a treadmill. Oxygen was supplied from an external source through the PLSS bottle and oxygen regulation system. This procedure was used because bottle qualification was not complete, so pressure was limited to 2,068 kilonewtons per sq m (300 psig). An external battery was used for power because the new batteries that were required by the change to the all-battery LEM were not yet available. The thermal transport system including the porous plate sublimator was completely self-contained in the PLSS. All systems operated within specification requirements and the test was considered an unqualified success.

"ASPO Weekly Management Report, November 4-12, 1965."

November 12

The portable life support system Preliminary Design Review was completed. The design was essentially complete and no major discrepancies were noted during the review.

Ibid.

November 12-18

MSC and Grumman representatives reviewed Grumman's timeline analysis for the intravehicular LEM crew activities subsequent to lunar landing. This timeline was being rewritten for a test program to be conducted to determine what crew mobility problems existed within the LEM so that they could be better evaluated at the Certification Design Review.

"ASPO Weekly Management Report, November 12-18, 1965."

November 12-18

MSC directed Ryan Aeronautical Corporation to present to RCA and Grumman areas in which weight could be saved on the LEM landing radar. Of specific interest was the power supply and the possibility of its overdesign.

Ibid.

November 15

MSC instructed North American to:

- Submit a preliminary design of Block II CSM jettisonable covers to protect the radiator and CM heatshield thermal coatings from degradation by the boost environment.
- Furnish preliminary design of nonablative reaction control system (RCS) plume heat protection to prevent SM coating degradation on Block II CSMs.
- Determine the effect on the overall SM and LEM adapter thermal design of coating degradation to a level specified by MSC and to propose design changes or mission constraints for Block I and Block II CSMs.
- Determine the effect on the SM RCS thermal design of coating degradation to the level specified by MSC and to propose design changes or mission constraints for Block I and II CSMs.

Letter, J. B. Alldredge, MSC, to NAA, Space and Information Systems Division, "Contract Change Authorization No. 478," November 15, 1965.

November 19

The manned portion of the coast and maneuver simulation program was completed, evaluating man-in-the-loop capabilities and their effects upon maneuver accuracy, maneuver time, and propellant

consumption. The maneuvers and pilot techniques satisfied the midcourse attitude and translation control requirements for the Block I Spacecraft 012 manned mission. The study was conducted in eight phases, including more than 950 runs. Preliminary analysis of the results indicated there was compatibility between the pilots and the maneuver control equipment.

"Apollo Monthly Progress Report," SID 62-300-44, p. 6.

November 22

Christopher C. Kraft, Jr., MSC's Assistant Director for Flight Operations, outlined results of recent studies of the problems associated with lunar landing. The programs studied were Surveyor, Lunar Orbiter, deployment of probes on a simulated manned lunar landing mission, deployment of probes during lunar orbit on an unmanned mission, and deployment of landing aids during the manned lunar landing mission.

The studies supported the conclusion that it was still desirable to have an earth launch window of several days to give launch opportunity flexibility. For this purpose, it would be necessary to have a group of longitudinally spaced landing areas available. However, if there were a particular advantage, such as site certification, in being limited to one area and, consequently, one launch opportunity per month, this was considered to be acceptable. At least one launch opportunity per month would be required. Therefore, the certified area would have to be within the area available from performance consideration. This might mean a night launch, which was confirmed as feasible.

Although the manned lunar landing mission ought not to depend upon a successful Surveyor program, information for Apollo as well as general scientific information should be expected from the program. The concept was not supported that probes were a necessary prerequisite to a lunar landing nor was the idea of a separate probe mission approved. If the Surveyor program failed to provide evidence of the suitability of at least one area and if the consensus favored gathering additional information from probes, the feasibility of carrying probes on the actual lunar landing mission should be fully considered, together with the development of aids to real-time assessment.

Memorandum, Christopher C. Kraft, Jr., MSC, to Manager of Special Design Efforts, "Problems associated with lunar landing," November 22, 1965.

November 22

Little Joe II Program Manager Milton A. Silveira suggested to ASPO Manager Joseph F. Shea that if the next Little Joe II flight test was successful there would be no further requirement for the Little Joe II to support the Apollo program. Silveira said planning had been made with General Dynamics Convair to store the remaining three vehicles, parts, and tooling for one year in case a new requirement from ASPO or NASA should develop. The additional cost of one-year storage compared to normal program closeout was estimated to be small. ASPO concurred with the suggestion on December 1.

Memorandums, Silveira to Shea, "Little Joe II program close-out," November 22, 1965; J. Thomas Markley to Silveira, December 1, 1965.

November 23

North American informed MSC of a fire in the reaction control system (RCS) test cell during a CM RCS test for spacecraft 009. The fire was suspected to have been caused by overheating the test cell when the 10 engines were activated, approximately 30 sec prior to test completion. An estimated test delay of two to three weeks, due to shutdown of the test cell for refurbishment, was forecast. MSC informed the Apollo Program Director that an investigation was underway.

TWX, Joseph F. Shea, MSC, to NASA Headquarters, Attn: Apollo Program Director, sgd. William A. Lee, November 23, 1965.

November 24

MSC notified Grumman that all electrically actuated explosive devices on the LEM would be fired by the Apollo standard initiator. This would be a common usage item with the CSM and would be the single wire configuration developed by NASA and provided as Government-furnished equipment.

Letter, James L. Neal, MSC, to GAEC, Attn: John C. Snedeker, "Contract NAS 9-1100, Contract Change Authorization 159, Phase-in of Single Bridge Apollo Standard Initiator," November 24, 1965.

November 26

Grumman was directed by MSC to provide for the disposition and bacteriological control of the LEM urine containers by off-loading all containers to the lunar surface immediately prior to LEM ascent, locating them so their physical integrity would be assured during ascent stage launch. Incorporation of an appropriate germicide in all LEM urine containers would effectively sterilize the internal part of the container and the contained urine.

Letter, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Disposition and Bacteriological Control of LEM Urine Containers," November 26, 1965.

November 28

Ordnance separation tests on the first three spacecraft-LEM-adapters (SLA) in a series of four were completed at North American's Tulsa facility. The tests successfully demonstrated the deployment of the SLA's forward panels in preparation for the first spacecraft orbital flight.

"Apollo Monthly Progress Report." SID 62-300-44, p. 8; memorandum, Lyle D. White, MSC, to Chief,

Systems Engineering Division, "SLA panel separation follow-up report," November 8, 1965; MSC, "ASPO Weekly Management Report, November 18-24, 1965"; MSC, "ASPO Weekly Management Report, November 25-December 2, 1965."

November 30

Usage of a multiple gas connector (MGC) with the extravehicular mobility unit (two per suit) was deleted. Instead of the MGC, a separate inlet and outlet suit umbilical gas connector manufactured by Airlock, Inc., would be used (two inlets and two outlets per suit). This design change applied to all Block II space suits, environmental control systems, and portable life support systems. Hamilton Standard was directed to implement the change by means of a negotiated revision of a supplemental agreement to its contract.

Letter, R. Wayne Young, MSC, to GAEC, Attn: R. S. Mullaney, "Contract NAS 9-1100, Deletion of multiple gas connector (substitute separate Airlock, Inc., connectors)," November 30, 1965.

November 30

Apollo Mission Simulator No. 1 was shipped from Link Group, General Precision, Binghamton, New York, to MSC.

Memorandum, Owen E. Maynard, MSC, to Manager, ASPO, "Apollo Mission Simulator Status," November 30, 1965; "ASPO Weekly Management Report, November 18-24, 1965."

During the Month

Grumman completed negotiations with Thompson-Ramo-Wooldridge for the LEM abort guidance system.

"Monthly Progress Report No, 34," LPR-10-50, p. 19.

During the Month

Ten flights were made with the lunar landing research vehicle. All flights were for attitude control and handling qualities research. Landings on all flights were made in the lunar landing mode.

Letter, Office of Director, Flight Research Center, to NASA Headquarters, "Lunar Landing Research Vehicle progress report No. 29 for the period ending November 30, 1965," sgd. Paul F. Bikle, December 14, 1965.

During the Month

A series of tests were run to determine the cause of stress corrosion of the reaction control system titanium tanks. Results showed that tanks exposed to chemically pure nitrogen tetroxide (N₂O₄) oxidizer suffered stress corrosion cracking, but tanks exposed to N₂O₄ containing small amounts of nitric oxide did not fail. The qualification testing program would soon resume.

"Apollo Monthly Progress Report," SID 62-300-44, p. 10; NAA, "Project Apollo Spacecraft Test Program Weekly Activity Report (Period 15 November 1965 through 21 November 1965), p. 3.

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December 2

NASA had essentially completed negotiations with North American on the incentive contract. Based on agreements reached with the contractor during negotiations, Master Development Schedule 9 was published, which included Block I and Block II spacecraft schedules, SLA schedules, SM Block II primary structure schedules, and a tabulated list of milestones containing former and new schedule dates.

Memorandum, C. L. Taylor, MSC, to each ASPO Branch Chief and each Subsystem Manager, "New NAA Schedule MDS-9," December 2, 1965.

December 2

Maj. Gen. Samuel C. Phillips, NASA Apollo Program Director, approved the deletion of the LEM TM-5 from the ground test program. He requested that MSC consider the following recommendations:

- A Langley Research Center drop test program using a full-scale LEM as part of the LEM test program.
- Expansion of the one-sixth scale model tests in the areas of nonsymmetrical landings and soil landings.
- Planning of mechanism tests on LTA-3 with attention to their timelines.
- Investigation of use of the LTA-3 or LEM-1 for structural elasticity tests.

On December 23, ASPO Manager Joseph F. Shea replied regarding the recommendations:

- Langley had been requested by MSC to support the LEM ground test program by conducting tests of a simulated LEM on the Langley one-sixth gravity simulation test rig.
- Additional tests of one-sixth LEM drop models would be conducted to cover nonsymmetrical landings. Evaluation of LEM landing performance in soil was starting at MSC in a program that would include both analysis and experimental studies.
- MSC felt that sufficient demonstration of the mechanism capabilities of the landing gear would be provided by the planned dynamic tower tests and the Langley tests. The LTA-3 drop tests,

however, would be used as a further means of demonstrating the mechanism's functionability.

- An analytical study to evaluate the structural "elastic spring-back" effects on LEM landing performance was being conducted by Grumman. If evaluation of this study showed the need for experimental testing, the use of the LTA-3 for elasticity tests would be investigated. The use of a flight article, such as LEM-1, for such tests was not considered desirable because of the possibility of structural damage.

TWX, Maj. Gen. Samuel C. Phillips, NASA Headquarters, to MSC, Attn: J. F. Shea, December 2, 1965; letter, Joseph F. Shea, MSC, to NASA Headquarters, Attn: Maj. Gen. Samuel C. Phillips, "Deletion of TM-5 from LEM Ground Test Program," December 23, 1965,

December 3

MSC was considering the use of both water and air bacteria filters in the LEM to reduce contamination of the lunar surface. Crew Systems Division (CSD) would attempt to determine by tests what percentage concentration of micro-organisms would be trapped by the filters. CSD hoped to begin limited testing in January 1966.

At an MSC meeting attended by ASPO, CSD, and Lunar Sample Receiving Laboratory representatives, it was decided that the following directions would be sent to Grumman:

1. In order to prolong the prevention of lunar surface contamination, provisions should be made to store urine and lithium hydroxide canisters in the descent stage; and
2. the portable life support systems and associated extravehicular mobility items should be dumped onto the lunar surface after all lunar surface exploration had been completed.

Memorandum, Robert V. Battey, Chief, Systems Operations Branch, ASPO, to Chief, Systems Engineering Division, ASPO, "Status of Lunar Surface Contamination," December 3, 1965.

December 3

The Flight Readiness Review for Mission A-004 was conducted at White Sands Test Facility. The board concurred in proceeding with launch preparations. Subsequent to the review, the failure analysis of the autopilot subsystem revealed loose solder connections, and the launch was rescheduled for December 15, from the original December 8 planned launch. The launch was later scheduled for December 18; then, because of continued problems with the autopilot, was scrubbed until January. (See January 20, 1966, entry.)

"Project Apollo, Abstract of Proceedings, Mission A-004 (CSM 002/LJ II 12-51-3) Flight Readiness Review, December 3, 1965, at the White Sands Test Facility," Chairman, F. J. Bailey, Jr.; MSC, "ASPO Weekly Management Report, December 2-9, 1965"; TWX, Manager, ASPO, MSC, to NASA Headquarters, Attn: Director, Apollo Program Office, December 22, 1965.

December 3-7

The U.S.S.R. launched *Luna VIII*, an unmanned spacecraft, toward the moon December 3. The objectives were to test a soft lunar landing system and scientific research. Weighing 1,552 kg (3,422 lbs), the spacecraft was following a trajectory close to the calculated one and the equipment was functioning normally. *Luna VIII* impacted on the moon December 7. Indications were that it was destroyed instead of making a soft landing. Tass reported that "the systems were functioning normally at all stages of the landing except the final touchdown."

Astronautics and Aeronautics, 1965, pp. 536, 542.

December 4-18

Gemini VII, the fourth manned mission of that program, was launched from Cape Kennedy December 4 with command pilot Frank Borman and pilot James A. Lovell, Jr., as the crew. Their primary objective was to evaluate the physiological effects of long-duration (14 days) flight on man. Secondary objectives included: providing a rendezvous target for the *Gemini VI-A* spacecraft (see December 15-16 entry), conducting 20 experiments, and evaluating the spacecraft's reentry guidance capability. The rendezvous was successfully accomplished during the 11th day of the mission. The crew established another first for American spacemen as first one, then the other, and finally both flew with their flight suits removed. The landing, on December 18, was little more than six miles from the planned landing point.

Grimwood, Hacker, with Vorzimmer, "*Project Gemini, A Chronology*" (NASA SP-4002), 1969, pp. 224- 226.

December 5

Hamilton Standard successfully tested a life-support back pack designed to meet requirements of the lunar surface suit. The system functioned as planned for more than three hours inside a vacuum chamber, while the test subject walked on a treadmill to simulate the metabolic load of an astronaut on the lunar terrain. The 29.48-kg (65-lb) portable life support system supplied oxygen, pressurized to a minimum 25,510 newtons per sq m (3.7 lbs psi), controlled its temperature and relative humidity, and circulated it through the suit and helmet. The pack pumped cooled water through the tubing of the undergarment for cooling inside the pressure suit. A canister of lithium hydroxide trapped carbon dioxide and other air contaminants to purify the oxygen for reuse.

Astronautics and Aeronautics, 1965, p. 540.

December 6

George E. Mueller, NASA Associate Administrator for Manned Space Flight, notified MSC Director

Robert R. Gilruth that NASA Administrator James E. Webb and Associate Administrator Robert C. Seamans, Jr., had selected Lockheed Aircraft Corporation, The Martin Company, McDonnell Aircraft Corporation, and Northrop Corporation for Phase I of the Apollo Experiments Pallet Procurement. The contracts would be for four months and each would be valued at about \$375,000.

Letter, Mueller to Gilruth, December 6, 1965.

December 6-17

The Block II CSM Critical Design Review (CDR) was held at North American, Downey, Calif. The specifications and drawings were reviewed and the CSM mockup inspected. Review Item Dispositions were written against the design where it failed to meet the requirements.

As a result of the CDR North American would update the configuration of mockup 27A for use in zero-g flights at Wright-Patterson AFB. The flights could not be rescheduled until MSC approved the refurbished mockup as being representative of the spacecraft configuration.

MSC, "ASPO Weekly Management Report, December 16-23, 1965."

December 7

ASPO Manager Joseph F. Shea informed North American, Grumman, and Bell Aerosystems Company that NASA's Associate Administrator for Manned Space Flight, George E. Mueller, had requested a presentation on the incompatibility of titanium alloys and nitrogen tetroxide and its impact on the Apollo Program, this to be done at the NASA Senior Management Council meeting on December 21.

In light of recent failures of almost all titanium tanks planned for use in the Apollo Program when exposed to nitrogen tetroxide under conditions which might be encountered in flight, the matter was deemed to be of utmost urgency.

A preliminary meeting was scheduled at NASA Headquarters on December 16 and one responsible representative from each of the prime contractors and subcontractors was requested to be present. Prior to the December 16 meeting, it would be necessary for each organization to complete the following tasks:

- Tabulate and analyze all tank tests to date and all related materials tests.
- Establish a format for presentation of the effects of time, temperature, and stress levels on failure.
- Obtain the best correlation between actual tank tests and related materials tests.
- Establish limits of operation and confidence levels for all current titanium tanks and relate these to all planned flights.
- Tabulate all titanium tank hardware in inventory and complete costs of development and manufacture of this hardware to date.

- Consider and recommend a course of action which would alleviate problems for early flights using existing hardware with minimum cost and schedule impact.
- Consider and recommend a course of action for future flights and indicate cost and schedule impact.
- If recommendations for future action include coatings, surface preparation, or alternate materials, present component weight increase and overall spacecraft increase.
- Consider changes in mission ground rules which would decrease time of tanks under pressure.
- Consider possibility of venting and repressurization and impact on pressurization system design, weight, cost and schedule.
- Review all missions and present pressurization times, stress levels, and thermal environment of all Apollo titanium tanks which contain nitrogen tetroxide.

TWX, Joseph F. Shea, MSC, to D. Myers, NAA; J. Gavin, Grumman; and J. Piselli, Bell Aerosystems Company, December 7, 1965.

December 8

MSC's Deputy Director George M. Low told Willis B. Foster of NASA Headquarters that the standing committee appointed by him had performed an invaluable service to the Center in identifying the requirements to be incorporated in the Lunar Sample Receiving Laboratory. Low said, "Additionally, we are indebted to individual members of that committee for providing detailed specialized inputs during the preliminary engineering phase just ended."

Low noted that the committee had prepared a report, "Review of the Preliminary Engineering Report (PER) of the Lunar Sample Receiving Laboratory (LSRL) by the Standing Committee of LSRL." He said that an examination of this report revealed that the committee had addressed itself to a detailed review task which far exceeded the scope envisioned when Foster conceived the idea for such a committee.

Low suggested that the committee be "discharged of any further responsibility relating to the facility design and construction." He added that MSC would look forward to providing Foster and his staff, as well as interested outside scientists, periodic briefings and reports of status and progress on the facility.

Letter, Low to Foster, "Manned Space Science Standing Committee for the Lunar Sample Receiving Laboratory," December 8, 1965.

December 8

An 889-kilonewton (200,000-lb) thrust J-2 engine was captive-fired for 388 sec on a new test stand at MSFC. The J-2 engine would be used to power the Saturn S-IVB stage for the Saturn V. Ten tests of the liquid hydrogen-liquid oxygen powered rocket engine had been conducted at MSFC since the J-2 engine test facility was put into use in August 1965.

Astronautics and Aeronautics, 1965, p. 543.

December 8

The service propulsion system burn time for AS-502 was confirmed to be 385 sec flight time. Previously the plan had called for a total of 515 sec - 310 sec for SPS-1 and 205 sec for SPS-2. This action required that all mission plans be restudied and revised.

Memorandum, Carl R. Huss, JSC, to JSC Historical Office, "Comments on Volume III of *The Apollo Spacecraft: A Chronology*, "June 6, 1973.

December 9-16

Investigations were continuing of the best alternative for resolving the AS-502 mission incompatibilities. The incompatibilities resulted from the restriction of the usable life of the Block I service propulsion system (SPS) engine to 385 to 400 sec total burn time. The alternatives were:

- Retain the current mission profile by burning the SPS engine for 500 sec, the minimum time the Block I engine was to be qualified for in ground tests.
- Decrease the burn time to about 385 sec and permit the apogee of the AS-502 mission to increase well above the planned 16,668 km (9,000 nmi). The increased flight time would result in increased dispersions at reentry, requiring some means to be found to decrease guidance dispersions during flight.
- Plan a primary AS-502 mission which stayed within the 400-sec burn time limitation and which did not achieve the desired reentry conditions for the heatshield test.
- Put a Block II SPS engine on CM 020. Because of the number of changes in the SPS subsystem between Block I and Block II, this would probably mean an extensive rework of the 020 SM.
- Develop engine modifications specifically for the 020 spacecraft that would permit firing the engine for 500 sec. This would mean a dead-end development over and above the Block I requirements.

The necessary information for reaching a decision among those alternatives was being collected.

MSC, "ASPO Weekly Management Report, December 9-16, 1965."

December 9-16

The Block II Apollo food stowage problems were explored at North American. Methods of restraint were resolved to allow accessibility of the man-meal assemblies. The contractor, Melpar, Inc., would rework and reposition mockup man-meal assemblies to conform with suggestions by the Crew Provisions Office of the MSC Apollo Support Office and North American representatives.

Ibid.

December 9-16

Nine review item dispositions were submitted at the Block II critical design review concerning the earth landing system and shock attenuation system (struts). Six were on specifications, one on installation drawings, and two on capability. The two most significant were:

1. the contract for Block II parachutes had not been awarded and consequently top installation drawings were not yet available for review; and
2. specifications defining crew couch strut loading tolerances had not been released but the strut drawings had.

Ibid.

December 9-16

Preliminary results of the "fire-till-touchdown" study by Grumman indicated that this maneuver was not feasible. The engine might be exploded by driving the shock wave into the nozzles. The base heatshield temperature would exceed 1,789K (5,000 degrees F), which was high enough to melt portions of the structure, possibly causing destruction of the foot pads. The allowable pressure on the nonstructural elements of the base heatshield would be exceeded; and the descent engine flow field would tend to cause a "POGO" effect which would cause landing instability and could prevent engine cutoff.

As an outgrowth of the study, the landing probes would have to be made longer (137.1 to 187.9 cm [54 to 74 in] with automatic cutoff, 228.6 to 304.8 cm [90 to 120 in] with manual cutoff). The probe switches would be moved from the tip of the probe to the base, which was objectionable from the standpoint of a possible false reading due to probe dynamics.

MSC, "ASPO Weekly Management Report, December 16-23, 1965."

December 10

At-sea operational qualification tests, using boilerplate 29 to simulate spacecraft 009, were completed. All mechanical system components performed satisfactorily, except for the recovery flashing light. Test results were:

1. uprighting system - during the first mission cycle, the vehicle was uprighted in three minutes, during the second, in two minutes;
2. VHF antenna deployment - the antennas were in the erect position when the test started. Communication was achieved with a fly-by plane;

3. the sea dye marker canister deployed as expected when the HF was erected; and
4. the recovery flashing light was deployed before the test started; when switched on the light did not flash. Post-test analysis indicated a water-short in the wiring installed by MSC.

MSC, "ASPO Weekly Management Report, December 9-16, 1965."

December 15

Grumman was invited to provide NASA with a cost-plus-incentive-fee proposal to provide four LEMs subsequent to LEM-11, with the proposal due at MSC by the close of business on the following day. The proposal should be based on a vehicular configuration similar to LEM-11 in all respects, including supporting activities, contractual provisions, and specifications applicable to LEM-11. The required shipment dates for the four vehicles would be December 13, 1968, February 11, 1969, April 11, 1969, and June 10, 1969, respectively.

TWX, James L. Neal, MSC, to GAEC, Attn: J. C. Snedeker, December 15, 1965.

December 15

NASA Associate Administrator for Space Science and Applications Homer E. Newell informed MSC that an experiment proposed by Ames Research Center had been selected as a space science investigation for, if possible, the first manned lunar landing as a part of the Apollo Lunar Surface Experiments Package. Principal investigator of the proposed experiment, the magnetometer, was C. P. Sonett of Ames with Jerry Modisette of MSC as associate.

The Apollo Program Director was being requested by Newell to authorize the funding of flight hardware for this experiment.

Letter, Homer E. Newell, NASA Headquarters, to Director, MSC, Attn: Experiments Program Manager, "Selection of Apollo Lunar Science Magnetic Field Investigations," December 15, 1965.

December 15

CSM ultimate static testing began. A failure occurred at 140 percent of the limit load test which simulated the end of the first-stage Saturn V boost. The loads were applied at room temperature. Preliminary inspection revealed a core compression failure and upper face sheet separation of the aft bulkhead directly beneath both SM oxidizer tank supports.

A second failure was also observed where the radial beams between the oxidizer and fuel tanks joined the bulkhead and shell. The bulkhead closeouts were peeled for a distance of approximately two inches. No decisions were made regarding repairs, test schedule, etc. These tests were constraints on spacecraft 012. MSC, "ASPO Weekly Management Report, December 9-16, 1965."

December 15-16

Gemini VI-A, the fifth manned flight and first rendezvous mission in the Gemini Program, was launched from Cape Kennedy on December 15, with Astronaut Walter M. Schirra, Jr., serving as command pilot and Astronaut Thomas P. Stafford, pilot. Their primary objective was to rendezvous with the *Gemini VII* spacecraft, and secondary objectives included station-keeping with the other spacecraft, evaluating spacecraft reentry guidance capability, and performing three experiments.

A coelliptic maneuver was performed 3 hours and 47 minutes after launch; the terminal initiation was performed an hour-and-a-half later; braking maneuvers were started at 5 hours and 50 minutes into the flight and rendezvous was technically accomplished six minutes later. The two spacecraft began station-keeping maneuvers which continued for three and a half orbits while they were separated by as much as 100 m and as little as 0.3 m.

Grimwood *et al.*, *Project Gemini, A Chronology*, 1969, p, 227; *Gemini VII/Gemini VI, Long Duration/Rendezvous Missions*, MSC Fact Sheet 291-D, January 1966 [Ivan D. Ertel].

December 16

The NASA Director of Mission Operations notified the Directors of MSC, MSFC, and KSC that the communication satellite operational capability for Apollo mission support was scheduled for September 30, 1966.

Letter, E. E. Christensen, NASA, to KSC, MSFC, and MSC, Attn: Directors, "Communications Satellite Planning Status," December 16, 1965, with enclosure: "Communications Service by Communications Satellites for Support of Project Apollo," November 30, 1965.

December 16

Apollo Program Director Samuel C. Phillips said the Apollo Weight and Performance management system, jointly developed by the Apollo Program Office and the Centers had proved itself as a useful management tool. He considered that the system had matured to the point that changes in organizational responsibility were needed. He set a target date of December 31, 1965, to complete the following actions:

- The focal point for the work had been in Apollo Program Control. Since it was a systems engineering function, Phillips was transferring this responsibility to his Apollo Systems Engineering organization.
- The APO Directorate of Systems Engineering would provide a quarterly weight and performance report and a monthly summary report on an integrated program basis.
- MSC would be responsible for and provide to the Apollo Program Office the weight and performance material which had been directed to Apollo Program Control.

Phillips acknowledged that an important element of the Apollo Weight and Performance management system had been the prediction analysis (weight growth) assessment effort performed by GE Apollo Support Division, under contract to the Apollo Program Control Office. Phillips felt, however, that weight growth analyses were a Center responsibility, and there was no continuing need for GE to perform in this area since the prediction analysis methodology had been established.

Phillips told ASPO Manager Joseph F. Shea that if he wished to continue to use GE's service in this area, he would support his request with the stipulation that GE's prediction analysis operation be supervised by MSC personnel.

Letter, Phillips to Shea, December 16, 1965.

December 16-23

A working group was formed at MSC to determine the effects of lunar soil properties on LEM landing performance. Various potential sources of lunar surface information, including Surveyor spacecraft, would be investigated in an effort to evaluate LEM landing performance in a lunar soil. The effect of footpad size and shape on landing performance in soil would also be studied.

MSC, "ASPO Weekly Management Report, December 16-23, 1965."

December 16-23

The requirement to use the LEM rendezvous radar for surface or skin track and for tracking in the cooperative mode during powered LEM mission phases was deleted from the Grumman Technical Specification and the Master End Item Specification.

Ibid.

December 16-23

The following responsibilities were transferred from MIT to AC Electronics:

1. design responsibility for the Block I and Block II eyepiece compartment;
2. responsibility for all Block II and LEM system coatings which were exposed to the spacecraft or space environment; and
3. design responsibility for the LEM navigation base.

Ibid.

December 17

The MSC Systems Development Branch rejected a proposal that the Development Flight Instrumentation (DFI) on LEM-3 be deleted for the following reasons:

1. LEM-3 would be the first full-weight LEM launched on a Saturn V vehicle. This would be the only chance of obtaining necessary information about the responses of LEM during launch.
2. The AS-503 mission would offer the only opportunity of obtaining information on the characteristics of a fully loaded, mated LEM and CSM prior to attempting a lunar landing.
3. Three LEMs with DFI were considered the minimum number acceptable in the program to provide flexibility in flight planning and ability to accommodate the loss of LEMs 1 or 2 without a major impact on the program.

Memorandum, Chief, Systems Development Branch, MSC, to Bob Williams, MSC, "DFI on LEM-3," December 17, 1965.

December 19

Apollo Program Director Samuel C. Phillips informed J. L. Atwood, President of North American Aviation, Inc., that he and the team working with him in examining the Apollo Spacecraft and S-II stage programs had completed their task "in sufficient detail . . . to formulate reasonably accurate assessment of the current situation concerning these two programs." Phillips and a task force had started this study at North American November 22, 1965.

Phillips added: "I am definitely not satisfied with the progress and outlook of either program and am convinced that the right actions now can result in substantial improvement of position in both programs in the relatively near future.

"Inclosed are ten copies of the notes which we compiled on the basis of our visits. They include details not discussed in our briefing and are provided for your consideration and use.

"The conclusions expressed in our briefing and notes are critical. Even with due consideration of hopeful signs, I could not find a substantive basis for confidence in future performance. I believe that a task group drawn from NAA at large could rather quickly verify the substance of our conclusions, and might be useful to you in setting the course for improvements.

"The gravity of the situation compels me to ask that you let me know, by the end of January if possible, the actions you propose to take. . . ."

Letter, Phillips to Atwood, December 15, 1965; Hearings before the Committee on Aeronautical and Space Sciences, United States Senate, Ninetieth Congress, First Session, "To Hear Officials of North American Aviation, Inc., Prime Contractor to NASA in the Apollo Program," Apollo Accident, Part 5,

pp. 414-415, May 4, 1967.

December 20

Robert C. Duncan, Chief of MSC's Guidance and Control Division, revealed that recent discussions between himself, NASA Associate Administrator for Manned Space Flight George E. Mueller, and ASPO Manager Joseph F. Shea had resulted in a decision to continue both radar and optical tracking systems into the hardware development phase. It was also agreed that some specific analytical and hardware homework must be done. The hardware action items were being assigned to Robert A. Gardiner and the analytical action items to Donald C. Cheatham.

The primary objective was to design, develop, and produce rendezvous sensor hardware that was on time and would work, Duncan said; second, that "we must have a rendezvous strategy which takes best advantage of the capability of the rendezvous sensor (whichever type it might be)."

The greatest difficulty in reducing operating laboratory equipment into operating spacecraft hardware occurred in the process of packaging and testing for flight. This milestone had not been reached in either the radar or the optical tracker programs.

Duncan said, "We want to set up a 'rendezvous sensor olympics' at some appropriate stage . . . when we have flight-weight equipment available from both the radar contractor and the optical tracker contractor. This olympics should consist of exposing the hardware to critical environmental tests, particularly vibration and thermal-cycling, and to operate the equipment after such exposure." If one or the other equipment failed to survive the test, it would be clear which program would be continued and which would be canceled. "If both successfully pass the olympics, the system which will be chosen will be based largely upon the results of the analytical effort. . . . If both systems fail the olympics, it is clear we have lots of work to do," Duncan said.

Memorandum, Robert C. Duncan, MSC, to Engineering and Development Directorate, Attn: Assistant Chief for Engineering and Development and Assistant Chief for Project Management, "Competition of radar and optical tracker system for the LEM," December 20, 1965.

December 21

Robert C. Seamans, Jr., was sworn in as Deputy Administrator of NASA, succeeding Hugh L. Dryden who died December 2. Seamans would also retain his present position as Associate Administrator for an indefinite period of time.

NASA Administrator James E. Webb administered the oath of office. He had announced in Austin, Tex., on December 10, that President Lyndon B. Johnson had accepted his recommendation that Seamans be named to the number two NASA post.

Astronautics and Aeronautics, 1965, p. 546; TWX, NASA Headquarters, Public Information Office, to all NASA Centers and Offices, December 21, 1965.

December 30

Because earth landing system qualification drop tests on boilerplate 6A and boilerplate 19 had failed to demonstrate that Block I recovery aids would not be damaged during landing, MSC notified North American that certain existing interim configuration recovery aid mockups must be replaced by actual hardware capable of fulfilling test requirements. The hardware included: two VHF antennas; one flashing light; one RF antenna, nondeployable; sea marker, swimmer umbilical, nondeployable. In addition, existing launch escape system tower leg bolts should be replaced by redesigned Block I tower bolts, including protective covers, to demonstrate that the redesigned bolts and covers did not degrade the performance of the earth landing system. North American was to reply with a total change plan by January 5, 1966.

TWX, J. B. Alldredge, MSC, to NAA, Attn: J. C. Cozad, December 30, 1965.

December 30-January 6

As a result of joint efforts by the Resident ASPO and MSFC Resident Manufacturing Representative, a simulated forward bulkhead for the CM inner-crew compartment was fabricated by North American and sent to MSFC for use in developing a head for the magnetic hammer which would be compatible to the extremely thin skins used on the compartment. The need for the magnetic hammer arose from the "canning" and "wrinkles" found after welding on the forward bulkhead. A tryout for the magnetic hammer on the simulated bulkhead was scheduled the first week in January.

MSC, "ASPO Weekly Management Report, December 30, 1965-January 6, 1966."

December 30-January 6

A potential problem still existed with the boost environment for the LEM and the associated spacecraft-LEM-adaptor (SLA) thermal coating. Systems Engineering Division authorized North American to proceed with implementation of an SLA thermal coating to meet the currently understood SLA requirements. Grumman would review the North American study in detail for possible adverse impact on the LEM and would negotiate with MSC.

Ibid.

December 30-January 6

Grumman and MSC reached agreement to continue with Freon for prelaunch cooling of LEM-1. By changing to a different Freon the additional heat sink capability was obtained with minor changes to

flight hardware. The ground support equipment for supplying Freon had to be modified to increase the flow capability, but this was not expected to be difficult. Plans were to use the same prelaunch cooling capability for LEM-2 and LEM-3.

Ibid.

December 30-January 6

NASA Headquarters had directed that crew water intake be recorded on all Apollo flights. To meet this requirement the Government-furnished water gun would have to be modified to include a metering capability. A gun with this capability was successfully flown on the Gemini VI and Gemini VII flights and could be used without change in the CM and LEM if it could withstand the higher water pressure. Incorporation of the gun could require bracket changes in the CM and the LEM.

Ibid.

December 31

The SM reaction control system engine qualification was completed with no apparent failures.

Ibid.

During the Month

During the month 16 flights were made in the LLRV. Of these, 11 were devoted to concluding the handling qualities evaluation of the rate- command vehicle attitude control system. The other five flights were required to check out a new pilot, Lt. Col. E. E. Kluever of the Army, who would participate in the remaining research flight testing performed on the LLRV at Flight Research Center. On December 15 the craft was grounded for cockpit modifications which would make the pilot display and controllers more like those of the LEM.

Letter, Office of Director, Flight Research Center, to NASA Headquarters, "Lunar Landing Research Vehicle progress report No. 30 for the period ending December 31, 1965," sgd. Joseph Weil, January 19, 1966.

During the Month

MSC and Grumman completed negotiations to convert the LEM contract from cost-plus-fixed-fee to cost- plus-incentive fee. In addition to schedule and performance incentives, bonus points would be awarded for cost control during FY 66 and FY 67. Four LEMs were also added to the program. LEM mockup-3 would be used as the KSC verification vehicle; LEM test article-2 and LEM test article-10 (refurbished vehicles) would be used in the first two flights of the Saturn V launch vehicle.

A total of 167 contract change authorizations (CCAs) to the Grumman contract had been issued by December 31. Negotiation of the proposal for the conversion to a cost-plus-incentive-fee included all CCAs through No. 162, and CCA amendments dated before December 9. Proposals for CCAs 163167 were in process and would be submitted according to contract change procedures.

Ibid., pp. 1, 22.

During the Quarter

ASPO Manager Joseph F. Shea reported to Apollo Program Director Samuel C. Phillips on changes in spacecraft weights:

- The CM control weight was 4,989 kg (11,000 lbs) and current weight 4,954 kg (10,920 lbs), up 126.55 kg (279 lbs) from September.
- The SM control weight was 4,627 kg (10,200 lbs), and current weight was 4,591 kg (10,122 lbs), down 44.45 kg (98 lbs). The total amount of usable propellant, control weight, was 16,642 kg (36,690 lbs), and current weight was 16,468 kg (36,305 lbs), up 53.98 kg (119 lbs).
- The LEM control weight was 14,515 kg (32,000 lbs) and current weight was 14,333 kg (31,599 lbs), down 81.65 kg (180 lbs).
- The spacecraft-LEM-adaptor control weight was 1,724 kg (3,800 lbs) and the current weight was 1,624 kg (3,580 lbs), up 22.68 kg (50 lbs).
- The total spacecraft injected control weight was 43,091 kg (95,000 lbs), and current weight was 42,422 kg (93,526 lbs), up 77.11 kg (170 lbs).
- The launch escape system control weight was 3,719 kg (8,200 lbs), and current weight 3,741 kg (8,245 lbs), up 20.41 kg (45 lbs).
- The total launch control weight was 46,811 kg (103,200 lbs), and current weight was 46,163 kg (101,771 lbs), up 97.52 kg (215 lbs).

Memorandum, Joseph F. Shea, MSC, to NASA Headquarters, Attn: Maj. Gen. Samuel C. Phillips, "Weight and Performance Data Submittal (January 1966)," January 22, 1966.

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Advanced Design, Fabrication, and Testing

January 3 to January 20, 1966

1966

January 3

An OMSF memorandum spelled out operational constraints for Apollo experimenters to prevent experiment-generated operational problems. The author, E. E. Christensen, investigated the area at the request of NASA Associate Administrator for Manned Space Flight George E. Mueller and developed some general conclusions, based on experience gained in the Gemini experiments program.

Christensen said the following items should be considered:

1. The experimenter should be required to produce all hardware and paperwork on schedule or resign himself to the fact that the experiment would be deferred to a later flight.
2. Training hardware should be identical to flight hardware except for flight certification documentation.
3. The experimenter should be informed that control fuel and power resources are limited aboard the spacecraft and his requirements should specify minimum usage.
4. The experimenter should be informed that recording and telemetry facilities are definitely limited and he should provide for alternate modes of data collection.
5. The experimenter should be requested to submit, as early as possible, detailed operational requirements, including timeline data, to MSC for inclusion in the flight plan and to allow a maximum time for solution of operational problems.
6. The experimenter should indicate both minimum and optimum experiment data requirements to allow mission planners some latitude in mission design.
7. The experimenter should be informed that every effort would be made to fly assigned experiments, but that certain prime mission requirements might be generated in flight and take precedence. In this event NASA would make every effort to reassign a deleted experiment to a later mission.
8. The experimenter should be informed that flight crew prime mission time demands can be exacting and that experiments requiring conscious efforts on the part of the crew may have to be compromised so as not to interfere with primary mission objectives.

Christensen suggested that NASA Headquarters could assist by providing guidance to MSC regarding the assignment of experiment priorities on each mission and the extent of allowable degradation of

experimentation. He indicated that he felt the following experiments appeared to contain potential operational problems: S5, Synoptic Terrain Photography; M9A, Human Otolith Function; S14, Frog Otolith Function; S16, Trapped Particles Asymmetry; S17, X-ray Astronomy; and S18, Micrometeorite Collection.

Memorandum, Christensen to Director, Apollo Program, "Operational constraints for Apollo experiments/ experimenters," January 3, 1966.

January 3

MSC directed International Latex Corporation to use the following cross section of materials in fabricating the A6L thermal meteoroid garment, outside to inside: One layer of six-ounce Nomex cloth; seven layers of H.R.C. super-insulation, starting with one-fourth mil aluminized mylar and alternating with 1.5-mil unwoven dacron spacers; two layers of seven-ounce neoprene rip stop nylon (one side coated with neoprene).

TWX, Richard S. Johnston, MSC, to International Latex Corporation, January 3, 1966; TWX, Richard S. Johnston, MSC, to International Latex Corporation, January 20, 1966.

January 3

Contractor personnel began an exercise to identify problem areas associated with activity within the LEM. Subjects using pressurized suits and portable life support systems ran through various cockpit procedures in the LEM mockup. Evaluations would continue during the week of January 10, using astronauts. The purpose of the exercise was to identify and gather data on problem areas in support of the Critical Design Review scheduled to be held at Grumman in late January.

MSC, "ASPO Weekly Management Report, December 30, 1965-January 6, 1966."

January 3-7

The Preliminary Design Review for the Block II pressure garment assembly was held at International Latex Corporation.

MSC, "ASPO Weekly Management Report, January 6-13, 1966."

January 3-14

The LEM landing gear subsystem was reviewed during the LEM Critical Design Review at MSC and Grumman. The review disclosed no major design inadequacies of the landing gear. The review included: lunar landing performance, structural and mechanical design, structural and thermal analysis, overall subsystem test program including results of tests to date, and conformance of landing gear design to

LEM specifications.

MSC, "ASPO Weekly Management Report, January 20-27, 1965."

January 5

The Apollo Joint Operations Group (JOG) was disestablished by its cochairmen. JOG had been established in February 1964 to exchange up-to-date status information on operational problems and to provide a means for their solution.

Subsequent to the establishment of JOG, responsibility for the Panel Review Board was transferred to the Apollo Program Director, and the Operations Management Group and Operations Executive Group were established. Those activities satisfied the requirements of both the Apollo Program Director and Mission Operations Director and provided the operational problem status and solution capability.

Letter, from Chairmen, Apollo Joint Operations Group, to Permanent Membership, Apollo Joint Operations Group, "Disestablishment of the Apollo Joint Operations Group," sgd. Samuel C. Phillips and E. E. Christensen, January 5, 1966.

January 6-13

The 500-second limitation for the Block I service propulsion system SPS engine qualification program was increased to 600 seconds for the last three altitude qualification tests. The spacecraft 020 SPS mission duty cycle required a 310-second burn and a 205-second burn. Discussions with Systems Engineering Division indicated that the long SPS burns were needed to support a full-duration S-IVB mission and there was little likelihood the requirement could be modified. The Block II engine delivery schedules prohibited obtaining a Block II engine in time to support spacecraft 020.

MSC, "ASPO Weekly Management Report, January 6-13, 1966."

January 6-13

Apparently the only available spacecraft-LEM-adaptor SLA thermal coating material which would meet the emissivity requirements for LEM flights was 24-carat gold. North American Tulsa, Oklahoma was predicting 18-week and 10-week schedule slips, respectively, for the first two Block 11 SLAs and a \$10-12 million cost impact. A meeting would be held at Tulsa January 17 between North American, Grumman, and MSC to determine the course of the action to be taken.

Ibid.

January 7

George M. Low, Deputy Director of MSC, outlined the general purpose and plans for the Lunar Sample Receiving Laboratory during a telephone conversation with Oran W. Nicks, NASA Director of Lunar and Planetary Programs:

- The Laboratory would prepare the sample boxes which would be sent to the moon on Apollo missions for the collection of samples.
- These boxes with enclosed samples would be returned to the facility where they could be opened in the desired vacuum environment.
- The facility could provide a capability for low level radiation counting and other urgent examinations.
- Samples would be prepared in the facility for distribution to scientists around the country and abroad who would have previously been selected to conduct analyses.
- The facility would serve as a repository for the sample material, and its personnel would act as curators for the samples and scientific data generated.
- A modicum of Laboratory facilities would be available for use by guest investigators who wished to study samples for special purposes at MSC.
- The sample facility would incorporate a quarantine section to properly assay the lunar materials, and to ensure preventing contamination on earth. In addition, it was probable that astronaut quarantine accommodations would be an adjunct to the currently conceived facility.

Memorandum, Director, Lunar and Planetary Programs, to Distr., "Telephone Conversation with Mr. George Low on January 7, 1966, re Lunar Sample Receiving Laboratory," January 10, 1966.

January 8-11

The first fuel cell system test at White Sands Test Facility was conducted successfully. Primary objectives were: 1 to verify the capability of the ground support equipment and operational checkout procedure to start up, operate, and shut down a single fuel cell power plant; and 2 to evaluate fuel cell operations during cold gimbaling of the service propulsion engine.

TWX, Martin L. Raines, Manager MSC WSTF, to MSC, "Preliminary Report, First Fuel Cell System Test at WSTF," January 11, 1966.

January 10

Soviet life-support systems used in Vostok and Voskhod spacecraft appeared to use a sodium superoxide compound as a source of oxygen, A. W. Petrocelli, General Dynamics Corporation, told *Missiles and Rockets*. Petrocelli estimated the Russians had published three times more basic research papers than U. S. scientists on these materials and were continuing efforts to improve life-support systems by studying compounds such as new superoxides, peroxides, and ozonides. He also said they were searching for better carbon dioxide absorbers.

Missiles and Rockets, p. 33, January 10, 1966.

January 13

A decision made at a Program Management Review eliminated the requirement for a land impact program for the CM to support Block I flights. Post-abort CM land impact for Saturn IB launches had been eliminated from Complex 37 by changes to the sequence timers in the launch escape system abort mode. The Certification Test Specification and related Certification Test Requirements would reflect the new Block II land impact requirements.

MSC, "ASPO Weekly Management Report, January 20-27, 1965."

January 13-20

Mission requirements for AS-503 were reviewed to determine if the LEM test objectives which caused the crew to be in the LEM at high altitudes (3,704 to 12,964 km [2,000 to 7,000 nm]) could be deleted. The reason for keeping the crew out of the LEM at those altitudes was the possibility they might be exposed to a total radiation dose which might prevent them from flying a later lunar mission.

MSC, "ASPO Weekly Management Report, January 13-20, 1965."

January 13-20

The service propulsion subsystem (SPS) maximum total burn time was set at 515 sec for Mission AS-502, instead of 385 sec. The higher limit was expected to be attained due to the Block I testing burn time being extended to 600 sec. An SPS propellant loading of 16,783 kg (37,000 lbs) and the 515-sec burn limit had been included in the Apollo Mission Data Specifications, which was in the publication cycle for support of the AS-502 Reference Trajectory.

Ibid.

January 13-20

The LEM electrical power system use of the primary structure as the electrical ground return was approved after Grumman presentations were made to ASPO and Engineering and Development personnel. The descent-stage batteries would not use a descent-stage structure ground to preclude current flow through the pyrotechnic interstage nut and bolt assemblies. The ascent and descent stage batteries would be grounded to primary structure in the near vicinity of the ascent-stage batteries. In addition, several selected manually operated solenoids would ground. All other subsystems would remain grounded to the "single-point" vehicle ground. This change would be implemented by Grumman with no cost or schedule impact and would effect a weight savings of approximately 7.7 kg (17 lbs).

Ibid.

January 13-27

Hamilton Standard Division was directed by Crew Systems Division to use a 2.27-kg (5-lbs) battery for all flight hardware if the power inputs indicated that it would meet the four-hr mission. The battery on order currently weighed 2.44 kg (5.4 lbs). This resulted in an inert weight saving of 1.45 kg (3.2 lbs) and a total saving on the LEM and CSM of 5.44 kg (12 lbs).

MSC, "ASPO Weekly Management Report, January 20-27, 1965."

January 14

The Grumman contract revision, converting the contract to cost-plus-incentive-fee, was signed. The period of the contract was extended through December 1969.

"Quarterly Progress Report No. 1," LPR-10-52, p. 2.

January 20

Apollo Mission A-004 was successfully accomplished at White Sands Missile Range. This was the first flight test utilizing the Apollo Block I type spacecraft and the sixth and final test of the Apollo CSM development program at WSMR. Primary test objectives were:

1. to demonstrate satisfactory launch escape vehicle performance for an abort in the power-on, tumbling boundary region; and
2. to demonstrate the structural integrity of the launch escape vehicle airframe for an abort in the power-on, tumbling boundary region. The Little Joe II launch vehicle boosted the 4,536-kg 5-ton unmanned spacecraft to a 24-km (15-mi) altitude.

The only significant anomaly recorded was loss of RE telemetry about two seconds after abort.

TWX, White Sands Missile Range, New Mexico, to Distr., "MSC Apollo Mission A-004 (LJ II/SC 002) flight status," sgd. John Lobb for Joseph F. Shea, January 22, 1966; MSC, "ASPO Weekly Management Report, January 20-27, 1965."

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Appendix 1

Glossary of Abbreviations

AEDC - Arnold Engineering Development Center

AFRM - airframe

AP - Associated Press

ASPO - Apollo Spacecraft Program Office

Btu - British thermal units

cm - centimeter, centimeters

CM - command module

CSM - command and service modules

cu m - cubic meter, cubic meters

DOD - Department of Defense

ELS - earth landing system

F - Fahrenheit

fps - feet per second

ft - foot, feet

g - specific gravity

GAEC - Grumman Aircraft Engineering Corporation

GE - General Electric

HF - high frequency

IBM - International Business Machines Corporation

in - inch, inches

ITT - International Telephone and Telegraph Corporation

JPL - Jet Propulsion Laboratory

JSC - Johnson Space Center

K - Kelvin scale

kg - kilogram, kilograms

KSC - Kennedy Space Center

lb - pound

lbs - pounds

LEM - Lunar excursion module

LLRV - Lunar Landing Research Vehicle

LTA - LEM test article

m - meter, meters

MDF - mild detonating fuse

mi - mile, miles

MIT - Massachusetts Institute of Technology

MSC - Manned Spacecraft Center

MSFC - Marshall Space Flight Center

NAA - North American Aviation, Inc.

NASA - National Aeronautics and Space Administration

nm - nautical miles

OMSF - Office of Manned Space Flight

psia - pounds per square inch average

RCA - Radio Corporation of America

RCS - reaction control system

RF - radio frequency

SID - Space and Information Systems Division (NAA)

SM - service module

sq m - square meter, square meters

SSC - space suit communications

VHF - very high frequency

WSMR - White Sands Missile Range

WSTF - White Sands Test Facility yard, yards

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Appendix 2

Spacecraft Weights by Quarter

September 1964 - December 1965

December 1964

	Control Weight. kgs (lbs)	Current Weight.kgs (lbs)
Command Module	4,990 (11,000)	4,568 (10,070)
Service Module	4,627 (10,200)	4,581 (10,100)
SM Useful Propellant	16,894 (37,244)	16,869 (37,190)
S-IVB Adapter	1,724 (3,800)	1,678 (3,700)
Lunar Exc. Module	13,281 (29,500)	13,236 (29,181)
Total Spacecraft Injected	42,189 (93,010)	40,919 (90,211)

March 1965

	Control Weight. kgs (lbs)	Current Weight.kgs (lbs)
Command Module	4,990 (11,000)	4,695 (10,350)
Service Module	4,627 (10,200)	4,527 (9,980)
SM Useful Propellant	17,468 (38,510)	17,227 (37,980)
S-IVB Adapter	1,724 (3,800)	1,553 (3,425)
Lunar Exc. Module	13,281 (29,500)	13,768 (30,354)
Total Spacecraft Injected	42,189 (93,010)	41,771 (92,089)

June 1965

	Control Weight. kgs (lbs)	Current Weight.kgs (lbs)
Command Module	4,990 (11,000)	4,658 (10,270)
Service Module	4,627 (10,200)	4,550 (10,030)
SM Useful Propellant	17,468 (38,510)	17,309 (38,160)
S-IVB Adapter	1,724 (3,800)	1,556 (3,430)

Lunar Exc. Module	13,281 (29,500)	13,972 (30,802)
Total Spacecraft Injected	43,091 (95,000)	42,140 (92,902)

September 1965

	Control Weight. kgs (lbs)	Current Weight.kgs (lbs)
Command Module	4,990 (11,000)	4,833 (10,654)
Service Module	4,627 (10,200)	4,683 (10,324)
SM Useful Propellant	16,642 (36,690)	16,474 (36,320)
S-IVB Adapter	1,724 (3,800)	1,610 (3,550)
Lunar Exc. Module	14,515 (32,000)	14,420 (31,791)
Total Spacecraft Injected	43,091 (95,000)	42,474 (93,639)

December 1965

	Control Weight. kgs (lbs)	Current Weight.kgs (lbs)
Command Module	4,990 (11,000)	4,953 (10,920)
Service Module	4,627 (10,200)	4,591 (10,122)
SM Useful Propellant	16,642 (36,690)	16,468 (36,305)
S-IVB Adapter	1,724 (3,800)	1,624 (3,580)
Lunar Exc. Module	14,606 (32,200)	14,333 (31,599)
Total Spacecraft Injected	43,091 (95,000)	42,423 (93,526)

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APPENDIX 3

Major Spacecraft Component Manufacturers

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Appendix 4

Flight Summary

[October 1, 1964, through January 20, 1966]

The launches described in this table include only those related to the exploration of the moon: unmanned lunar probes, unmanned tests of spacecraft designed for later manned missions, and manned space flights. The table is not intended as a comprehensive summary of all American and Soviet space flights. The information used in this Appendix is taken primarily from *Astronautics and Aeronautics, 1964*, and *Astronautics and Aeronautics, 1965*, Appendixes A and B.

ETR - Eastern Test Range

WSMR - White Sands Missile Range

S - Successful

P - Partially successful

U - Unsuccessful

Mission Name	General Mission	Launch Vehicle	Performance Veh	Pay-load
====	=====	=====	===	====
=====				

1964

December 8

Apollo (BP-23)	Suborbital Apollo capsule test	Little Joe 11 (WSMR)	S	S	S
1965					
January 19					
Gemini- Titan II	Suborbital Gemini spacecraft test	Titan II (ETR)	S	S	S
February 17					
Ranger VIII	Scientific lunar probe, photographic, transmitted 7,000 photos of moon	Atlas- Agena B (ETR)	S	S	S
March 18					
Voskhod II	Continuation of study of manned spaceflight, conduct extra- vehicular activity	Unknown (Baikonur, U.S.S.R.)	S	S	S
March 21					
Ranger IX	Scientific lunar probe, photo- graphic, transmitted 5,814 photos of moon's craters to earth before impacting	Atlas- Agena B (ETR)	S	S	S
March 23					
Gemini III	Orbital manned Gemini flight, first U.S. 2-man spaceflight	Titan II	S	S	S
May 9					
Luna V	Attempt soft landing on lunar surface	Unknown (U.S.S.R.)	S	Unknown	F

May 19

Apollo (BP-22)	Suborbital Apollo capsule test	Little Joe II (WSMR)	U	S	P
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May 22

Fire II	37,000 fps reentry test	Atlas D (ETR)	S	S	S
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June 3

Gemini IV	Orbital manned Gemini flight; first U.S. extravehicular space activity	Titan II (ETR)	S	S	S
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June 8

Luna VI	Investigate the moon; develop techniques and technology for lunar investigation	Unknown (U.S.S.R.)	Unknown		
---------	---	-----------------------	---------	--	--

June 29

Apollo pad abort test (BP-23A)	Demonstrate the capability of the launch escape vehicle, equipped with a canard system and boost protective cover, to abort from the launch pad and recover	Escape rocket (WSMR)	S	S	S
--	--	----------------------------	---	---	---

August 21

Gemini V	Orbital manned Gemini flight	Titan II (ETR)	S	S	S
-------------	------------------------------	-------------------	---	---	---

October 4

Luna VII	Soft-land on the moon; take measurements of lunar en-	Unknown (U.S.S.R.)	Impacted on Moon Oct 7		
-------------	--	-----------------------	---------------------------	--	--

1965

vironment

October 25

Agena (GATV)	Agena stage target vehicle for Gemini VI flight, rendezvous and docking	Atlas-GATV (ETR)	U		U
-----------------	---	---------------------	---	--	---

December 4

Gemini VII	Orbital manned Gemini flight, endurance	Titan II (ETR)	S	S	S
---------------	---	-------------------	---	---	---

December 15

Gemini VI-A	Orbital manned Gemini flight, rendezvous	Titan II (ETR)	S	S	S
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1966

January 20

Apollo (A-004)	Final suborbital Apollo capsule test	Little Joe II (WSMR)	S	S	S
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Appendix 4

Flight Summary

October 1, 1964, through January 20, 1966

The launches described in this table include only those related to the exploration of the moon: unmanned lunar probes, unmanned tests of spacecraft designed for later manned missions, and manned space flights. The table is not intended as a comprehensive summary of all American and Soviet space flights. The information used in this Appendix is taken primarily from *Astronautics and Aeronautics, 1964*, and *Astronautics and Aeronautics, 1965*, Appendixes A and B.

ETR - Eastern Test Range

WSMR - White Sands Missile Range

S - Successful

P - Partially successful

U - Unsuccessful

Name	General Mission	Launch Vehicle (Site)	Performance Veh	Performance Payload	Performance Mission Results
December 8 1964					
Apollo (BP-23)	Suborbital Apollo capsule test	Little Joe 11 (WSMR)	S	S	S
January 19, 1965					

Gemini-Titan II	Suborbital Gemini spacecraft test	Titan II (ETR)	S	S	S
February 17					
Ranger VIII	Scientific lunar probe, photographic, transmitted 7,000 photos of moon	Atlas-Agena B (ETR)	S	S	S
March 18					
Voskhod II	Continuation of study of manned spaceflight, conduct extra vehicular activity	Unknown (Baikonur, U.S.S.R)	S	S	S
March 21					
Ranger IX	Scientific lunar probe, photographic, transmitted 5,814 photos of moon's craters to earth before impacting	Atlas-Agena B (ETR)	S	S	S
March 23					
Gemini III	Orbital manned Gemini flight, first U.S. 2-man spaceflight	Titan II	S	S	S
May 9					
Luna V	Attempt soft landing on lunar surface	Unknown (U.S.S.R.)	S	Unknown	F
May 19					
Apollo (BP-22)	Suborbital Apollo capsule test	Little Joe II (WSMR)	U	S	P

May 22					
Fire II	37,000 fps reentry test	Atlas D (ETR)	S	S	S
June 3					
Gemini IV	Orbital manned Gemini flight; first U.S. extravehicular space activity	Titan II (ETR)	S	S	S
June 8					
Luna VI	Investigate the moon; develop techniques and technology for lunar investigation	Unknown (U.S.S.R.)	Unknown		
June 29					
Apollo pad abort test (BP-23A)	Demonstrate the capability of the launch escape vehicle, equipped with a canard system and boost protective cover, to abort from the launch pad and recover	Escape rocket (WSMR)	S	S	S
August 21					
Gemini V	Orbital manned Gemini flight	Titan II (ETR)	S	S	S
October 4					
Luna VII	Soft-land on the moon; take measurements of lunar environment	Unknown (U.S.S.R.)	Impacted on Moon Oct 7, 1965		

Agena (GATV)	Agena stage target vehicle for Gemini VI flight, rendezvous and docking	Atlas-GATV (ETR)	U		U
December 4					
Gemini VII	Orbital manned Gemini flight, endurance	Titan II (ETR)	S	S	S
December 15					
Gemini VI-A	Orbital manned Gemini flight, rendezvous	Titan II (ETR)	S	S	S
January 20					
Apollo (A-004)	Final suborbital Apollo capsule test	Little Joe II (WSMR)	S	S	S

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Appendix 5

Apollo Program Flight Objectives

Apollo Mission A-002 (December 8, 1964)

First Order Objectives:

1. Demonstrate satisfactorily launch escape vehicle performance utilizing the canard subsystem and boost protective cover and to verify the abort capability in the maximum-dynamic pressure region with conditions approximating emergency detection system limits.
2. Deliver the Apollo boilerplate spacecraft to the desired conditions for demonstration of the launch escape vehicle.

Second Order Objectives:

1. Determine the performance of the launch escape vehicle in the maximum-dynamic pressure region.
2. Demonstrate satisfactorily launch escape vehicle power-on stability for abort in the maximum-dynamic pressure region with conditions approximating emergency detection subsystem limits.
3. Demonstrates satisfactory canard deployment, launch escape vehicle turnaround dynamics, and main heatshield forward flight stability prior to launch escape subsystem jettison.
4. Demonstrate satisfactory separation of the launch escape system plus boost protective cover from the command module.
5. Demonstrate satisfactory operation and performance of the emergency landing system using reefed dual drogues.
6. Determine the command pressure loads, including possible plume impingement, in the maximum dynamic pressure system.

Apollo Mission A-003 (May 19, 1965)

First Order Objectives:

1. Demonstrate satisfactory launch escape vehicle performance at an altitude approximating the upper limit for the canard subsystem.

2. Demonstrate orientation of the launch escape vehicle to a main heatshield forward attitude.
3. Deliver the Apollo boilerplate spacecraft to the desired conditions for demonstration of the launch escape vehicle.

Second Order Objectives:

1. Determine the damping of the launch escape vehicle oscillations with the canard subsystem deployed.
2. Demonstrate jettison of the launch escape system plus boost protective cover after high-altitude entry.

Pad Abort Test 2 (June 29, 1965)

First Order Objective:

1. Demonstrate the capability of the launch escape vehicle, equipped with a canard subsystem and a boost protective cover, to abort from the launch pad and recover.

Second Order Objectives:

1. Determine the performance and stability characteristics of the launch escape vehicle with boost protective cover and control weight command module.
2. Determine the turnaround dynamics of the launch escape vehicle following canard deployment.
3. Demonstrate satisfactory separation of the launch escape subsystem and boost protective cover from the command module.
4. Demonstrate proper event sequencing during abort from the launch pad and recovery.

Apollo Mission A-004 (January 20, 1966)

First Order Objectives:

1. Demonstrate satisfactory launch escape vehicle performance for an abort in the power-on tumbling boundary region.
2. Demonstrate the structural integrity of the launch escape vehicle airframe structure for an abort in the power-on tumbling boundary region.
3. Deliver the Apollo spacecraft to the desired conditions for demonstration of the launch escape vehicle.

Second Order Objectives:

1. Demonstrate the capability of the canard subsystem to satisfactorily reorient and stabilize the

launch escape vehicle heatshield forward after a power-on tumbling abort.

2. Demonstrate the structural capability of the production boost protective cover to withstand the launch environment.
3. Demonstrate the capability of the command module forward heatshield thrusters to satisfactorily separate the forward heatshield after the tower has been jettisoned by the tower jettison motor.
4. Determine the static loads on the command module during launching and abort sequence.
5. Determine the dynamic loading on the command module inner structure.
6. Determine the dynamic loads and the structural response of the service module during launch.
7. Determine the static pressures imposed on the command module by free stream conditions and launch escape motor plumes during a power-on tumbling abort.

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Appendix 6

Funding

Compiled by F. B. Hopson, Administration and Program Support Directorate.

Fiscal Year 1965

Original budget request including Fiscal Year 1964 supplemental

NASA: \$4,523,000,000

Apollo: \$2,818,500,000

Fiscal budget appropriation with Fiscal Year 1964 supplemental

NASA: \$4,270,695,000

Apollo: \$2,614,619,000

- CSM: \$577,834,000
- LEM: \$242,600,000
- Guid.& Nav.: \$81,038,000
- Integ., reliab. & checkout: \$24,763,000
- Spacecraft support: \$83,663,000
- Saturn I: \$40,265,000
- Saturn IB: \$262,690,000
- Saturn V: \$964,924,000
- Engine Development: \$166,300,000
- Apollo mission support: \$170,542,000

1966

Original budget request - No supplemental for prior Fiscal Year

NASA: \$4,575,900,000

Apollo: \$2,997,385,000

Fiscal budget appropriation - No supplemental for prior Fiscal Year

NASA: \$4,511,644,000

Apollo: \$2,967,385,000

- CSM: \$615,000,000
- LEM: \$310,800,000
- Guid.& Nav.: \$115,000,000
- Integration, reliab. & checkout: \$34,400,000
- Spacecraft support: \$95,400,000
- Saturn I: \$800,000
- Saturn IB: \$274,185,000
- Saturn V: \$1,177,320,000
- Engine Development: \$134,095,000
- Apollo mission support: \$210,385,000

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APPENDIX 7

Organization Charts

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Courtney G. Brooks has been a Research Associate with the History Department of the University of Houston July 1969. Born in Savannah Georgia (1939), he received his B.A. degree from Huntingdon College, Montgomery, Alabama (1964), and his M.A. (1966) and Ph.D. (1969) degrees in history from Tulane University, New Orleans, Louisiana.

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Foreword

This fourth and final volume of the Apollo Spacecraft Chronology covers a period of eight and a half years, from January 21, 1966, through July 13, 1974. The events that took place during that period included all flight tests of the Apollo spacecraft, as well as the last five Gemini flights, the AS-204 accident, the AS-204 Review Board activities, the Apollo Block II Redefinition Tasks, the manned Apollo flight program and its results, as well as further use of the Apollo spacecraft in the Skylab missions.

The manned flights of Apollo, scheduled to begin in early 1967, were delayed by the tragic accident that occurred on January 27, 1967, during a simulated countdown for mission AS-204. A fire inside the command module resulted in the deaths of the three prime crew astronauts, Virgil I. Grissom, Edward H. White II, and Roger B. Chaffee. On January 28, 1967, the Apollo 204 Review Board was established to investigate the accident. It was determined that action should be initiated to reduce the crew risk by eliminating unnecessary hazardous conditions that would imperil future missions. Therefore, on April 27, a NASA Task Team - Block II Redefinition, CSM - was established to provide input on detailed design, overall quality and reliability, test and checkout, baseline specification, configuration control, and schedules.

Months of scrutinizing and hard work followed. The testing of the unmanned spacecraft began with the successful all-up test launch and recovery of the Saturn V-Apollo space system on November 9, 1967. This flight, designated *Apollo 4*, marked the culmination of more than seven years of developmental activity in design, fabrication, testing and launch-site preparation by tens of thousands of workers in government, industry and universities. The unmanned *Apollo 4* placed 126,000 kilograms in earth orbit. It accomplished the first restart in space of the S-IVB stage; the first reentry into the earth's atmosphere at the speed of return from the moon, nearly 40,200 kilometers per hour; and the first test of Launch Complex 39.

As time for the first manned Apollo flight neared, a decision was reached to use a 60-percent-oxygen and 40-percent-nitrogen atmosphere in the spacecraft cabin while on the launch pad and to retain the pure oxygen environment in space. By March 14, 1968, testing of the redesigned interior of the vehicle demonstrated that hardware changes inside the cabin, minimized possible sources of ignition, and materials changes had vastly reduced the danger of fire propagation.

During the beginning of the period covered by this chronology (from March through November 1966) the last five Gemini spacecraft were flown. The objectives of the Gemini program that were applicable to Apollo included: (1) long-duration flight, (2) rendezvous and docking, (3) postdocking maneuver capability, (4) controlled reentry and landing, (5) flight- and ground-crew proficiency, and (6) extravehicular capability. The prelaunch checkout and verification concept as originated during the Gemini program was used for Apollo. The testing and servicing tasks were very similar for both

spacecraft. Although complexity of the operations substantially increased, the mission control operations for Apollo evolved from Projects Mercury and Gemini. The medical data collected during the Gemini flights verified that man could function in space for the planned duration of the lunar landing mission. Many of the concepts for crew equipment - such as food and waste management, housekeeping, and general sanitation - originated from the Gemini experience with long-duration missions. The Gemini missions also provided background experience in many systems such as communications, guidance and navigation, fuel cells, and propulsion.

While the Mercury and Gemini spacecraft were being developed and operated, the three-man Apollo program had grown in magnitude and complexity and included a command module, a service module, a lunar module, and a giant Saturn V rocket. The spacecraft and launch vehicle towered 110 meters above the launching pad, and weighed some 3 million kilograms. With the Apollo program, the missions and flight plans had become much more ambitious, the hardware had become more refined, the software had become more sophisticated, and ground support equipment also grew in proportion.

In October 1968 *Apollo 7* became the first manned flight test of the Apollo command and service modules in earth orbit and demonstrated the effectiveness of the manned space flight tracking, command and communications network. This first mission was a rousing success, with all systems meeting or exceeding requirements.

The second Apollo flight was the much-publicized *Apollo 8* mission in December 1968, during which man for the first time orbited the moon. Aside from the fact that the flight marked a major event in the history of man, it also was technically a remarkable mission. The purpose of the mission, to check out the navigation and communication systems at lunar distance, was accomplished with a complete verification of those systems.

Apollo 9 (March 1969) was an earth-orbital flight and included the first engineering test of a manned lunar module and the first rendezvous and docking of two manned space vehicles.

In May 1969 *Apollo 10* journeyed to the moon and completed a dress rehearsal for the landing mission to follow in July. This mission was designed to be exactly like the landing mission except for the final phases of the landing, which were not attempted. The lunar module separated from the command module and descended to within 15 kilometers of the lunar surface, proving that man could navigate safely and accurately in the moon's gravitational field.

With the flight of *Apollo 11*, man for the first time stepped onto the lunar surface on July 20, 1969. The mission proved that man could land on the moon, perform specific tasks on the lunar surface, and return safely to earth.

Apollo 12 (November 1969) was the second manned lunar landing. Pieces from the unmanned Surveyor III spacecraft were recovered, and the first Apollo Lunar Surface Experiments Package (ALSEP) was deployed.

Apollo 13 (April 1970) had been scheduled to be the third manned lunar landing. However, the lunar landing portion of the mission was aborted because of the explosion of an oxygen tank in the service module en route to the moon. A cislunar mission was accomplished and the lunar module was used to provide life support and propulsion for the disabled command and service module en route home. A safe return and landing was effected in the Pacific.

Apollo 14 (January-February 1971) successfully landed on the lunar surface, with the crew performing two extravehicular activities (EVAs), deploying the second Apollo Lunar Surface Experiments Package, and completing other scientific tasks with the aid of a rickshawlike mobile equipment transporter (MET). The crew remained on the lunar surface 33½ hours.

The fourth manned lunar landing, *Apollo 15* (July-August 1971), was the first mission to use the Lunar Rover, the first to deploy a subsatellite in lunar orbit, the first to perform experiments in lunar orbit by using a scientific instrument module (SIM) in the service module, and the first to conduct extravehicular activity during the journey back to earth. Lunar stay time was 66 hours and 55 minutes.

Apollo 16 (July 1972), the fifth manned lunar landing, was essentially identical to *Apollo 15* and configured for extended mission duration, remote sensing from lunar orbit, and long-distance surface traverses. The scientific instrument module was included in the service module.

The splashdown of *Apollo 17* on December 19, 1972, not only ended one of the most perfect missions, but also drew the curtain on the manned flights of Project Apollo. It was the most ambitious moon probe, the longest moon mission - about 40 hours longer than *Apollo 16*, with 75 hours on the lunar surface from touchdown to liftoff. The extensive scientific exploration utilized a new generation of experiments. The crew traversed from the LM farther than ever before, traveling 32 kilometers in the Lunar Rover.

Although *Apollo 17* was the last of the manned flights to the moon, it was not the last of the Apollo spacecraft. Apollo paved the way for missions to follow. The next program using an Apollo command module was Skylab (May 14, 1973-February 8, 1974), occurring within the time frame of this chronology, as studies of lunar samples and data returned from Project Apollo continued in laboratories throughout the world. Skylab was man's most ambitious and organized scientific probing of his planet and proved the value of manned scientific space expeditions. Skylab proved man's value in space as a manufacturer, an astronomer, and an earth observer, using the most sophisticated instruments in ways that unmanned satellites cannot match. Skylab also demonstrated man's great utility as a repairman in space.

Detailed studies of man's physiological responses to prolonged exposure to weightlessness proved his ability to adjust to the space environment and to perform useful and valuable work in space. In solar physics, Skylab enriched our solar data more than a hundredfold, with a total of some 200,000 photographs of the sun made from the Apollo Telescope Mount. As observers of earth resources from Skylab, the crews returned over 40,000 photographs and more than 60 kilometers of high-density

magnetic tape. Data were acquired for all 48 continental United States and 34 foreign countries.

Beyond the period covered by this chronology, but before its publication, the Apollo spacecraft was used again in the Apollo-Soyuz Test Project (ASTP), July 15-24, 1975. This joint space flight culminated in the first historical meeting in space between American astronauts and Soviet cosmonauts. The event marked the successful testing of a universal docking system and signaled a major advance in efforts to pave the way for joint experiments and mutual assistance in future international space explorations. There were some 44 hours of docked joint activities during ASTP, highlighted by four crew transfers and the completion of a number of joint scientific experiments and engineering investigations. All major ASTP objectives were accomplished, including testing a compatible rendezvous system in orbit, testing androgynous docking assemblies, verifying techniques for crew transfers, and gaining experience in the conduct of joint international flights.

We will continue to apply what we learned from Apollo, as well as Skylab and ASTP, as we venture into the next manned program, known as the Space Shuttle. The Shuttle will be another leap forward. It will be the first reusable space vehicle. It will consist of three components: solid rocket boosters, a jettisonable external propellant tank, and an orbiter. The Space Shuttle will be launched like a rocket, fly in orbit like a spaceship, and land like an airplane. These vehicles are being designed to last for at least a hundred missions. The reusability will reduce the cost of putting men and payloads in orbit to about 10 percent of the Apollo costs.

In this chronology, as with any collection of written communications on a given project, the negative aspects of the program, its faltering and its failures, become more apparent because these are the areas that require written communication for corrective action. However, it should be stressed that in spite of the failures, the moon was reached by traveling an unparalleled path of success for an undertaking so complex. The disastrous fire at Cape Kennedy had given the Apollo program a drastic setback. But when *Apollo 7* was launched, the first manned flight in nearly two years, it was a success. Every spacecraft since that time improved in performance with the exception of the problems experienced in *Apollo 13*. For example, consider the *Apollo 8* spacecraft and booster, which contained some 15 million parts. If those parts had been 99.9 percent reliable, there still would have been 15,000 failures. But it had only five failures, all in noncritical parts.

To summarize Project Apollo - there were 11 manned flights; 27 Americans orbited the moon; 12 walked on its surface; 6 drove lunar vehicles. Perhaps one of the most important legacies of Apollo to future programs is the demonstration that great successes can be achieved in spite of serious difficulties along the way.

No other event in the history of mankind has served to bring the peoples of the world closer together than the lunar landings of Project Apollo. This feeling of "oneness" was fully displayed during the flight of *Apollo 13* when many nations of the earth offered assistance in recovering the voyagers from their crippled spacecraft. From nearly every country came prayers and words of encouragement. The crippling of the *Apollo 13* spacecraft en route to the moon called forth maximum cooperative use of the

ability of astronauts, the ground support organization, and the contractors. The men and the equipment they designed and operated proved capable of handling this emergency.

Besides the demonstration of the power of teamwork, many areas of understanding have come out of the lunar landing program. The command and service modules on the last three lunar missions carried some 450 kilograms of cameras, sophisticated remote-sensing equipment, and additional consumables to investigate the moon thoroughly from orbit. Detailed studies of the moon were accomplished - of its size, shape, and surface, and the interrelationship of the lunar surface features and its gravitational field. On the surface of the moon, where there is no atmosphere to erode, secrets were uncovered that have long since been worn away here on earth. Understanding the geology of the moon improves the understanding of our own planet.

Twelve men, who spent a total of 296 hours exploring the lunar surface in six radically different areas, mined 382 kilograms of lunar rocks and material. Scientists have catalogued, distributed, and analyzed this lunar material. Much of the real discovery is still being unraveled in laboratories around the world.

Five lunar science stations, originally designed to last a minimum of a year, are still at work on the lunar surface, continuing to transmit to earth technical data about the moon.

The national space program became an example of a successful management approach to accomplish an almost impossible project. The task of going to the moon required a government, industry, and university team which, at its peak, organized 400,000 people, hundreds of universities, and 20,000 separate industrial companies for a common goal. This project was accomplished in full public view of the world. These management techniques are available to our country to use again on what are considered almost impossible tasks.

The Apollo photographs of the entire earth in one frame have made us realize how small and finite and limited are the resources of spaceship Earth. Apollo not only brought home to us more clearly the problems we must face in protecting this tiny planet, but it also suggested solutions. As we now turn some of our attention to such problems as mass transportation, pollution of our atmosphere and our fresh water resources, urban renewal, and utilization of new power sources, the same management approach, techniques, and teams that landed men on the moon can combine to help solve these kinds of problems. The photographs of our earth taken by astronauts on Gemini, Apollo, Skylab, and ASTP have clearly demonstrated that we can make ecological surveys from space in geography, in agriculture and forestry, geology, hydrology, and oceanography. We can update maps, study pollution, predict floods, and help locate our natural resources and good commercial fishing grounds. We have only scratched the surface in the application of space technology.

The Apollo spacecraft not only made history, but laid a great foundation of hope for a better future. The really important benefits are yet to be derived, for we have merely cracked open the door to a completely new laboratory in which to pursue knowledge.

Kenneth S. Kleinknecht

Director of Flight Operations

Johnson Space Center

October 1975

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The Key Events

1966

February 14: First scientific experiments for lunar surface investigations were selected.

February 26: Apollo Saturn 201 - an Apollo Block I spacecraft (CSM 009) on a Saturn IB launch vehicle was launched from Cape Kennedy on a suborbital test mission.

March 8: First integrated test of service propulsion system, electrical power system, and cryogenic gas storage system was successfully completed at White Sands, N. Mex., Test Facility.

March 16: Gemini VIII mission was launched with astronauts Neil A. Armstrong and David R. Scott. The crew rendezvoused with the target vehicle, and the first docking in space was confirmed 6 hours 33 minutes after liftoff.

During March: NASA Hq. told Congress run-out cost of Apollo program would be an estimated \$22.718 billion.

May 5: The Apollo Spacecraft Program Office was asked to reassess spacecraft control weights and delta V budget and prepare recommendations for first lunar landing mission weight and performance budgets.

May 19: After a fire in the environmental control system unit at AiResearch, a concerted effort was under way to identify nonmetallic materials and other potential fire problems.

June 2: Surveyor I softlanded on the moon and began transmitting the first of 10,000 clear, detailed TV pictures to earth.

July 5: AS-203 was launched on an unmanned orbital test mission. All objectives were achieved. No recovery was planned.

July 26: Robert C. Seamans, Jr., NASA Deputy Administrator, assigned specific space flight program responsibilities to the offices of each of the Associate Administrators.

August 10: Lunar Orbiter 1 was launched. By the time of completion of photo readouts from the spacecraft on September 14, it had photographed 9 primary potential Apollo landing sites and 11 areas

on the back of the moon.

August 25: AS-202 was launched on an unmanned suborbital test mission. The space vehicle comprised S-IB stage, S-IVB stage, instrument unit, CSM 011. Spacecraft recovery was in Pacific Ocean.

October 19: NASA announced that AS-204 would be the first Apollo manned flight (earth orbital). Crewmen named were Virgil I. Grissom, Edward H. White II, and Roger B. Chaffee.

November 6: Lunar Orbiter II was launched. During a 23-day operational period it photographed 13 Apollo primary potential landing sites and a number of secondary sites. Two micrometeorite hits were detected.

December 13: Lunar landing research vehicle No. 1 was received at MSC. December 22: NASA announced names of crews selected for second and third manned Apollo missions.

1967

January 19: Numerous deficiencies were noted in the AS-204 spacecraft (CSM012) during testing at Downey, Calif., and KSC.

January 20: The S-IVB stage for Saturn launch vehicle 503 exploded and was destroyed at the Douglas Co., Sacramento, Calif., Test Facility.

January 23: The Lunar Mission Planning Board held its first meeting. Principal topic was photography from Lunar Orbiter missions and application to Apollo landing site selection.

January 27: During a simulated countdown for the AS-204 mission, a flash fire swept through command module 012, taking the lives of the crew, Virgil I. Grissom, Edward H. White II, and Roger B. Chaffee.

January 28: The Apollo 204 Review Board was established by NASA Deputy Administrator Robert C. Seamans, Jr., to investigate the AS-204 accident.

February 1: Manned Spaceflight Center directed contractors and government agencies to stop all MSC-related manned testing in environments with high oxygen content until further notice.

February 7: The Apollo 204 Review Board Chairman established 21 Task Panels to support the Board in its investigation.

February 10: The Board of Inquiry into the January 20 S-IVB stage explosion identified the probable cause of the accident.

March 14: Apollo Program Director Samuel C. Phillips appointed a team to make a special audit of quality control and inspection procedures and contractors and NASA Centers.

April 5: The Apollo 204 Review Board sent its final report to NASA Administrator James E. Webb.

1967

April 6: A program of biology training for lunar mission crews was formulated.

April 10: MSC's ASPO Manager George M. Low established two task teams to investigate CSM electrical systems and flammable materials.

April 27: NASA Task Team - Block II CSM Redefinition was established in residence at North American Aviation to provide timely decisions during spacecraft redefinition following the January 27 AS-204 fire.

May 1: NASA estimated that the impact of the AS-204 accident on program costs for FY 1967 and 1968 would be \$81 million.

May 18: Crew members for the Apollo 7 (first manned Apollo flight) were named: Walter M. Schirra, Jr., Donn F. Eisele, and R. Walter Cunningham.

June 1: A meeting at MSC discussed CSM and LM changes, schedules, and related test and hardware programs.

August 1: Lunar Orbiter V was launched; five potential Apollo landing sites were photographed during mission.

August 18: The NASA Block II CSM Redefinition Task Team, established April 27, was phased out.

September 6: An Apollo System Safety program was established by NASA Hq.

October 3: An Apollo Spacecraft Incident Investigation and Reporting Panel was established at MSC.

October 24-November 3: Eberhard F. M. Rees made a preliminary survey at North American Rockwell before forming an Apollo Special Task Team to support MSC on manufacturing problems.

November 4: NASA announced an Apollo mission schedule for six flights in 1968 and five in 1969.

November 9: The Apollo 4 mission was successfully flown. The spacecraft landed in the Pacific Ocean

after an 8-hour 37-minute flight.

December 16: NASA and North American Rockwell personnel reached decisions on flammability problems related to coax cables in CMs.

December 17: A LM test failed at Grumman when a window shattered during the initial pressurization test of the LM-5 ascent stage.

December 25: The first fire-in-the hole test was successfully completed at White Sands Test Facility. The vehicle test configuration was LM-2.

1968

January 2: The Associate Administrator for Manned Space Flight summarized key decisions required to certify the Apollo system-design for manned flight.

January 17: Eberhard Rees, Director of the Apollo Special Task Team at North American Rockwell Downey, told ASPO Manager George M. Low he had found "serious quality and reliability resources deficiencies."

January 22: NASA launched Apollo 5, the first LM flight (unmanned). The AS-204 launch vehicle was used.

January 24: CSM Manager Kenneth S. Kleinknecht listed what he thought were the chief problems facing the program.

February 5: The Senior Flammability Board decided on action to prepare for a 60-percent oxygen/40 per-cent nitrogen prelaunch atmosphere in CSM 101.

February 28: Priorities for scientific objectives vs mission operations for the first lunar landing mission were established.

April 4: Apollo 6 was launched on a Saturn V booster, with an unmanned Block I CSM and a lunar test article. The spacecraft landed in the Pacific Ocean in good condition.

April 5-7: A 48-hour delayed-recovery test was successfully conducted in the Gulf of Mexico with three astronauts in CSM 007.

April 10: The Apollo Program Director said a TV camera would be carried in CM 101 (Apollo 7).

May 6: Lunar landing research vehicle No. 1 crashed at Ellington AFB, Tex., during a training flight.

Astronaut Neil A. Armstrong ejected and suffered minor injuries. The vehicle was a total loss.

May 28: The LM ascent engine problem was resolved, with North American Rockwell's Rocketdyne Division responsible for delivery. The engines would be furnished by Bell Aerosystems Co. to Rocketdyne, and the Rocketdyne injector installed in the engine.

July 3: The final drop test to qualify the CSM earth landing system was successfully conducted.

August 9: ASPO Manager George M. Low initiated a series of actions that resulted in the ultimate decision several months later to send Apollo 8 on a lunar-orbit mission.

August 30: The Director of the Apollo Special Task Team at North American Rockwell, notified the contractor that the facilities there were relinquished to the company. The team's mission was ended.

September 23: The Apollo Guidance Software Task Force submitted its final report.

October 11: Apollo 7 was successfully launched from Kennedy Space Center on a Saturn IB launch vehicle. The first manned Apollo flight was completed October 22.

1968

December 8: Lunar landing training vehicle No. 1, with MSC test pilot Joe Algranti at the controls, crashed and burned at Ellington AFB, Tex. Algranti ejected safely.

December 21: *Apollo 8* was launched from KSC on a Saturn V booster. The spacecraft made 20 orbits around the moon on Christmas Eve and Christmas Day and returned to earth, landing in the Pacific Ocean December 27.

1969

February 3: NASA announced a 12-month forecast of manned space flight missions, *Apollo 9* through *Apollo 13*.

March 3: *Apollo 9* was launched from KSC and carried the LM for the first time on a manned flight. The LM separated and docked with the CSM during the flight and the first Apollo EVA was accomplished. The mission ended March 13 with an Atlantic Ocean splashdown.

March 24: NASA announced that *Apollo 10* would be a lunar orbit mission.

May 18: *Apollo 10* was launched from KSC on a nine-day mission. The spacecraft orbited the moon and the LM descended to an altitude of 15 kilometers over the planned site for the first lunar landing. Color

TV was transmitted to earth. The CM landed safely in the Pacific May 26.

May 27: MSFC was authorized to proceed with development of a manned lunar roving vehicle.

June 17: A seven-day simulation of Lunar Receiving Laboratory activities was successfully completed.

July 16: *Apollo 11* was launched from KSC and on July 20 astronauts Neil A. Armstrong and Edwin E. Aldrin, Jr., became the first men to walk on the moon. The spacecraft returned to land in the Pacific July 24, and the space goal set by President Kennedy on May 25, 1961, was accomplished.

August 7: Conclusions were reached at MSC concerning modes for future lunar surface exploration.

November 14: *Apollo 12* was launched and landed on the moon 163 meters from the *Surveyor III* spacecraft. The two astronauts performed two EVAs on the lunar surface, retrieved samples and pans of Surveyor III, left the lunar surface after a stay of 31 hours 31 minutes, redocked with the CSM, and landed in the Pacific on November 24.

1970

January 5-8: Detailed reports on the *Apollo 11* sample analyses were presented at a Lunar Science Conference at MSC.

March 7: The President listed six specific objectives for the space program.

April 11: *Apollo 13* was launched on a lunar landing mission but 7 hours 55 minutes into the flight an explosion in an SM oxygen tank required an abort. The astronauts powered up the LM, powered down the CSM, and used the LM propellant for a free-return trajectory around the moon. They returned safely to earth, and landed in the mid-Pacific on April 17.

April 17: NASA Hq. established an *Apollo 13* Review Board to investigate the Apollo 13 accident.

1971

January 31: *Apollo 14* was launched from KSC and the LM landed on the Fra Mauro area of the moon on February 5. Two EVAs were performed, the second using a mobile equipment transporter to permit a longer traverse. The LM lifted off from the moon February 6 and the CM splashed down in the Pacific on February 9.

April 26: Quarantine for crew members who would go to the moon on future Apollo flights was discontinued.

July 26: *Apollo 15* was launched, and on July 30 the LM landed in the Hadley-Apennine region of the moon. Three EVAs were completed with a total EVA time of 18 hours 35 minutes. The LM ascent stage liftoff on August 2 was the first televised, and the lunar roving vehicle was used for the first time. *Apollo 15's* CM landed in the Pacific on August 7.

1972

April 16: *Apollo 16* was launched from KSC and landed in the moon's Descartes region April 20. Three EVAs were completed, using the lunar roving vehicle for a total distance of 26.7 kilometers. The LM lifted off April 23 and docked with the CSM to transfer astronauts and samples. The CM returned to land in the Pacific April 27.

December 7: *Apollo 17*, the final manned lunar landing mission, was launched from KSC. The astronauts in the LM landed in the Taurus-Littrow region of the moon on December 11 and explored the area on the lunar roving vehicle during three EVAs with a total of about 22 hours. They lifted off December 14 and landed in the Pacific December 19.

1973

January 22: A tribute to the Apollo program from former President Johnson, who had died earlier in the day, was read at the National Space Club's "Salute to Apollo," held in Washington, D.C.

November 2: A stained glass Space Window with a two-centimeter *Apollo 11* lunar sample in its center was commissioned for the National Cathedral, Washington, D.C.

1974

July 13: President Nixon proclaimed July 16-24 United States Space Week in recognition of the fifth anniversary of *Apollo 11*.

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Preface

Project Apollo was announced to representatives of American industry during a conference in Washington, D.C., July 28-29, 1960, as a program to land men on the moon and return them safely to earth. President John F. Kennedy proposed to Congress on May 25, 1961, that this goal be attained before the end of the decade, stimulating an accelerated program. That challenge resulted in an ultimate success when Apollo 11 landed on the lunar surface July 20, 1969; two astronauts walked on the moon; and they, along with their spacecraft, returned safely to earth and were recovered from the Pacific Ocean on July 24, 1969.

The Apollo Spacecraft: A Chronology, Volume I, was published in 1969. It covered the concepts that led to the Apollo program; design-decision - contract; and the lunar orbit rendezvous - mode and module. The last activity covered in Volume I was November 7, 1962.

Volume II of The Apollo Spacecraft: A Chronology was published in 1973 and covered the period November 8, 1962, through September 30, 1964. It, too, was broken down into three major subject areas: defining contractual relations, developing hardware distinctions, and developing software ground rules.

Volume III appeared in 1976. It covered activities beginning with October 1, 1964, and ending January 20, 1966. This was a one-part volume because almost the total emphasis during that period was on advanced design, fabrication, and testing.

This fourth and final volume of the chronology is also divided into three parts. The first, "Preparation for Flight, the Accident, and Investigation," covers the period January 21, 1966, through April 5, 1967. Part II, "Recovery, Spacecraft Redefinition, and the First Manned Flight," includes activities from April 6, 1967, through October 22, 1968. Part III, "Man Circles the Moon, the Eagle Lands, and Manned Lunar Exploration," covers October 23, 1968, through July 13, 1974.

Volume IV is more extensive than the three preceding volumes because of both the nature of events during the period covered and the length of that period.

As far as possible, primary sources were used to document the entries, with the main documentation coming from the archives of Johnson Space Center Historian James M. Grimwood. These primary sources included congressional documents, official correspondence, government and contractor status and progress reports, memorandums, working papers, and minutes of meetings. Additionally, a relatively few entries are based on NASA and contractor news releases and newspaper and magazine articles.

An effort was made at all times to cover only the most relevant events throughout the program, without concern for whether the item was about a contractor, NASA installation, or NASA Headquarters.

We have often used acronyms for the NASA installations most frequently mentioned in the text; for instance, NASA Hq., MSC for Manned Spacecraft Center (after February 17, 1973, JSC for Johnson Space Center), KSC for Kennedy Space Center, MSFC for Marshall Space Flight Center, and LaRC for Langley Research Center. A glossary of abbreviations and acronyms is given in Appendix 1.

For any errors discovered the authors accept the responsibility. For the good qualities that may be found we are indebted to the many NASA and contractor personnel members who contributed materials and gave us advice. These include Grimwood and Sally D. Gates from the JSC History Office; Frank W. Anderson, Jr., of the NASA History Office for his patience and prompt responses to many questions; Lee D. Saegesser, who kept a constant flow of documentation uncovered by him coming our way; and Hilda J. Grimwood, who typed this effort and fought the battle of converting seemingly never-ending statistics from the U .S. standard units of measure to the metric system and managed to keep a smile on her face while doing so.

I.D.E.

R.W.N.

C.G.B.

April 1975

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Part 1 (A)

Preparation for Flight, the Accident, and Investigation

January 21, 1966, through March 1966

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1966

January 21

NASA converted one of its major contracts from a cost-plus-fixed-fee to a cost-plus-incentive-fee agreement. The contract was with North American Aviation's Space and Information Systems Division, Downey, Calif., for development of the Apollo spacecraft command and service modules (CSM) and spacecraft-lunar excursion module adapter (SLA).

NASA News Release 66-15, "Apollo Spacecraft Major Contract Is Converted," Jan. 21, 1966.

January 21

NASA negotiated a contract with Massachusetts Institute of Technology (MIT) for a program of radar and radiometric measurements on the surface of the moon. The program, which would be active until March 31, 1967, would have Paul B. Sebring of MIT's Lincoln Laboratory as principal investigator. Results would be used to select areas for intensive study to support investigations related to manned landing sites.

Arthur T. Strickland of NASA's Lunar and Planetary Programs Office would be the technical monitor. Andrew Patteson of the MSC Lunar Surface Technology Branch was requested as alternate technical

monitor.

Ltr., Oran W. Nicks, NASA Hq., to Robert R. Gilruth, MSC, " Alternate Technical Monitor for MIT Contract NSR 22-009-106," Jan. 21, 1966.

January 28

The Manned Spacecraft Center (MSC) Checkout and Test Division was informed by the Flight Crew Operations Director that in reference to a request for "our desires for altitude chamber runs on Apollo spacecraft, we definitely feel three runs are mandatory on CSMs 012 and 014. For planning purposes I think we should assume this is a steady-state requirement although it should be a subject for review as we accumulate experience." Runs on backup crews had been deleted in several instances if they had already flown and the mission was essentially the same. The value of chamber runs in terms of crew confidence was great and it was assumed that no one would care to make a manned run without a previous unmanned run.

Memo, Donald K. Slayton, MSC, to Chief, Checkout and Test Div., MSC, "Altitude Chamber runs on manned spacecraft," Jan. 28, 1966.

January 28

NASA Hq. requested the Apollo Spacecraft Program Office at Manned Spacecraft Center to evaluate the impact, including the effect on ground support equipment and mission control, of a dual AS-207/208 flight as early as AS-207 was currently scheduled. ASPO was to assume that launch vehicle 207 would carry the Block II CSM, launch vehicle 208 would carry the lunar excursion module (LEM), and the two launches would be nearly simultaneous. Kennedy Space Center (KSC) and Marshall Space Flight Center (MSFC) were asked to make similar studies for their systems. Response was requested by February 7, 1966.

TWX, Samuel C. Phillips, NASA OMSF, to Joseph F. Shea, MSC, Jan. 28, 1966.

February 1

MSC's Robert R. Gilruth, Maxime A. Faget, and William E. Stoney visited Langley Research Center to discuss the Orbiter program status and plans for distributing photos obtained from Orbiter with Floyd Thompson, Charles Donlan, and other Langley personnel members connected with the Orbiter program. Important aspects of the program were presented, with particular emphasis on the camera system and the kind and quality of photography to be obtained. In the discussion of data handling it was apparent there were no conflicts of purpose or planned activity between LaRC and MSC. It was determined that strong MSC representation at Langley during the photo screening period would be advantageous to MSC and of great benefit in MSC's subsequent lunar landing site evaluation.

Memo for Record, Faget, "Discussion between MSC and Langley Research Center regarding reduction of Orbiter data," March 1, 1966.

February 1

MSC Assistant Director for Flight Crew Operations Donald K. Slayton said he did not think that current testing or proposed evaluation would do anything to resolve the basic debate between optics versus radar as a primary LEM rendezvous aid. Slayton said, "The question is not which system can be manufactured, packaged, and qualified as flight hardware at the earliest date; it is which design is most operationally suited to accomplishing the lunar mission. The 'Olympics' contribute nothing to solving this problem." He proposed that an MSC management design review of both systems at the earliest reasonable date was the only way to reach a conclusion, adding, "This requires only existing paperwork and knowledge - no hardware."

Memo, Slayton to Chief, Guidance and Control Div., MSC, "LORS-RR 'Olympics,'" Feb. 1, 1966.

February 2

MSC awarded \$70,000 contract to Rodana Research Corp. to develop emergency medical kits that would "satisfy all inflight and training requirements for the Apollo Command Module and the Lunar Excursion Module." Under terms of contract, two training units would be delivered for each flight, in addition to one mockup and six prototype models. The small kits would contain loaded injectors, tablets, capsules, ointments, inhalers, adhesives, and compressed dressings.

MSC News Release 66-8, Feb. 2, 1966.

February 2-24

In response to a January 28 TWX from NASA Hq., MSC personnel made recommendations after evaluating the impact of a dual AS-207/208 flight on ground support and mission control. On February 2, John P. Mayer, Chief, Mission Planning and Analysis Division, told the Assistant Director for Flight Operations that the sole area of concern would be in providing the necessary Real Time Computer Complex readiness in a time frame consistent with the AS-207 launch schedule. Mayer also recommended that a decision be made in the very near future to commit AS-207 and AS-208 to a dual mission and that, if possible, IBM personnel knowledgeable in the Gemini dual vehicle system be diverted to the proposed mission if major modifications were not required for the Gemini XI and Gemini XII missions.

On February 4, John D. Hodge, Chief of the Flight Control Division, listed for the Technical Assistant for Apollo some problem areas that could arise in the operational aspects of the proposed mission with AS-207 carrying a manned CSM and AS-208 carrying only a LEM. Hodge recommended that the two launches not be attempted simultaneously, saying that some time between the launches should be

determined, which would eliminate most of the problems anticipated.

Howard W. Tindall, Jr., Assistant Chief, Mission Planning and Analysis Division, in a memo documented some design criteria and philosophy on which the AS-207/208 rendezvous mission plan was being developed by the Rendezvous Analysis Branch. Tindall pointed out that, from the Gemini program experience, the plan was felt to be relatively firm. Tindall named some of the basic features recommended by the study:

1. The CSM should be launched before the LEM.
2. The first CSM orbit should be 482 km and the LEM orbit should be 203 km high, both circular. The inclination should be about 29 degrees.
3. There should be two "on-time" launch opportunities each day of about three minutes each, during which a LEM launch would provide ideal in-plane and phasing conditions.
4. It was anticipated that the basic rendezvous could be completed within four-and-a-half hours after LEM liftoff.
5. It was estimated that about 1,317 km per hr of spacecraft in-orbit propulsion would be required to carry out the rendezvous, with about seven service propulsion system maneuvers including terminal phase initiation.

MSC Memos, Mayer to Assistant Director for Flight Operations, "Dual Apollo Missions," Feb. 2, 1966; Hodge to Technical Assistant for Apollo, "Simultaneous Launch for AS-207 and AS-208," Feb. 4, 1967; Tindall to distribution, "Apollo AS-207/208 rendezvous mission planning," Feb. 24, 1966.

February 4

Alfred Cohen, head of the ground support equipment (GSE) office of the Resident Apollo Spacecraft Office (RASPO) at Grumman Aircraft Engineering Corp., objected to the unrealistic production schedule set up by Grumman Manufacturing for LEM GSE. Cohen pointed out that Grumman had been notified many times that NASA did not believe that GSE could be produced in the short time spans formulated by Grumman. Cohen added that Grumman had been informed that this disbelief was based on actual experience with North American Aviation and McDonnell Aircraft Corp. Tracking of the manufacture of such items showed that Grumman was unable to produce in accordance with schedules. Cohen cited that Grumman had planned to complete 99 GSE items in December 1965 and had completed 27; in January it had scheduled 146 items for completion and had completed 43. Cohen requested that the RASPO Manager confront Grumman management with the facts and suggest that they

1. establish realistic schedules for fabricating GSE based on past experience; and
2. step up efforts in expediting purchase of parts and adding manpower that would be required.

Memo, Cohen to Manager, RASPO, "Manufacturing of GSE, Unrealistic Planning," Feb. 4. 1966.

February 6-8

The first test of the cryogenic gas storage system was successfully conducted from 12:30p.m. February 6 through 8:50 p.m. February 8 at the White Sands Test Facility (WSTF), N. Mex. Primary objectives were to demonstrate the compatibility between the ground support equipment and cryogenic subsystem with respect to mechanical, thermodynamic, and electrical interfaces during checkout, servicing, monitoring, and ground control. All objectives were attained.

TWX, MSC WSTF to MSC, "Preliminary Report, First Cryogenic System Test at WSTF," Feb. 9, 1966.

February 7

The CSM weight program was reviewed by James L. Bullard of MSC and D. Morgan of North American Aviation at a meeting in Houston. The CM 011 projected weight was at its upper limit as designed by the earth-landing-system restraint, about 68 kilograms above the maximum weight used for mission planning. Data to revise the 011 specification to show a CM weight of 5,352 kilograms were being prepared.

CMs 012 and 014 would present definite weight problems. At the time the CM weight vs earth-landing system factors of safety relationships were investigated in the study of the possibility of shaving ablator material from the heatshield, a maximum weight of 5,296 kilograms was established for the manned spacecraft. Bullard had discussed the possibility of a higher CM weight with James M. Peacock of the Systems Engineering Division and the earth-landing-system subsystem manager but had received no definite reply. Bullard said it was imperative that a firm weight be established, above which the weight could not grow, before any weight reductions could be seriously considered. It appeared that 90 to 136 kilograms would have to be eliminated from the spacecraft, and that the reduction would have to be accomplished primarily by removing items.

Memo, Bullard to Chief, Systems Engineering Div., "CSM weight status," Feb. 7, 1966.

February 14

NASA's Associate Administrator for Space Science and Applications Homer E. Newell advised MSC that he had selected space science investigations to be carried to the moon on Apollo missions, emplaced on the lunar surface by Apollo astronauts, and left behind to collect and transmit data to the earth on lunar environmental characteristics following those missions. Newell assigned the experiments to specific missions and indicated their priority. Any changes in the assignments would require Newell's approval. The experiments, institutions responsible, and principal investigators and coinvestigators were:

- Passive Lunar Seismic Experiment, Massachusetts Institute of Technology, Frank Press; Columbia University, George Sutton.
- Lunar Tri-axis Magnetometer, Ames Research Center, C. P. Sonett; MSC, Jerry Modisette.
- Medium-Energy Solar Wind, Jet Propulsion Laboratory (JPL), C. W. Snyder; JPL, M. M.

Neugebauer.

- Suprathermal Ion Detection, Rice University, J. W. Freeman, Jr.; MSC, F. C. Michel.
- Lunar Heat Flow Management, Columbia University, M. Langseth; Yale University, S. Clark.
- Low-Energy Solar Wind, Rice University, B. J. O'Brien.
- Active Lunar Seismic Experiment, Stanford University, R. L. Kovach; U.S. Geological Survey, J. S. Watkins.

By separate actions, Newell asked the Associate Administrator for Manned Space Flight to approve the assignment of these experiments to the Apollo Program and the Director of the Apollo Program was asked to assign the experiments, part of the Apollo Lunar Surface Experiment Package, to the missions indicated. MSC was authorized to use not in excess of \$5.109 million to develop the experiments through flight qualified prototype, including provision for all necessary software for operational and support purposes, as well as data analysis.

Ltr., Newell to MSC, Attn: Manager, Experiments Program Office, "Authorization to Procure Space Science and Applications Investigations for Apollo Lunar Missions," Feb. 14, 1966.

February 15

NASA announced conversion of its contract with Grumman Aircraft Engineering Corp. for development of the LEM to a cost-plus-incentive agreement. Under the terms of the new four-year contract Grumman was to deliver 15 flight articles, 10 test articles, and 2 mission simulators. The change added 4 flight articles to the program. The contract provided incentive for outstanding performance, cost control, and timely delivery as well as potential profit reductions if performance, cost, and schedule requirements were not met.

TWX, NASA Hq. to MSC, MSFC, Western Operations Office, KSC, Attn: Public Information Officers, "NASA Converts Apollo Contract to Cost-Plus-Incentive," Feb. 15, 1966.

February 25

The LEM Configuration Control Panel approved Grumman's request for government-furnished-equipment (North American Aviation-manufactured) optical alignment sights (OAS) for installation in the LEM. A total of 21 OAS units would be required (including 2 spares). Detailed interface requirements between the OAS and LEM would be negotiated between North American and Grumman and delivery dates would be specified during negotiations.

Memo, Project Officer, LEM, MSC, to Project Officer, CSM, MSC, "PCCP SID-150-551 Optical Alignment Sights for Use in LEM," Feb. 25, 1966.

February 26

Apollo-Saturn 201 was launched from Cape Kennedy, with liftoff of an Apollo Block I spacecraft (CSM 009) on a Saturn IB launch vehicle at 11:12:01 EST. Launched from Launch Complex 34, the unmanned suborbital mission was the first flight test of the Saturn IB and an Apollo spacecraft. Total launch weight was 22,000 kilograms.

Spacecraft communications blackout lasted 1 minute 22 seconds. Reentry was initiated with a space-fixed velocity of 29,000 kilometers per hour. CM structure and heatshields performed adequately. The CM was recovered from the Atlantic about 72 kilometers uprange from the planned landing point. (Mission objectives are listed in Appendix 5.)

Missions Operations Div., MSC, "Postlaunch Report for Mission AS-201 (Apollo S/C)," May 6, 1966.

March 1

Recent discussion between Axel Mattson of LaRC and Donald K. Slayton of MSC concerning the possibility of astronauts' using the Lunar Landing Research Facility (LLRF) at Langley led to agreement that astronauts should fly the LLRF for a week before flying the MSC lunar landing training vehicle. An evaluation of the proposal at MSC resulted in a letter from Director Robert R. Gilruth to LaRC Director Floyd L. Thompson indicating the desirability of using the LLRF and also the desirability of some equipment modifications that would improve the vehicle with a minimum effort. These included such items as LEM flight instruments, hand controllers, panel modifications, and software changes. Also discussed was the training benefit that could be realized if the facility were updated to use a vehicle like the LEM so the pilots could become familiar with problems of a standup restraint system, pressure suit and helmet interface with the cockpit structure and window during landing operations, and sensing and reacting to the dynamic cues of motion while standing up.

Ltr., Gilruth to Thompson, March 1, 1966.

March 1

ASPO Manager Joseph F. Shea informed Apollo Program Director Samuel C. Phillips, in response to a January 28 TWX from Phillips, that MSC had evaluated the capability to support a dual launch of AS-207 208 provided an immediate go-ahead could be given to the contractors. Shea said the evaluation had covered mission planning, ground support equipment (GSE), flight hardware, and operations support. Modifications and additional GSE would be required to update Launch Complex 34 at Cape Kennedy to support a Block II CSM. The total cost of supporting the AS-207/208 dual launch was estimated at \$10.2 million for the GSE and additional boiler plate CSM configuration, but Shea added that these costs could be absorbed within the FY 1966 budget. Shea recommended that the dual mission be incorporated into the program.

TWX, Shea to Phillips, "Saturn IB Dual Launch," March 1, 1966.

March 7

Apollo Program Director Samuel C. Phillips, in a memo to the Director, Office of Advanced Research and Technology, NASA Hq., pointed out that in July 1965 the Apollo program encountered stress corrosion of titanium tanks from nitrogen tetroxide propellant, and that through his auspices Langley Research Center initiated a crash effort that had been a key factor in solving the problem. Phillips said that Langley's effort had been vigorous, thorough, and of the highest professional calibre. An excellent team relationship had been maintained with MSC, MSFC, KSC, vehicle contractors, and tank subcontractors and LaRC personnel had given dedicated and outstanding support. He cited that

1. within nine days from go-ahead a test facility was constructed, equipped, and in operation;
2. within one hour after the request from MSC, coupon tests were under way in support of the *Gemini VII* flight;
3. glass bead peening was demonstrated as a solution and many tanks were peened on a crash schedule for flight and test use; and
4. coupon tests in direct support of AS-201 were instrumental in providing confidence for proceeding with that flight.

Memo, Phillips to Director, Research Div., NASA OART, "Compatibility of Titanium Propellant Tanks with Nitrogen Tetroxide," March 7, 1966.

March 8

Apollo Program Director Samuel C. Phillips notified the three manned space flight Centers that they were requested to plan for a dual AS-207/208 mission, assuming that launch would occur one month later than the 207 launch now scheduled. TWX, Phillips to MSC, MSFC, and KSC, "Saturn IB Dual Launch," March 8, 1966.

March 9-10

The first integrated test of the service propulsion system, electrical power system, and cryogenic gas storage system was successfully conducted at the White Sands Test Facility.

TWX, Samuel C. Phillips to Joseph F. Shea, "Block I CSM Delivery Dates," March 14, 1966. 101," March 10, 1966.

March 14

NASA Hq. told MSC that delivery changes should be reflected in manned space flight schedules as controlled milestone changes and referred specifically to CSM 008 - April 1966; CSM 011 - April 15, 1966; and CSM 007 - March 31, 1966. Headquarters noted that the "NAA [North American Aviation Inc.] contract delivery date remains 28 February 1966" for each and that "every effort should be made to

deliver these articles as early as possible, since completion of each is constraining a launch or other major activity."

TWX, Samuel C. Phillips to Joseph F. Shea, "Block I CSM Delivery Dates," March 14, 1966.

March 16-17

The Atlas-Agena target vehicle for the *Gemini VIII* mission was successfully launched from KSC Launch Complex 14 at 10 a.m. EST March 16. The *Gemini VIII* spacecraft was launched from Launch Complex 19 at 11:41 a.m., with command pilot Neil A. Armstrong and pilot David R. Scott aboard. The spacecraft and its target vehicle rendezvoused and docked, with docking confirmed 6 hours 33 minutes after the spacecraft was launched. About 27 minutes later the spacecraft-Agena combination encountered unexpected roll and yaw motion. The crew reduced the rates sufficiently to undock from the target and began troubleshooting to determine the cause of the problem. The problem arose again and when the yaw and roll rates became too high the crew activated and used both rings of the reentry control system to reduce the spacecraft rates to zero. This action required that the mission be ended, and splashdown was scheduled for the western Pacific during the seventh revolution. The spacecraft landed at 10:23 p.m. EST March 16 and Armstrong and Scott were picked up by the U.S.S. *Mason* at 1:37 a.m. EST March 17. Although the flight was cut short by the incident, one of the primary objectives - rendezvous and docking (the first rendezvous of two spacecraft in orbital flight) - was accomplished.

Memo, NASA Associate Administrator for Manned Space Flight to Administrator, "Gemini VIII Mission, Post Launch Report No. 1," March 23, 1966 (Mission Operation Report M-913-66-09).

March 16

NASA Administrator James E. Webb and Deputy Administrator Robert C. Seamans, Jr., selected Bendix Systems Division, Bendix Corp., from among three contractors for design, manufacture, test, and operational support of four deliverable packages of the Apollo Lunar Surface Experiments Package (ALSEP), with first delivery scheduled for July 1967. The estimated cost of the cost-plus-incentive-fee contract negotiated with Bendix before the presentation by the Source Evaluation Board to Webb and Seamans was \$17.3 million.

Memo, NASA Deputy Associate Administrator to Associate Administrator for Manned Space Flight, "Selection of Contractor for Phase D (Phase II) for Apollo Lunar Surface Experiments Package," March 17, 1966.

March 16

Apollo Program Director Samuel C. Phillips informed MSC Director Robert R. Gilruth of specific NASA Hq. management assignments that had been implemented in connection with the ALSEP program. He told Gilruth he had asked Len Reiffel to serve as the primary focus of Headquarters on

ALSEP and that he would be assisted by three members of the Lunar and Planetary Program Office of the Office of Space Science and Applications: W. T. O'Bryant, E. Davin, and R. Green.

Ltr., Phillips to Gilruth, March 16, 1966.

March 16

MSC analysis of Grumman ground support equipment (GSE) showed that a serious problem in manufacturing and delivery of GSE would have a significant program impact if not corrected immediately. Information submitted to NASA indicated a completion rate of 35 percent of that planned. Grumman was requested to initiate action to identify causes of the problem and take immediate remedial action. A formal recovery plan was to be submitted to NASA, considering the following guidelines:

1. the plan would take into account the interrelations of the LEM vehicle, site activation, vehicle checkout, and GSE end-item manufacturing schedules;
2. a priority system should be established by which "critical" equipment would be identified, with all other equipment identified in either "preferred" or "not essential" categories ("critical" was defined as that mission-essential or mission-support equipment without which the successful completion of the vehicle test or launch would be impossible); and
3. manufacturing schedules should be revised to emphasize completion of all critical category equipment, including such means as two- or three-shift operation or additional subcontracting, or both.

Grumman was required to initiate the recovery plan as soon as possible but not later than 30 days from receipt of the instructions, and progress reports were to be submitted to NASA biweekly, starting two weeks from receipt of the TWX. TWX, James L. Neal, MSC, to Grumman, Attn: J. C. Snedecker, "LEM GSE," March 16, 1966.

March 17

John D. Hodge, Chief of MSC's Flight Control Division, proposed that time-critical aborts in the event of a service propulsion system failure after translunar injection (TLI; i.e., insertion on a trajectory toward the moon) be investigated. Time-critical abort was defined as an abort occurring within 12 hours after TLI and requiring reentry in less than two days after the abort.

He suggested that if an SPS failed the service module be jettisoned for a time-critical abort and both LEM propulsion systems be used for earth return, reducing the total time to return by approximately 60 hours. As an example, if the time of abort was 10 hours after translunar injection, he said, this method would require about 36 hours; if the SM were retained the return time would require about 96 hours.

He added that the LEM/CM-only configuration should be studied for any constraints that would preclude initiating this kind of time-critical abort. Some of the factors to be considered should be:

1. maximum time the LEM environmental control system could support two or three men on an earth return;
2. maximum time the CM electrical system could support minimum power-up condition;
3. time constraints on completely powering down the CM and using the LEM systems for support;
4. effects on planned landing areas from an open loop reentry mode;
5. stability of the LEM/CM configuration during the descent and ascent propulsion burns;
6. total time to return using the descent propulsion system only or both the LEM's descent propulsion system and ascent propulsion system; and
7. communications with Manned Space Flight Network required to support this abort.

Memo, Hodge to Technical Assistant for Apollo, MSC, "Time critical translunar coast aborts for SPS failure case," March 17, 1966.

March 28

Apollo Program Director Samuel C. Phillips discussed cost problems of the contract with General Motors' AC Electronics Division, in a memo to NASA Associate Administrator for Manned Space Flight George E. Mueller. One of the problems was late design releases from Massachusetts Institute of Technology to AC Electronics, resulting in an increase of \$2.7 million. Phillips also pointed out that computer problems at Raytheon Corp. had increased the program cost by \$6.7 million, added that many of these problems had their origins in the MIT design, and listed seven of the most significant technical problems. Phillips stated that MSC in conjunction with AC Electronics had taken several positive steps:

1. to establish a factory test method review board to review all procedures encompassing fabrication of the computer in the manufacturing process;
2. to schedule 100-percent audit of all hardware in fabrication; and
3. to increase the AC Electronics resident technical staff at the Raytheon plant.

Memo, Phillips to Mueller, "Cost problems on AC Electronics Contract NAS 9-497 for G&N Systems," March 28, 1966.

March 29

MSC requested use of Langley Research Center's Lunar Orbit and Landing Approach (LOLA) Simulator in connection with two technical contracts in progress with Geonautics, Inc., Washington, D.C. One was for pilotage techniques for use in the descent and ascent phases of the LEM profile, while the other specified construction of a binocular viewing device for simplified pilotage monitoring. Langley concurred with the request and suggested that MSC personnel work with Manuel J. Queijo in setting up the program, in making working arrangements between the parties concerned, and in defining the trajectories of interest.

Ltrs., Director, MSC, to Director, LaRC, March 29, 1966, "Use of Lunar Orbit and Landing Approach Simulator (LOLA)"; Director, LaRC, to Paul E. Purser, April 29, 1966, "Proposed pilotage study using interim LOLA simulator."

March 30

NASA Deputy Administrator Robert C. Seamans, Jr., said he had been reflecting on network coverage for Apollo, as a result of the *Gemini VIII* experience. He recognized that Apollo had more weight-carrying ability and stowage space than Gemini and that as a consequence live TV from the spacecraft might be a good possibility. This coverage could allow for extensive TV during travel to and from the moon as well as during lunar landing, disembarkation, and lunar exploration. The TV equipment would not be solely for news purposes but he felt "all manner of demands will be placed upon us for continuous live coverage." He requested a review at an early date as to

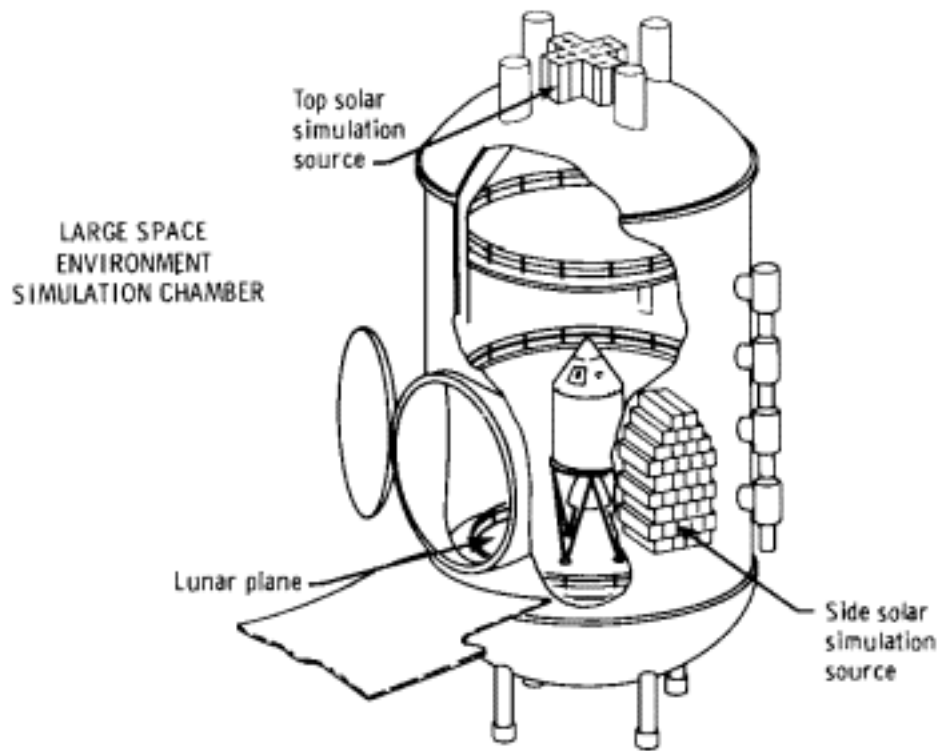
1. the technical capability of planned equipment,
2. preliminary plans for network coverage, and
3. possible modification of Apollo equipment to provide greater capability for scientific, technical, operational, and information coverage of the missions by camera and television techniques.

Memo, Seamans to George Mueller, OMSF, and Julian Scheer, NASA Hq., "Potential TV Coverage on Apollo," March 30, 1966.

March 31

A Space Science Office was established as an interim-organizational element of MSC's Engineering and Development Directorate, pending development of a permanent organization. The Office would report to the E&D Manager, Experiments, and would be responsible for providing support technology for manned space flight in environmental elements such as space radiation, micrometeoroid flux, lunar surface conditions and planetary atmospheres. It would also participate in making measurements and conducting experiments with and from manned spacecraft. Robert O. Piland was named Acting Manager of the Office.

Memo, Maxime A. Faget, MSC, to distr., "Establishment of a Space Science Office within E&D," March 31, 1966.



A cutaway view of the large space environment chamber in the Space Environment Simulation Laboratory at Manned Spacecraft Center shows how Apollo spacecraft components were tested at the extreme temperatures they would meet in space.

During the Month

NASA OMSF prepared a position paper on NASA's estimated total cost of the manned lunar landing program. Administrator James E. Webb furnished the paper for the record of the FY 1967 Senate authorization hearings and the same statement was given to the House Committee. The paper was approved by Webb and George E. Mueller and placed the run-out costs for the program at \$22.718 billion.

MSF Staff Paper, "Statement on Cost of Manned Lunar Landing Program," March 1966.

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Part 1 (B)

Preparation for Flight, the Accident, and Investigation

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April 4

MSC sent proposed organizational changes to NASA Hq. for approval by the Administrator. The two basic changes to be made were:

1. establishment of a Space Medicine Directorate and
2. establishment of a Space Science Division within the Engineering and Development (E&D) Directorate.

Both proposals, it was pointed out to Associate Administrator for Manned Space Flight George E. Mueller, had been discussed with him and other key members of the Headquarters staff. The proposed Space Medicine Directorate would combine the functions of the Chief of Center Medical Programs and the Center Medical Office, along with biomedical research functions currently performed in the Crew Systems Division of the E&D Directorate. The Offices of Chief of Center Medical Programs and Center Medical Office would be abolished by the change.

The Space Science Division had been discussed with NASA Associate Administrator for Space Science and Applications Homer E. Newell and would consolidate into a single organization several of the space science activities of MSC, including those under the Assistant Chief for Space Environment in

Advanced Spacecraft Technology Division as well as the planned Lunar Sample Receiving Laboratory. The four basic functions of the Division, reflecting the increased scientific program emphasis, would be

1. interpretation of environmental data for spacecraft design and operations criteria,
2. experiments,
3. obtaining lunar samples, and
4. astronaut training.

In addition a name change was proposed for heads of the five major operating elements of MSC, from "Assistant Director for" to "Director of"; e.g., from Assistant Director for Flight Operations to Director of Flight Operations. This change was suggested to eliminate frequent and continuing misunderstandings in dealing with persons outside the organization who assumed that the "Assistant Director for Flight Operations," etc., was the number two man in that organization, rather than the number one.

Ltr., MSC Director Robert R. Gilruth to Mueller, "Changes in MSC Basic Organization," April 4, 1966.

April 6

In response to an April 1 query from George E. Mueller, NASA OMSF, asking, "Could GE or Boeing help on GAEC [Grumman Aircraft Engineering Corp.] GSE?" Apollo Program Director Samuel C. Phillips replied that on several occasions in the recent past he had made known to both Center and industry representatives that a highly capable, quick-response ground support equipment (GSE) organization had been built by and through General Electric, which the Centers and other companies should take advantage of whenever it could help with schedules or costs. He also recalled that "in one of our last two meetings with Grumman" he had reminded them of this capability and had suggested they consider it.

Notes, Mueller to Phillips, April 1, 1966; Phillips to Mueller, April 6, 1966.

April 7

In response to the March 30 memo from NASA Deputy Administrator Robert C. Seamans, Jr., regarding potential uses of TV on Apollo, Associate Administrator for Manned Space Flight George E. Mueller replied that ". . . we have been making a progressive review of the Apollo electronic systems. Performance and application of the Apollo TV system are being looked at as part of the review." He added that he expected to be in position by mid-May to discuss plans with Seamans in some detail.

Memo, Mueller to Seamans, "Potential TV Coverage on Apollo," April 7, 1966.

April 8

Deputy Administrator Robert C. Seamans, Jr., received a letter from John S. Foster, Jr., Director of

Defense Research and Engineering, expressing pleasure that the agreement between the Department of Defense and NASA on extraterrestrial mapping, charting, and geodesy support had been consummated. He was returning a copy of the agreement for the NASA files.

Ltr., Foster to Seamans, April 8, 1966.

April 12

A Bellcomm, Inc., memo to Apollo Program Director Samuel C. Phillips presented the status of the Apollo Block I spacesuit assembly. A modified Gemini suit manufactured by the David Clark Manufacturing Co., the overall assembly consisted of a constant-wear garment and a pressure garment assembly. Crew members would also be provided with coveralls to wear in a pressurized cabin as desired. The primary functional requirement of the Block I suit was to provide environmental protection in a depressurized CSM cabin. Therefore, it did not incorporate a thermal and micrometeoroid-protection garment or the helmet visor assembly, which were required for extravehicular operation. The memo listed seven major modifications required to adapt the Gemini suit to make it acceptable for use as an Apollo Block I item.

Memo, Bellcomm, Inc., to distr., "Status of Block I Space Suit Assembly (SSA) Development - Case 330," sgd. T. A. Bottomley, Jr., April 12, 1966, with Bellcomm routing slip to Phillips from J. Z. Menard, April 13, 1966.

April 15

MSC Director Robert R. Gilruth told Associate Administrator for Manned Space Flight George E. Mueller he felt it was necessary either to proceed with the Apollo Experiment Pallet program or to cancel the program, reaching a decision not later than April 22. Gilruth pointed out that four contracts had been initiated in December 1965 for Phase C of the program, that the contracts were completed on April 6, that full-scale mockups had been delivered, and that documentation with cost proposals were due April 22. The four contractors were McDonnell Aircraft, Martin-Denver, Northrop, and Lockheed Aircraft-Sunnyvale. Gilruth said it was apparent that all contractors had done an exceptionally good job during the Phase C effort. Low cost had been emphasized in every phase of the program, with contractors responding with a very economical device and at the same time a straightforward design that offered every chance of early availability and successful operation.

Of equal significance, he said, "the Pallet offers the opportunity to minimize the interface with both North American and the Apollo program. It provides a single interface to Apollo and NAA, allowing the multiple-experiment interfaces to be handled by a contractor whose specific interest is in experiments. If experiments are to be carried in the Service Module, the Pallet both by concept and experience offers the most economical approach." Gilruth said the following plan had been developed:

1. April 22 - receive documentation and cost proposals.

2. April 22-May 22 - evaluate four proposals and negotiate four acceptable contracts in the same manner as for ALSEP.
3. May 23-24 - Source Evaluation Board Review.
4. May 25-June 1 - Center and Headquarters Review.
5. June 1 - date of cost incurrence for selected contractor.

Gilruth strongly recommended that the pallet program be implemented as planned. On April 22, Mueller gave his approval to proceed as planned. (See August 22.)

Ltrs., Gilruth to Mueller, April 15, 1966; Mueller to Gilruth, April 22, 1966.

April 18

Spacecraft 007 and 011 were delivered to NASA by North American Aviation. Spacecraft 007 was delivered to Houston to be used for water impact and flotation tests in the Gulf of Mexico and in an environmental tank at Ellington AFB. It contained all recovery systems required during actual flight and the total configuration was that of a flight CM.

The CM of spacecraft 011 was similar to those in which astronauts would ride in later flights and the SM contained support systems including environmental control and fuel cell systems and the main service propulsion system. Spacecraft 011 was scheduled to be launched during the third quarter of 1966.

TWX, NAA Space and Information Systems Div. to MSC, April 18, 1966.

April 18

ASPO Manager Joseph F. Shea and members of his organization were invited to attend the formal presentation by the Aeronutronic Division of Philco Corp. on a "Study of Lunar Worm Planetary Roving Vehicle Concept," at LaRC on May 3. The exploratory study to determine the feasibility of a bellows-concept mobile vehicle included a mobility and traction analysis for several kinds of bellows motion and several soil surfaces; analysis of both metallic and nonmetallic construction to provide the bellows structure; brief design studies of the concept as applied to a small unmanned vehicle, a supply vehicle, a small lunar shelter, a large lunar shelter; and an overall evaluation of the suitability of the concept for carrying out various missions as compared with other vehicles.

Ltr., Floyd L. Thompson, LaRC, to Shea, "Final Briefing, Contract NAS-1-5709, 'Study of Lunar Worm Planetary Roving Vehicle Concept,' by the Aeronutronic Division of the Philco Corp.," April 18, 1966.

April 21

MSC announced the establishment of a Flight Experiment Board. The Board would select and recommend to the Director space flight experiments proposed from within the Center and judged by the

Board to be in the best interest of the Center and the NASA space flight program. MSC-originated flight experiments were expected normally to be designated as one of two general classifications: Type I - Medical, Space Science, Flight Operations or Engineering that would yield new knowledge or improve the state of the art; Type II - Operational, which would be required in direct support of major manned flight programs such as Apollo.

Members appointed to the Board were George M. Low, chairman; Warren Gillespie, Jr., executive secretary; Maxime A. Faget; Robert O. Piland; Charles A. Berry; Christopher C. Kraft, Jr.; Donald K. Slayton; Kenneth S. Kleinknecht; and Joseph N. Kotanchik. The Board would meet bimonthly on the first Friday of every even month, with called meetings at the direction of the chairman when necessary to expedite experiments.

MSC Announcement 66-47, MSC Flight Experiments Selection Board, April 21, 1966.

April 22

NASA Office of Manned Space Flight policy for Design certification Reviews (DCRs) was defined for application to manned Apollo missions by a NASA directive. The concept stressed was that design evaluation by NASA management should begin with design reviews and inspections of subsystems and culminate in a DCR before selected flights. Documentation presented at DCRs were to reflect this sequence of progressive assessment of subsystems.

Ltr., Samuel C. Phillips to R. A. Petrone, KSC; J. F. Shea, MSC; and E. F. O'Connor, MSFC: "Program Directive No. 7 - Apollo Design Certification Review," April 22, 1966.

April 28

J. K. Holcomb, Director of Apollo Flight Operations, NASA OMSF, reported to Apollo Program Director Samuel C. Phillips that the NASA flight scoring system was considered satisfactory in its present form. NASA Associate Administrator for Manned Space Flight George E. Mueller had taken exception to including a statement of primary and secondary objectives in the AS-202 Mission Rules Guidelines. The scoring system, established by the Office of Program Reports, labeled each flight a success or a failure in a report to the Administrator and Deputy Administrator and was used in briefing Congress and the press. Flights were categorized only as "successful" or "unsuccessful." Criteria for judging success of a mission were based on the statement of primary objectives in the Mission Operations Report. If one primary objective was missed the flight was classified as "unsuccessful."

Memo, Holcomb to Phillips, "NASA Scoring System," April 28, 1966.

May 3

MSC Director Robert R. Gilruth wrote George E. Mueller, NASA OMSF, that plans were being

completed for MSC in-house, full-scale parachute tests at White Sands Missile Range (WSMR), N. Mex. The tests would be part of the effort to develop a gliding parachute system suitable for land landing with manned spacecraft. Tests were expected to begin in July 1966, with about six tests a year for two or three years. Gilruth pointed out that although full-scale tests were planned for WSMR it would not be possible to find suitable terrain at that site, at Edwards Air Force Base, Calif., or at El Centro, Calif., to determine operational and system requirements for land landing in unplanned areas. Unplanned-area landing tests were cited as not a major part of the program but a necessary part. He pointed out that the U.S. Army Reservation at Fort Hood, Tex., was the only area which had the required variety of landing obstacle sizes and concentrations suitable for the unplanned-area tests. Scale-model tests had been made and would be continued at Fort Hood without interference to training, and MSC had completed a local agreement that would permit occasional use of the reservation but required no fiscal reimbursement or administrative responsibility by MSC. This action was in response to a letter from Mueller July 8, 1965, directing that MSC give careful consideration to transfer of parachute test activities to WSMR.

Ltr., Gilruth to Mueller, "Parachute landing test areas for MSC land landing development tests," May 3, 1966.

May 5

NASA Hq. requested the MSC Apollo Spacecraft Program Office to reassess the spacecraft control weights and delta-V budget and prepare recommendations for the first lunar landing mission weight and performance budgets. The ASPO spacecraft Weight Report for April indicated that the Block II CSM, when loaded for an 8.3-day mission, would exceed its control weights by more than 180 kilograms and the projected value would exceed the control weight by more than 630 kilograms. At the same time the LEM was reported at 495 kilograms under its control weight. Credit for LEM weight reduction had been attributed to Grumman's Super Weight Improvement Program.

Memo, Apollo Program Director to Manager, ASPO, "Lunar Landing Mission Weights and Performance," May 5, 1966.

May 5

Engine testing at the Arnold Engineering Development Center (AEDC) had been the subject of discussions during recent months with representatives from MSC, Apollo Program Quality and Test groups, AEDC, Air Force Systems Command and ARO, Inc., participating. While AEDC had not been able to implement formal NASA requirements, the situation had improved and MSC was receiving acceptable data.

In a letter to ASPO Manager Joseph F. Shea, Apollo Program Director Samuel C. Phillips said, ". . . I do not think further pressure is in order. However, in a separate letter to Lee Gossick, I have asked that he give his personal attention to the strict adherence to test procedures, up-to-date certification of

instrumentation, and care and cleanliness in handling of test hardware."

Ltr., Phillips to Shea, May 5, 1966.

May 9

The Grumman-directed Apollo Mission Planning Task Force reported on studies of abort sequences for translunar coast situations and the LEM capability to support an abort if the SM had to be jettisoned. The LEM could be powered down in drifting flight except for five one-hour periods, and a three-man crew could be supported for 57 hours 30 minutes. It was assumed that all crewmen would be unsuited in the LEM or tunnel area and that the LEM cabin air, circulated by cabin fans, would provide adequate environment.

Grumman LEM Engineering Memo to distribution, "LEM Consumable Capability for Abort to Earth from Translunar Coast," May 9, 1966.

May 11

MSC Deputy Director George M. Low recommended to Maxime A. Faget, MSC, that, in light of Air Force and Aerospace Corp. studies on space rescue, MSC plans for a general study on space rescue be discontinued and a formal request be made to OMSF to cancel the request for proposals, which had not yet been released. As an alternative, Low suggested that MSC should cooperate with the Air Force to maximize gains from the USAF task on space rescue requirements.

Memo, Low to Faget, "Space rescue," May 11, 1966.

May 12

A memo to KSC, MSC, and MSFC from the NASA Office of Manned Space Flight reported that the NASA Project Designation Committee had concurred in changes in Saturn/Apollo nomenclature recommended by Robert C. Seamans, Jr., George E. Mueller, and Julian Scheer:

- lunar excursion module to be called lunar module.
- Saturn IB to become the "uprated Saturn I."

The memo instructed that the new nomenclature be used in all future news releases and announcements.

Memo, NASA Hq. to Center Public Affairs Officers, May 12, 1966.

May 19

George E. Mueller, NASA Associate Administrator for Manned Space Flight, forwarded views and recommendations of the Interagency Committee on Back Contamination to MSC Director Robert R. Gilruth for information and necessary action. The Committee had met at MSC to discuss the status of the Lunar Receiving Laboratory (LRL) on April 13.

The committee agreed in general philosophy and preliminary specific detail with the overall design plan, schedule, size containment provisions, and functional areas of the LRL; it approved the plan to secure Baylor Medical School or an equally qualified institution to head a development for the bioanalysis protocol; it expressed its concern with the possibility of uncontrolled outventing of CM atmosphere following splashdown; and it recommended that MSC investigate alternate means of treatment and isolation of Apollo space crews and associated physicians and technicians. MSC replied on June 8 that the analytical work in the engineering and biologic areas of the recommendations had been started and that the date for review and evaluation of the studies would be June 27.

Ltrs., Mueller to Gilruth, May 19, 1966; Gilruth to Mueller, June 8, 1966; "Interagency Committee on Back Contamination Views and Recommendations," updated.

May 19

E. E. Christensen, NASA OMSF Director of Mission Operations, in a letter to Christopher C. Kraft, Jr., MSC, said he was certain the problem of potential mission abort was receiving considerable attention within the Flight Operations Directorate. The resulting early development of related mission rules should provide other mission activities with adequate planning information for design, engineering, procedural, and training decisions. Christensen requested that development of medical mission rules be given emphasis in planning, to minimize the necessity for late modification of spacecraft telemetry systems, on-board instrumentation, ground-based data-processing schemes, and training schedules.

Ltr., Christensen to Kraft, May 19, 1966.

May 19

As a result of a fire in the environmental control system (ECS) unit at AiResearch Co., a concerted effort was under way to identify nonmetallic materials as well as other potential fire problems. MSC told North American Aviation it appeared that at least some modifications would be required in Block I spacecraft and that modifications could be considered only as temporary expedients to correct conditions that could be more readily resolved in the original design. MSC requested that North American eliminate or restrict as far as possible combustible materials in the following categories in the Block II spacecraft:

1. materials contained in sufficient quantities to contribute materially to a fire once started,
2. materials present in lengths which could propagate a flame front over 46 centimeters,
3. materials used with the electrical system, and

4. materials that could be ignited by a spark source.

Additionally, North American Aviation was requested to review, evaluate, and institute design measures to eliminate other potential fire hazards, such as hydrogen leakage from batteries, overheated lamps, and large areas of exposed fabric or foam.

TWX, C. L. Taylor, MSC, to North American Aviation, Attn: J. C. Cozad, May 19, 1966.

May 25

AS-500-F, the first full-scale Apollo Saturn V launch vehicle and spacecraft combination, was rolled out from Kennedy Space Center's Vehicle Assembly Building to the launch pad, for use in verifying launch facilities, training crews, and developing test procedures. The 111-meter, 227,000-kilogram vehicle was moved by a diesel-powered steel-link-tread crawler-transporter exactly five years after President John F. Kennedy asked the United States to commit itself to a manned lunar landing within the decade.

Marshall Space Flight Center News Release 66-114; MSFC, *Marshall Star*, June 1, 1966.

May 27

ASPO Manager Joseph F. Shea informed Rocco A. Petrone, KSC, that structural problems in the CSM fuel and oxidizer tanks required standpipe modifications and that they were mandatory for Block I and Block II spacecraft. Retrofit was to be effective on CSM 011 at KSC and other vehicles at North American's plant in Downey, Calif.

TWX, Shea to Petrone, May 27, 1966.

June 1

Apollo Program Director Samuel C. Phillips asked NASA Procurement Director George J. Vecchietti to help ensure there would be no gap in the Philco Corp. Aeronutronic Division's development of penetrometers to assess the lunar surface. Originally the penetrometers were to be deployed from a lunar survey probe, but the Apollo Program Office had concluded that they should be further developed on an urgent basis for possible deployment from the LEM just before the first lunar landing. Phillips sought to prevent development gaps that could critically delay the landing program.

Memo, Phillips to Vecchietti, "Lunar Penetrometer Development," June 1, 1966.

June 2

Surveyor I, launched May 30 from Cape Kennedy on an Atlas-Centaur, softlanded on the moon in the

Ocean of Storms and began transmitting the first of more than 10,000 clear, detailed television pictures to Jet Propulsion Laboratory's Deep Space Facility, Goldstone, Calif. The landing sequence began 3,200 kilometers above the moon with the spacecraft traveling at a speed of 9,700 kilometers per hour. The spacecraft was successfully slowed to 5.6 kilometers per hour by the time it reached 4-meter altitude and then free-fell to the surface at 13 kilometers per hour. The landing was so precise that the three footpads touched the surface within 19 milliseconds of each other, and it confirmed that the lunar surface could support the LM. It was the first U.S. attempt to softland on the moon.

Astronautics and Aeronautics, 1966 (NASA SP-4007, 1967), pp. 203-204.

June 2

MSC top management had agreed with Headquarters on early Center participation in discussions of scientific experiments for manned flights, Deputy Director George M. Low informed MSC Experiments Program Manager Robert O. Piland. NASA Associate Administrator for Space Science and Applications Homer E. Newell had asked, during a recent OSSA Senior Council meeting at MSC, that the Center and astronauts comment on technical and operational feasibility of experiments before OSSA divisions and subcommittees acted on proposals. Low and Director Robert R. Gilruth had agreed. Because of manpower requirements MSC refused a request to be represented on all the subcommittees, but MSC would send representatives to all meetings devoted primarily to manned flight experiments and would contribute to other meetings by phone.

Memo, Low to Piland, "Feasibility review of manned space science experiments," June 2, 1966.

June 2

Headquarters informed MSC that MSFC had been assigned development responsibility for the S027 X-ray Astronomy experiment for integration with the Saturn S-IVB/instrument unit. Should development be found not feasible, a modified version of the equipment was planned. MSC was requested to study:

1. the practicality of modifying the equipment to perform the scientific objectives and
2. the feasibility of integrating the modified experiment hardware in a Block II SM on an early Apollo Applications flight.

Study results were requested no later than July 1, 1966, including cost, schedule, and technical data.

Ltr., John H. Disher, NASA Hq., to George M. Low, MSC, June 2, 1966.

June 6

In response to a query on needs for or objections to an Apollo spacecraft TV system, MSC Assistant Director for Flight Crew Operations Donald K. Slayton informed the Flight Control Division that FCOD

had no operational requirements for a TV capability in either the Block I or the Block II CSM or LM. He added that his Directorate would object to interference caused by checkout, crew training, and inflight time requirements.

Memo, Slayton to Chief, Flight Control Div., MSC, "Apollo Spacecraft Television System," June 6, 1966.

June 7

A series of actions on the LM rendezvous sensor was summarized in a memo to the MSC Apollo Procurement Branch. A competition between LM rendezvous radar and the optical tracker had been initiated in January 1966 after discussion by ASPO Manager Joseph F. Shea, NASA Associate Administrator for Manned Space Flight George E. Mueller, and MSC Guidance and Control Division Chief Robert C. Duncan. On May 13, RCA and Hughes Aircraft Co. made presentations on the rendezvous radar optical tracker. The NASA board that heard the presentations met for two days to evaluate the two programs and presented the following conclusions:

1. both sensors could meet the difficult environmental requirements of the lunar mission with near specification performance,
2. the tracker had several possible specification deviations,
3. optical production training represented a difficult schedule problem at Hughes, and
4. either sensor could be produced in time to meet LM and program schedules.

The board's evaluation, an analytical presentation by Donald Cheatham, a weight-and-power comparison by R. W. Williams, and a cost presentation by the two contractors were given MSC management May 19. Management recommended that RCA's radar be continued as the main effort and that a backup optical tracker program be continued by Hughes on a greatly reduced level. The recommendations were made to Apollo Program Director Samuel C. Phillips and NASA Associate Administrator George E. Mueller at KSC on May 25. Phillips and Mueller concurred but stipulated that the optical tracker program was to be completed on a fixed-price basis and that MSC would qualify the optical tracker using the facilities of the MSC laboratories. Mueller expressed concern about developmental difficulties and possible production problems in the radar program. RCA representatives visited MSC May 27 and reviewed all developmental difficulties and their potential effect on production.

Memo, Robert C. Duncan, MSC, to Henry P. Yschek, MSC, "LEM Rendezvous Sensor Evaluation," June 7, 1966.

June 9

MSC informed the NASA Associate Administrator for Manned Space Flight that it had established a Lunar Receiving Laboratory Program Office with Joseph V. Piland as Program Manager. The office included the functions of program control, procurement, requirements, engineering, and construction.

Ltr., MSC Director Robert R. Gilruth to George E. Mueller, NASA OMSF, June 9, 1966.

June 16

The MSC Flight Experiments Selection Board reviewed and endorsed three proposals for analysis of lunar samples and forwarded them to NASA Hq. for consideration. Titles of the proposals and principal investigators were:

1. Cataloging and Preliminary Examination of Lunar Samples - E. A. King, MSC.
2. Study of Alpha Particle Activity of Returned Lunar Samples - K.A. Richardson, MSC.
3. Analysis of Lunar Sample Effluent Gases for Organic Components - G. G. Meisells, University of Houston, and D. A. Flory, MSC.

Ltrs., MSC Director to NASA Hq., Attn: Homer E. Newell, "Proposals for analysis of lunar samples," June 16, 1966.

June 16

Joseph N. Kotanchik, MSC, told H. E. McCoy of KSC that his April 4 letter discussing problems and solutions in packing parachutes at KSC by Northrop-Ventura Co. had been studied. To effect economies in the program and move forward delivery of a complete spacecraft to KSC, the upper-deck buildup would be done at North American Aviation's plant in Downey, Calif., and therefore parachutes would be packed at Northrop-Ventura beginning with spacecraft 017. Kotanchik requested KSC to support the parachute packing at Northrop-Ventura by assigning two experienced inspectors for the period required (estimated at two to four weeks for each spacecraft).

Ltr., Kotanchik to McCoy, "Apollo Spacecraft parachute packing," June 16, 1966.

June 23

A memorandum for the file, prepared by J. S. Dudek of Bellcomm, Inc., proposed a two-burn deboost technique that required establishing an initial lunar parking orbit and, after a coast phase, performing an added plane change to attain the final lunar parking orbit. The two-burn deboost technique would make a much larger lunar area accessible than that provided by the existing Apollo mission profile, which used a single burn to place the CSM and LM directly in a circular lunar parking orbit over the landing site and would permit accessibility to only a bow-tie shaped area approximately centered about the lunar equator. On August 1, the memo was forwarded to Apollo Program Director Samuel C. Phillips, stating that the trajectory modification would increase the accessible lunar area about threefold. The note to Phillips from R. L. Wagner stated that discussions had been held with MSC and it appeared that the flight programs as planned at the time could handle the modified mission.

Memo for file, Bellcomm, Inc, "A Generalized Two Burn Deboost Technique which Increases Apollo Lunar Accessibility - Case 310," June 23, 1966; note, Wagner to Phillips, "Working Note," Aug. 1, 1966.

June 30

Grumman LM thermodynamics studies showed the LM thermal shield would have to be modified because fire-in-the-hole pressures and temperatures had increased. Portions of the LM descent stage would be redesigned, but modification of the descent stage blast deflector was unlikely.

Apollo Spacecraft Program Quarterly Report No. 16, for Period Ending June 30, 1966.

June 30

Crew procedures in the LM during lunar stay were reported completed and documented for presentation to NASA Hq. personnel.

Apollo Spacecraft Program Quarterly Status Report No. 16, for Period Ending June 30, 1966.

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1966

July 1

Melvyn Savage, Apollo Test Director in NASA Hq., was named to head the Apollo Applications Program Test Directorate. LeRoy E. Day was named to replace Savage in Apollo.

Note, John H. Disher, NASA OMSF, to Monte Wright, NASA History Office, "Comments on Volume IV - The Apollo Spacecraft, Draft Copy," May 21, 1975.

Week Ending July 1

The Quarterly Program Review was held at Grumman by NASA Associate Administrator for Manned Space Flight George E. Mueller and Apollo Program Director Samuel C. Phillips. Attendees included MSC's Robert R. Gilruth, Joseph F. Shea, and William A. Lee. The meeting focused on excessive costs experienced by Grumman and Grumman President L. J. Evans's announcement of the immediate establishment of a Program Control Office with a subcontract manager reporting directly to Vice President Joseph Gavin. Hugh McCullough was appointed to head the Program Control Office.

The next week Evans made the following appointments: Robert Mullaney was relieved as Program Manager and appointed Assistant to Senior Vice President George F. Titterton; William Rathke was

relieved as Engineering Manager and named Program Manager; Thomas Kelly was promoted from Assistant Engineering Manager to Engineering Manager; and Brian Evans was relieved as corporate Director of Quality Assurance and appointed LEM Subcontract Manager, reporting to Gavin.

Memos, Frank X. Battersby to Chief, Apollo Procurement Br., Procurement and Contracts Div., MSC, "Weekly Activity Report, BMR Bethpage, Week Ending July 1, 1966," July 6, 1966; and "Weekly Activity Report, BMR Bethpage, Week Ending July 8, 1966," July 12, 1966.

July 1

Director of Flight Operations Christopher C. Kraft, Jr., said that MSC had been directed by NASA OMSF to outline technical problems and both cost and schedule impact of adding three backup Apollo missions to the planned flight schedule. The missions to be evaluated would be AS-207/208 or AS-206/207; AS-503D; and AS-503F. Each of these missions would provide alternate means of obtaining primary program objectives in the event of flight contingencies during tests or of major schedule adjustments. They had been constructed using as much of the primary mission characteristics as possible. The goal was to be able to switch from a primary to a backup mission within three or four months before a launch without any schedule slip. Kraft pointed out that it was unlikely that additional funds would be available to cover the additional work and that it was important to determine areas in the primary mission plan that would suffer from either dilution or deletion should a decision be made to make these missions a part of the test development program. Recognizing that a number of man-weeks of effort would be required for adequate evaluation, Kraft requested that any impact determined from inclusion of the flights in the test program be made available at MSC for coordination and presentation to Apollo Program Director by July 15.

Memo, Kraft to distr., "Evaluation of the technical problems, cost and schedule impact of adding Apollo backup missions to the flight test programs," July 1, 1966.

July 5

AS-203 lifted off from Launch Complex 37, Eastern Test Range, at 10:53 a.m. EDT in the second of three Apollo-Saturn missions scheduled before manned flight in the Apollo program. All objectives - to acquire flight data on the S-IVB stage and instrument unit - were achieved.

The uprated Saturn I - consisting of an S-IB stage, S-IVB stage, and an instrument unit - boosted an unmanned payload into an original orbit of 185 by 189 kilometers. The inboard engine cutoff of the first stage occurred after 2 minutes 18 seconds of flight and the outboard engine cutoff was 4 seconds later. The S-IVB engine burned 4 minutes 50 seconds. No recovery was planned and the payload was expected to enter the earth's atmosphere after about four days.

Astronautics and Aeronautics, 1966, (NASA SP-4007, 1967), p. 233; memos, Mission Director for Apollo-Saturn 203, "AS-203 Mission Director's Post Mission Report," undated; Associate Administrator

for Manned Space Flight to Administrator, "Apollo-Saturn Flight Mission AS-203, Post Launch Report No. 1" (Mission Operation Report M-932-66-02), July 15, 1966.

July 5

NASA requested assignment of three additional sanitary engineers from the Public Health Service. Pointing out that one sanitary engineer had been on detail to NASA since 1964 and that his effort had been directed primarily to the control of outbound contamination, NASA said this problem and that of back contamination had reached proportions that required a more intensified effort. NASA would reimburse the Public Health Service under contract.

Ltr., Deputy Administrator Robert C. Seamans, Jr., to William Stewart, Public Health Service, July 5, 1966.

July 6

North American Aviation informed Grumman that it was closing out its office at Grumman's Bethpage, N.Y., plant at the close of business on July 8. If study found that reestablishment of a Space and Information Division resident representative at Bethpage was in the best interest of the program, North American Aviation would comply.

TWX, North American Aviation, Space and Information Systems Div., Downey, Calif., to Grumman, Bethpage, N.Y., July 6, 1966.

July 6

Homer E. Newell, NASA Associate Administrator for Space Science and Applications, told George E. Mueller, NASA Associate Administrator for Manned Space Flight, that "the highest scientific priority for the Apollo mission is for return to earth of lunar surface material." He added that the material would have a higher scientific value for geologists if the location and attitude of each sample were carefully noted and for the biologists if collected in an aseptic manner. He suggested the following sequence:

1. Collect an assortment of easily obtainable samples of any surface material at the landing site. The grab samples would be placed in the LM for easy packaging preparatory to return to earth for analysis if the planned stay time on the lunar surface was cut short.
2. Deploy the ALSEP.
3. Perform the lunar geological equipment experiment, which was a detailed geological and biological traverse by an astronaut. During this traverse both representative and unusual rocks or formations should be photographed and sampled.

Ltr., Newell to Mueller, "Apollo Lunar Surface Scientific Operational Procedure," July 6, 1966.

July 11

In reply to a letter from Grumman, MSC concurred with the recommendation that a 135-centimeter lunar surface probe be provided on each landing-leg footpad and that the engine cutoff logic retain its basic manual mode. MSC did not concur with the Grumman recommendation to incorporate the automatic engine cutoff logic in the LM design. MSC believed that the planned descent-stage engine's manual cutoff landing mode was adequate to accomplish lunar touchdown and had decided that the probe-actuated cutoff capability should not be included in the LM design.

TWX, James L. Neal, MSC, to Grumman, Attn: R. S. Mullaney, "LM Lunar Touchdown, Logic," July 11, 1966.

July 13

MSC Director of Flight Crew Operations Donald K. Slayton and Director of Flight Operations Christopher C. Kraft, Jr., told ASPO Manager Joseph F. Shea: "A comprehensive examination of the Apollo missions leading to the lunar landing indicates that there is a considerable discontinuity between missions AS-205 and AS-207/208. Both missions AS-204 and AS-205 are essentially long duration system validation flights. AS-207/208 is the first of a series of very complicated missions. A valid operational requirement exists to include an optical equal-period rendezvous on AS-205. The rendezvous would be similar to the one initially planned for the *Gemini VII* flight using, in this case, the S-IVB as the target vehicle." The maneuver would give the crew an opportunity to examine the control dynamics, visibility, and piloting techniques required to perform the basic AS-207/208 mission.

Memo, Slayton and Kraft to Shea, "Equal-Period Rendezvous for AS-205," July 13, 1966.

July 20

MSC Director Robert R. Gilruth informed MSFC Director Wernher von Braun that for the past two years MSC had studied the use of the mapping and survey system (M&SS) in conjunction with the Apollo program. The system objective would be lunar mapping and landing site certification, and management responsibility was assigned to the MSC Experiments Program Office. System parameters had been established and a decision made to configure the M&SS hardware and supporting systems in a cylindrical container. The container - a "payload module" - would be carried in the spacecraft-LM adapter in place of the LM during the boost phase of flight. The payload module would have docking capability with the CSM like the LM's and, in the docked mode, would map and survey the moon in a programmed lunar orbit.

The M&SS experiment had already been funded by NASA OMSF and would support five possible flights beginning with AS-504. Gilruth forwarded a statement of work and requested MSFC to study it and furnish MSC a cost estimate, technical proposal, and management plan by July 29.

Ltr., Gilruth to von Braun, July 20, 1966.

July 26

NASA Deputy Administrator Robert C. Seamans, Jr., told the Associate Administrators that it was NASA's fundamental policy that projects and programs were best planned and executed when responsibilities were clearly assigned to a management group. He then assigned full responsibility for Apollo and Apollo Applications missions to the Office of Manned Space Flight. OMSF would fund approved integral experiment hardware, provide the required Apollo and Saturn systems, integrate the experiments with those systems, and plan and execute the missions. Specific responsibility for developing and testing individual experiments would be assigned on the basis of experiment complexity, integration requirements, and relation to the prime mission objectives, by the Office of Administrator after receiving recommendations from Associate Administrators.

The Office of Space Science and Applications (OSSA) would be responsible for selecting scientific experiments for manned missions and the experimenter teams for data reduction, data analysis, and dissemination. OSSA would provide to OMSF complete scientific requirements for each experiment selected for flight.

The Office of Advanced Research and Technology (OART) was assigned the overall responsibility for the technology content of the NASA space flight program and for selecting technology experiments for manned missions. OART would provide OMSF complete technology requirements for each experiment selected for flight. When appropriate, scientific and technical personnel would be located in OMSF to provide a working interface with experimenters. The office responsible for each experiment would determine the tracking and acquisition requirements for each experiment; then OMSF would integrate the requirements for all experiments and forward the total requirements to the Office of Tracking and Data Acquisition.

Seamans also spelled out Center responsibilities for manned space flight missions: MSFC, Apollo telescope mount; MSC, Apollo lunar surface experiment package (ALSEP), lunar science experiments, earth resources experiments, and life support systems; and Goddard Space Flight Center, atmospheric science, meteorology, and astronomical science experiments.

Memo, Seamans to distr., "Management Responsibilities for Future Manned Flight Activities," July 26, 1966.

July 28

NASA Hq. authorized MSC to proceed with opening bids on August 1 for Phase I construction of the Lunar Receiving Laboratory. MSC was requested to announce the name of the contractor selected for final negotiations for Phase II construction, before opening bids for Phase I construction.

TWX, NASA Hq. to MSC, "Lunar Receiving Laboratory," July 28, 1966.

July 29

In response to a request from Apollo Program Director Samuel C. Phillips, Bellcomm, Inc., prepared a memorandum on the major concerns resulting from its review of the AC Electronics report on the Apollo Computer Design Review. In a transmittal note to Phillips, I. M. Ross said, "We have discussed these items with MSC. It is possible, however, that [Robert] Duncan and [Joseph] Shea have not been made aware of these problems." The Bellcomm memorandum for file, prepared by J. J. Rocchio, reported that in late February 1966 MSC had authorized AC Electronics Division (ACED) to initiate a complete design review of the Apollo guidance computer to ensure adequate performance during the lunar landing mission. A June 8 ACED report presented findings and included Massachusetts Institute of Technology comments on the findings. In addition to recommending a number of specific design changes, the report identified a number of areas which warranted further review. MSC authorized ACED to perform necessary additional reviews to eliminate all indeterminate design analyses and to resolve any discrepancies between the ACED and MIT positions. At the time Bellcomm prepared the memo many of the problem areas had been or were in process of being satisfactorily resolved. However, several still remained:

1. MSC had not had the opportunity to review an approved version of the final test method for the Block II/LM computer and as a result there was no official acceptance test for computers at that point, although the first of the flight-worthy computers had left the factory and the second was in final test at the factory.
2. The Design Review Report classified the timing margin of the Block II computer as indeterminate, since the team was unable to make a detailed timing analysis in the allotted time.
3. Both Block I and Block II Apollo guidance computer programs had experienced serious problems with parts qualification and with obtaining semiconductor devices which could pass the flight processing specifications.
4. The lack of adequate documentation to support the Block II computer and its design was cited "as perhaps the most significant fault uncovered" by the design review team.

Bellcomm, Inc., Memo for File, "Apollo Block II/LM Guidance Computer - Case 330," sgd. J. J. Rocchio, July 29, 1966, note, Ross to Phillips, July 29, 1966.

August 1

NASA Associate Administrator for Manned Space Flight George E. Mueller informed MSC Director Robert R. Gilruth that the MSC Procurement Plan for procurement of three lunar landing training vehicles and the proposed flight test program was approved.

Ltr., Mueller to Gilruth, Aug. 1, 1966.

August 1

NASA signed a supplemental agreement with Chrysler Corp.'s Space Division at New Orleans, La., converting the updated Saturn I first-stage production contract from cost-plus-fixed-fee to cost-plus-incentive-fee. Under the agreement, valued at \$339 million, the amount of the contractor's fee would be based on ability to perform assigned tasks satisfactorily and meet prescribed costs and schedules. The contract called for Chrysler to manufacture, assemble and test 12 updated Saturn I first stages and provide system engineering, integration support, ground support equipment, and launch services.

NASA News Release 66-201, "Agreement with Chrysler Converts Saturn I Contract to Incentive-Type," Aug. 1, 1966.

August 3

The architect-engineer of the Lunar Receiving Laboratory, Smith, Hinchman & Grylls, proposed using a much darker tint in the exterior windows of the LRL than used in other buildings at MSC. J. G. Griffith, Chief of the Engineering Office, inspected samples of the glass and reported:

1. when the building is viewed from the exterior, the windows might seem slightly darker than others at MSC.
2. the ability of personnel inside to see through the glass was not restricted but brightness was considerably reduced.
3. c. heat transfer through the glass would be reduced by about 40 percent from glass used in other windows at MSC.

Memo, Program Manager, LRL, to Deputy Director, MSC, "Exterior windows of the Lunar Receiving Laboratory," Aug. 3, 1966.

August 3

MSC requested LaRC to study the visibility of the S-IVB/SLA combination from the left-hand couch in the command module with the couch in the docked position. (Two positions could be attained, one of them a docking and rendezvous position that moved the seat into a better viewing area from the left-hand window.) LM and CM mockups were already at Langley from the CM-active moving-base docking simulation conducted May-July 1965.

The request was initiated because the flight crew had to rely on an out-the-window reference of the S-IVB/SLA to verify separation of the LM/CSM combination from the S-IVB/SLA. The question arose as to whether the out-the-window reference was sufficient or whether an electromechanical device with a panel readout in the CM was required to verify separation.

Ltr., Director, MSC, to LaRC, Attn: Floyd L. Thompson, Director, "Apollo visibility study," Aug. 3,

1966.

August 3

NASA modified its contract with IBM to provide for work to be performed under a multiple-incentive arrangement covering cost, performance, schedule and equipment management. It also ordered the Real Time Computer Complex (RTCC) at MSC to be converted to IBM System computers, which would increase the operational capability for Apollo. The contract with IBM's Federal Systems Division, Gaithersburg, Md., provided the computing capability required for mission monitoring, inflight mission planning and simulation activities.

NASA News Release 66-205, "Apollo Complex to Be Converted in IBM Contract," Aug. 3, 1966.

August 5

Maxime A. Faget, MSC, informed Center Director Robert R. Gilruth there was a continuing effort on lightweight, energy-absorbing, and stowable net couches, and development had been redirected to a nonelastic fabric net couch system attached to existing Apollo attenuation struts. North American Aviation had previously been given the task of investigating the use of net couches on Apollo. Results of that investigation indicated the spacecraft attenuation-strut-vehicle attachments would be overloaded when using net couches. The North American Aviation investigators made their calculations by assuming no-man attenuation in the lateral and longitudinal force directions. Those calculations were recomputed using the design criteria and proper loadings and the results indicated no overloading when using net couches. MSC's Advanced Spacecraft Technology Division had reviewed and approved the efforts, permitting use of the net couches on Apollo and Apollo Applications missions.

Memo, Faget to Gilruth, "Net couches for Apollo or Apollo Applications Missions," Aug. 5, 1966.

August 8

MSC requested Ames Research Center to conduct a manual control simulation of the Saturn V upper stages with displays identical to those planned in the spacecraft. On August 5, Brent Creer and Gordon Hardy of Ames had met with representatives from ASPO, Guidance and Control Division, and Flight Crew Operations Directorate to discuss implementation of a modified Ames simulation which would determine feasibility of manual control from first stage burnout, using existing spacecraft displays and control interfaces. Simulations at Ames in 1965 had indicated that the Saturn V could be manually flown into orbit within dispersions of 914 meters in altitude, and 0.1 degree in flight path angle.

Ames responded on August 24 that setting up the flight simulator had been initiated and that the project was proceeding according to a schedule arranged by Warren J. North of MSC and Creer.

Memo, Chief, Flight Crew Support Div., "Saturn V. Manual Control," Aug. 8, 1966; ltrs., Robert R.

Gilruth, Director MSC, to H. Julian Allen, Director, Ames Research Center, Aug. 8, 1966; Allen to Gilruth, Aug. 24, 1966.

August 9

MSC worked out a program with LaRC for use of the Lunar Landing Research Facility (LLRF) for preflight transition for LM flight crews before free-flight training in the lunar landing training vehicle. LM hardware sent to Langley to be used as training aids included two flight director attitude indicators, an attitude controller assembly, a thrust-translation controller assembly, and an altitude-rate meter.

Memo, George C. Franklin, MSC, to W. A. Lee, MSC, "Status of Lunar Module hardware for Langley Research Center Lunar Landing Research Facility (LaRC LLRF)," Aug. 9, 1966.

August 10 - September 14

Lunar Orbiter I was launched from Cape Kennedy Launch Complex 13 at 3:26 p.m. EDT August 10 to photograph possible Apollo landing sites from lunar orbit. The Atlas-Agena D launch vehicle injected the spacecraft into its planned 90-hour trajectory to the moon. A midcourse correction maneuver was made at 8 p.m. the next day; a planned second midcourse maneuver was not necessary. A faultless deboost maneuver on August 14 achieved the desired initial elliptic orbit around the moon, and one week later the spacecraft was commanded to make a transfer maneuver to place it in a final close-in elliptic orbit of the moon.

During the spacecraft's stay in the final close-in orbit, the gravitational fields of the earth and the moon were expected to influence the orbital elements. The influence was verified by spacecraft tracking data, which showed that the perilune altitude varied with time. From an initial perilune altitude of 58 kilometers, the perilune decreased to 49 kilometers. At this time an orbit adjustment maneuver began an increase in the altitude, which was expected to reach a maximum after three months and then begin to decrease again. The spacecraft was expected to impact on the lunar surface about six months after the orbit adjustment.

During the photo-acquisition phase of the flight, August 18 to 29, *Lunar Orbiter I* photographed the 9 selected primary potential Apollo landing sites, including the one in which *Surveyor I* landed; 7 other potential Apollo landing sites; the east limb of the moon; and 11 areas on the far side of the moon. *Lunar Orbiter I* also took photos of the earth, giving man the first view of the earth from the vicinity of the moon (this particular view has been widely publicized). A total of 207 frames (sets of medium- and high-resolution pictures) were taken, 38 while the spacecraft was in initial orbit, the remainder while it was in the final close-in orbit. *Lunar Orbiter I* achieved its mission objectives, and, with the exception of the high-resolution camera, the performance of the photo subsystem and other spacecraft subsystems was outstanding. At the completion of the photo readouts, the spacecraft had responded to about 5,000 discrete commands from the earth and had made about 700 maneuvers.

Photographs obtained during the mission were assessed and screened by representatives of the Lunar Orbiter Project Office, U.S. Geological Survey, DOD mapping agencies, MSC, and Jet Propulsion Laboratory.

Memo, NASA Associate Administrator for Space Science and Applications to Administrator, "Lunar Orbiter I Post Launch Report," Oct. 20, 1966 (Mission Operation Report S-814-66-01, Oct. 19, 1966).

August 11

MSC suggested that Grumman Aircraft Engineering Corp. redesign the injector for the Bell Aerospace Co. ascent engine as a backup immediately. The Center was aware of costs, but the seriousness of the injector fabrication problem and the impact resulting from not having a backup was felt to be justification for the decision.

TWX, MSC to Grumman, Aug. 11, 1966.

August 16

The mockup of LM test model No. 3 (TM-3) was shipped by *Super Guppy* aircraft to Cape Kennedy, on the first trip of the *Super Guppy* from Grumman, Bethpage, N.Y.

Memo, Frank X. Battersby to Chief, Apollo Procurement Br., Procurement and Contracts Div., MSC, "Weekly Activity Report, BMR Bethpage, Week Ending August 19, 1966," Aug. 24, 1966.

August 22

In a letter to the President of Westinghouse Electric Corp., George M. Low, Acting Director of MSC, expressed his concern about the lunar television camera program. Low pointed out that Westinghouse had been awarded the contract by MSC in October 1964, that delivery of the cameras was to be made over a 15-month period, and that the total value of the original cost-plus-fixed-fee contract was \$2,296,249 including a fee of \$150,300. The cost reports required by the contract (at the time of Low's letter) showed that Westinghouse estimated the cost to complete at \$7,927,000 and estimated the hardware delivery date as January 31, 1967. Low pointed out that the proposal letter from Westinghouse in May 1964 stated that "the Aerospace Division considers the Lunar Television Camera to represent a goal culminating years of concentrated effort directed toward definition, design, and verification of critical elements of this most important program. Accordingly, the management assures NASA Manned Spacecraft Center that the program will be executed with nothing less than top priority application of all personnel, facilities, and management resources." Low said that despite these assurances the overrun and schedule slippages indicated a lack of adequate program management at all levels and a general lack of initiative in taking corrective actions to solve problems encountered.

Westinghouse replied to Low on September 1 that it, too, was disappointed "when technology will not

permit a research and development program such as this to be completed within its original cost and schedule objectives." The reply stated "Our people have taken every precaution - gone to the extreme, perhaps, in its impact on cost and schedule - to achieve the required mission reliability. . . ." The letter concluded by expressing pleasure in the harmony that had existed between Westinghouse and MSC personnel and by praising the performance of the Gemini rendezvous radar, holding it up as an objective for excellence of performance for the lunar television camera.

Ltrs., Low to D. C. Burnham, President, Westinghouse Electric Corp., Aug. 22, 1966; Charles H. Weaver, Group Vice President, Atomic, Defense & Space Group, Westinghouse Electric Corp., to Low, Sept. 1, 1966.

August 22

MSC Director Robert R. Gilruth requested of Jet Propulsion Laboratory Director William H. Pickering that JPL fire the Surveyor spacecraft's vernier engine after the Surveyor landed on moon, to give insight into how much erosion could be expected from an LM landing. The LM descent engine was to operate until it was about one nozzle diameter from landing on the lunar surface; after the Surveyor landed, its engine would be about the same distance from the surface. Gilruth told Pickering that LaRC was testing a reaction control engine to establish surface shear pressure forces, surface pressures, and back pressure sources, and offered JPL that data when obtained.

Ltr., Gilruth to Pickering, "Surveyor spacecraft experiments," Aug. 22, 1966.

August 22

NASA informed four firms that had completed design studies on the Apollo experiment pallet that there would be no hardware development and fabrication of the pallet. The four firms had been selected in November 1965 to make four-month studies of a pallet to carry experiments in the spacecraft SM during the Apollo manned lunar landings. The firms were Lockheed Missiles and Space Co., Sunnyvale, Calif.; The Martin Co., Denver, Colo.; McDonnell Aircraft Corp., St. Louis, Mo.; and Northrop Space Laboratories, Hawthorne, Calif. (See April 15.)

NASA News Release 66-224, "Apollo Pallet Development Phase Vetoed," Aug. 22, 1966.

August 25

The unmanned suborbital Apollo-Saturn 202 mission was successfully flown - the third Saturn IB flight test and the second CM heatshield flight test. The 202 included an uprated Saturn I (Saturn IB) launch vehicle (S-IB stage, S-IVB stage, and instrument unit) and the Apollo 011 spacecraft (spacecraft-lunar module adapter, service module, command module, and launch escape system). Liftoff was from Launch Complex 34 at Cape Kennedy at 1:15 p.m. EDT. The command module landed safely in the southwest Pacific Ocean, near Wake Island 1 hour 33 minutes after liftoff. It was recovered by the U.S.S. *Hornet*

about 370 kilometers uprange from the recovery ship.

Spacecraft 011 was essentially a Block I spacecraft with the following exceptions: couches, crew equipment, and the cabin postlanding ventilation were omitted; and three auxiliary batteries, a mission control programmer, four cameras, and flight qualification instrumentation were added.

Of six primary test objectives assigned to the mission (see Appendix 5), the objectives for the environmental control, electrical power, and communications subsystems were not completely satisfied. All other spacecraft test objectives were successfully accomplished.

"MSC-A-R-66-5, Postlaunch Report for Mission AS-202 (Apollo Spacecraft 011)," MSC, Oct. 12, 1966, pp. 1-1, 2-1, 3-1; memo, Associate Administrator for Manned Space Flight to Administrator, "Apollo Saturn Flight Mission AS-202, Post Launch Report No. 1" (Mission Operations Report M-932-66-03), Sept. 1, 1966.

Week Ending August 26

The Bethpage RASPO Business Manager and Grumman representatives met to choose a vendor to produce the orbital rate drive electronics for Apollo and LM (ORDEAL). Three proposals were received: Arma Division of American Bosch Arma Corp., \$275,000; Kearfott Products Division of General Precision, Inc., \$295,000; and Bendix Corp., \$715,000. Kearfott's proposal was evaluated as offering a more desirable weight, more certain delivery, and smaller size within the power budget and consequently was selected although it was not the low bid. Evaluators believed that Arma's approach would not be easy to implement, that its delivery schedule was unrealistic, and that its proposal lacked a definite work statement in the areas of testing, quality control, reliability, and documentation.

Memo, Frank X. Battersby to Chief, Apollo Procurement Br., Procurement and Contracts Div., MSC, "Weekly Activity Report, BMR Bethpage, Week Ending August 26, 1966," Aug. 31, 1966.

August 26

Because of the reported NASA OMSF rejection of funding responsibility for prototyping and equipping the Lunar Receiving Laboratory (LRL) and the strong NASA Office of Space Science and Applications concern over the quarantine facilities and techniques, Craig K. Peper of OSSA suggested that

1. each concerned program office make a scientific review of OMSF's proposal for facility construction to determine its adequacy to meet the scientific requirements and
2. from those reviews the Director of Manned Space Flight Experiments, OSSA, would submit to the Associate Administrator, OSSA, a consolidated recommendation on additional requirements to satisfy the scientific standards the LRL facilities must meet.

Memo, Peper, NASA Hq., to Director, Manned Flight Experiments, OSSA, "Lunar Receiving

Laboratory," Aug. 26, 1966.

August 29

MSC's Flight Crew Support Division prepared an operations plan describing division support of flight experiments. Activities planned would give operational support to both flight crew and experimenters. Crew training, procedures development, and integration, mission-time support, and postmission debriefings were discussed in detail.

Memo, Warren J. North, MSC, to Technical Assistant for Apollo, "Flight Experiments Operations Plan of the Flight Crew Support Division," Aug. 22, 1966.

August 30

Because the Apollo Mission Simulator (AMS) was one of the pacing items in the Apollo Block II flight program, a critical constraint upon operational readiness was the availability of Government-furnished equipment (GFE) to the AMS contractor, General Precision's Link Group. For that reason MSC ASPO Manager Joseph F. Shea asked A. L. Brady, Chief of the Apollo Mission Simulator Office, to establish controls to ensure that GFE items were provided to Link in time to support the program. He requested that an individual be appointed to be responsible for each item and that a weekly report on the status be submitted on each item.

Memo, Shea to Manager, Apollo Mission Simulator Program, "GFE Support to AMS Block II Modifications," Aug. 30, 1966.

August 31

MSC Director of Flight Crew Operations Donald K. Slayton informed ASPO Manager Joseph F. Shea that total management during thermal vacuum testing of spacecraft 008 was inadequate, resulting in misunderstandings between personnel and organizational groups concerned with the test. Slayton offered a number of suggestions for future, similar tests:

- Overall planning policies and practices should be reviewed and further defined before commitment of future test crews.
- Timeline testing philosophy was not realistic or practical in a one- g environment. It was mandatory that test plans be developed with maximum data gain and minimum crew and hardware risks consistent with overall program objectives. For example, long thermal responses during manned tests.
- A crew systems operations office should be established within the Space Environmental Simulation Laboratory to tie down the interface between crew, hardware, and management. Its scope of operation should include representation, training, and scheduling.
- The Environmental Medicine Office should define all crew and test medical requirements before

crew selection. To help in this area, a flight surgeon should be assigned to each vehicle's prime and backup crews, to ensure adequate knowledge of crew members and test objectives for training and the real-time mission.

- It must be recognized that test crew participation in thermal vacuum testing was completely voluntary and that each member volunteering must weigh the hazards of such testing against the benefits to the program in general and his welfare in particular.

Memo, Slayton to Shea, "Management improvement of follow-on thermal vacuum testing," Aug. 31, 1966.

September 7

In response to a query from NASA Deputy Administrator Robert C. Seamans, Jr., Associate Administrator for Space Science and Applications Homer E. Newell said that no laboratories had been selected for receiving lunar materials but proposals had been solicited and were in process of review. Newell said the lunar samples fell under the planetary and planetary biology disciplines primarily. The Planetary Biology Subcommittee of the Space Science Steering Committee had four working groups evaluating the proposals geophysics, geochemistry, geology, and Lunar Receiving Laboratory (LRL). The working groups were expected to complete their evaluations in September and, following review by the program office, recommendations would be prepared for the Space Science Steering Committee. Following appropriate review by that Committee, Newell would select the Principal Investigators for approved experiments.

Funding for the analyses could be determined only after selections had been made, but budget estimates for that purpose had been made for \$2 million in FY 1968 and \$6 million in FY 1969, exclusive of laboratory upgrading and funding of the LRL. As a part of the continuing research effort, 33 laboratories had received support during 1966 for upgrading their ability to handle and examine lunar material. Newell added that 125 proposals for handling lunar material had been received and were under review.

Memo, Newell to Seamans, "Lunar Sample Analysis Program," Sept. 7, 1966.

September 14

MSC Deputy Director George M. Low submitted information to NASA Associate Administrator for Manned Space Flight George E. Mueller on manpower requirements and operating costs for testing in MSC's large thermal vacuum chamber. Spacecraft 008 testing reflected a manpower cost (civil service and contractor) of \$7,034,000, chamber operating cost of \$321,000, and material costs of \$277,000. The spacecraft had been in the chamber 83 days, during which time a 92-hour unmanned test and a 163-hour manned test had been conducted.

Ltr., Low to Mueller, Sept. 14, 1966.

September 20

Surveyor II was launched from Cape Kennedy at 8:32 a.m. EDT. The Atlas-Centaur launch vehicle placed the spacecraft on a nearly perfect lunar intercept trajectory that would have missed the aim point by about 130 kilometers. Following injection, the spacecraft successfully accomplished all required sequences up to the midcourse thrust phase. This phase was not successful because of the failure of one of the three vernier engines to ignite, causing eventual loss of the mission. Contact with the spacecraft was lost at 5:35 a.m. EDT, September 22, and impact on the lunar surface was predicted at 11:18 p.m. on that day.

Memo, Associate Administrator for Space Science and Applications to Administrator. "Surveyor II Lunar Flight Project, Post Launch Report No. 1," Oct. 7, 1966 (Mission Operation Report S-803-66-02).

September 21

NASA awarded a \$4.2-million contract to Honeywell, Inc., Computer Control Division, Framingham, Mass., to provide digital computer systems for Apollo command and lunar module simulators. Under the fixed-price contract, Honeywell would provide six separate computer complexes to support the Apollo simulators at MSC and Cape Kennedy. The complexes would be delivered, installed, and checked out by Honeywell by the end of March 1967.

NASA News Release 66-254, Sept. 21, 1966.

September 23

A Planning Coordination Steering Group at NASA Hq. received program options from working groups established to coordinate long-range planning in life sciences, earth-oriented applications, astronomy, lunar exploration, and planetary exploration. The Steering Group recommended serious consideration be given a four-phase exploration program using unmanned Lunar Orbiters, Surveyors, and manned lunar surface exploration. The first phase, consisting of Ranger, Surveyor, Orbiter, and the initial Apollo landing was under way. The second phase would match the Apollo Applications program and would extend surface sampling and geologic mapping beyond the walking capability of a suited astronaut. The group recommended this phase launch one 14-day two-man mission per year beginning in 1970, with one or two Surveyors, and one unmanned Orbiter per year. The third phase would consist of one three-man 90-day mission per year. The final phase would consist of semipermanent manned stations.

Memo, Edgar M. Cortright, Alfred J. Eggers, Jr., James C. Elms, and Gerald M. Truszynski, Cochairmen, Planning Coordination Steering Group, to Associate Deputy Administrator, "Preliminary Reports of Working Groups," Sept. 23, 1966.

September 28

NASA Hq. informed MSC that the second phase of the vacuum system in the Lunar Receiving Laboratory (\$480,200) was to be deferred because of the austerity of the NASA FY 1967 program. MSC was instructed, however, that sufficient redundancy in the central vacuum pumping systems should be provided to ensure the highest degree of reliability.

TWX, NASA Hq., to MSC, "Lunar Receiving Laboratory," Sept. 28, 1966.

September 28

MSC ASPO Manager Joseph F. Shea wrote Grumman Aircraft Engineering Corp. Senior Vice President George F. Titterton that he was encouraged by the good start Grumman had made on work packages for the LM program, which he hoped had set the stage for effective action to curtail the creeping cost escalation that had characterized the program during the past year. He said: "To me, the most striking point noted in engineering activities projected a relatively high change rate from vehicle to vehicle, even though the program logic calls for identical vehicles from LM 4 on, and minimum change from LM 3 to LM 4. This, too, was apparent in the engineering related activities. The only changes which should be planned for are those rising from hardware deficiencies found in ground or flight test, or those resulting from NASA directed changes."

Shea had written to Joseph G. Gavin, Jr., Grumman Vice President and LEM Program Manager, in April concerning cost escalation. He had said "A significant amount of the planning for your contract is based upon management commitments made to us by Grumman . . . [and] your estimates have helped significantly (and indeed are still changing) and currently significantly exceed the amounts upon which our budget has been based." In another letter, in September, to Grumman President L. J. Evans, Shea remarked: "The result of our fiscal review with your people last week was somewhat encouraging. It reconfirmed my conviction that Grumman can do the program without the cost increases which you have been recently indicating, and, depending on how much difficulty we have with the qualification of our flight systems, perhaps even with some additional cost reduction."

In a November letter to Titterton, Shea again referred to work packages and reaffirmed that permission to exceed approved monthly levels should be granted only by the LM Program Office. He said, "Unless this discipline is enforced throughout the Grumman in-house and subcontract structure, the work packages could turn out to be interesting pieces of paper which contain the information as to what might have been done, rather than the basis for program management."

Ltrs., Shea to Gavin, Apr. 14, 1966; Shea to Evans, Sept. 19, 1966; Shea to Titterton, Sept. 28, 1966; Nov. 18, 1966.

September 29

The second planned manned Apollo flight crew was named by NASA. Prime crew members were Walter M. Schirra, Jr., command pilot; Donn F. Eisele, senior pilot; and R. Walter Cunningham, pilot.

Backup crewmen were Frank Borman, command pilot; Thomas P. Stafford, senior pilot; and Michael Collins, pilot. The flight was scheduled for 1967. It would be the first space mission for Eisele and Cunningham.

The second manned Apollo mission was planned as an open-ended earth orbital mission up to 14 days. Increased emphasis on scientific experiments as well as repeating some activities from the first planned manned flight would characterize the mission. [The first planned manned Apollo mission was ended by a tragic accident during a test January 27, 1967.]

NASA News Release 66-260, Sept. 29, 1966.

Week Ending September 30

LM test model TM-6 and test article LTA-10 were shipped from Grumman on the *Pregnant Guppy* aircraft. When the *Guppy* carrying the LTA-10 stopped at Dover, Del., for refueling, a fire broke out inside the aircraft, but it was discovered in time to prevent damage to the LM test article.

Memo, Frank W. Battersby to Chief, Apollo Procurement Br., Procurement and Contracts Div., MSC, "Weekly Activities Report, BMR Bethpage, Week Ending September 30, 1966," Oct. 4, 1966.

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October 4

MSC Director Robert R. Gilruth told Langley Research Center Director Floyd Thompson, "Lunar Orbiter I has made significant contributions to the Apollo program and to lunar science in general. Details visible for the first time in Orbiter I photographs will certainly add to our knowledge of the lunar surface and improve our confidence in the success of the Apollo landing.

"Screening teams . . . are studying the photographs as they become available at the Lunar Orbiter Project Office, Langley Research Center. Several promising areas for Apollo landing sites have been studied here in Houston by the screening teams and will be studied in more detail later. This preliminary study has already influenced the selection of sites to be photographed on the next Orbiter mission. . . ."

TWX, Gilruth to Thompson, Oct. 4, 1966.

October 7

NASA Associate Administrator for Manned Space Flight George E. Mueller, at the conclusion of the AS-204 Design Certification Review (DCR), requested each NASA manager to reexamine his stages, modules, systems, and subsystems upon substantial completion of the review's closeout actions and to

file an updated certification statement to the Design Certification Board.

On November 16, Apollo Program Director Samuel C. Phillips asked ASPO Manager Joseph F. Shea to submit the updated certification statements and supporting data to him by December 14 to permit him to submit the statements and his affirmation to the Board before the December 20 Manned Space Flight Review. He pointed out that each certification statement should affirm:

1. that the reservations previously cited had been dispelled by appropriate action;
2. that design problems identified subsequent to the review had been resolved;
3. that actions identified during the review had been completed (except where specifically noted);
and
4. that his previous certification of the design of flight systems for flight worthiness and manned safety, or of the capability of Launch Support to support a manned mission, remained valid.

Any residual contingencies or actions, scheduled for completion at the Flight Readiness Review, should be specifically listed.

Ltr., Phillips to Shea, "AS-204 Design Certification Review," Nov. 16, 1966.

October 7

In a memorandum to the NASA Deputy Administrator, Associate Administrator for Manned Space Flight George E. Mueller commented on the AS-202 impact error. Mueller said the trajectory of the August 25 AS-202 mission was essentially as planned except that the command module touched down about 370 kilometers short of the planned impact point. A detailed study indicated that the command module had a lower than predicted angle of attack and a correspondingly lower lift-to-drag ratio. "In retrospect, it appears that our wind tunnel testing did not provide a complete understanding of . . . hypersonic aerodynamic characteristics of the command module." Plans were being made to fly AS-204 and AS-205 with the lower lift-to-drag ratio.

Memo, Mueller to Deputy Administrator, "205 Nautical Mile Error in AS-202 Impact," Oct. 7, 1966.

October 11

Apollo Program Director Samuel C. Phillips was informed of increasing engineering orders for spacecraft 012. C. H. Bolender, OMSF Mission Operations Deputy Director, reported information received from John G. Shinkle, Kennedy Space Center Apollo Program Manager, on October 10. At the time of spacecraft shipment to Cape Kennedy on August 25, 164 engineering orders were identified as open work, although the data package appeared to identify only 126. These orders were covered by 32 master change records, which reportedly were the documentation approved by the MSC Change Control Board rather than by individual engineering orders. By September 24, engineering orders totaled 377 - 213 more than on August 25 - and the master change records had increased to 77. KSC estimated that

some 150 of the 213 additional orders should have been identifiable within North American Aviation at the time of the Customer Acceptance Readiness Review. Bolender said that, if this were true, North American Aviation should be asked to provide better visibility for CSM changes that would be sent to the Cape for installation at the time of the review.

Memo for Record, Shinkle, KSC, "Engineering Orders for Spacecraft 012," Oct. 11, 1966; NASA Routing Slip, Bolender to Phillips, Oct. 11, 1966.

October 11

NASA reiterated its intention of examining the question of tracking ship *Vanguard* support for the AS-204 mission in the South Pacific as soon as mission plans were resolved. It informed the Department of Defense Manager for Manned Space Flight Support Operations, the Navy Deputy Commander for Ship Acquisitions, and Goddard Space Flight Center that plans could not be completed for the support of AS-205 at the time but, should the services of the *Vanguard* be required, an Atlantic Ocean location would be acceptable. NASA also expressed concern about the late delivery forecast for the *Redstone* and the *Mercury* tracking ships and requested top management attention within government, contractor, and subcontractor organizations be directed to the problems and that a special effort be made to accelerate delivery.

TWX, NASA Hq. to Lt. Gen. Leighton I. Davis, Rear Admiral J. Adair, and Goddard Space Flight Center, Oct. 11, 1966.

October 12

MSC Apollo Spacecraft Program Office Manager Joseph F. Shea reported that LM-1 would no longer be capable of both manned and unmanned flight and that it would be configured and checked out for unmanned flight only. In addition, LM-2 would no longer be capable of completely unmanned flight, but would be configured and checked out for partially manned flights, such as the planned AS-278A mission (with unmanned final depletion burn of the ascent stage) and AS-278B (with all main propulsions unmanned).

Memo, Shea to distr., "Change in policies for LM-1 and LM-2," Oct. 12, 1966.

October 12

Apollo Program Director Samuel C. Phillips told Mark E. Bradley, Vice President and Assistant to the President of The Garrett Corp., that "the environment control unit, developed and produced by Garrett's AiResearch Division under subcontract to North American Aviation for the Apollo spacecraft was again in serious trouble and threatened a major delay in the first flight of Apollo." He pointed out, "This current difficulty is the latest in a long string of failures and problems associated with the AiResearch equipment." Phillips told Bradley that he was about three levels removed from the subcontract project

details and thus could not give him a point by point discussion of the problems or their causes. Phillips felt, however, "they seem to lie in two categories - those arising from inadequate development testing, and those related to poor workmanship." Phillips hoped that Bradley could find what was needed to get the project on the right track.

Ltr., Phillips to Bradley, Oct. 12, 1966.

October 13

KSC proposed to MSC Director Robert R. Gilruth that the two General Electric Co. efforts at KSC supporting automatic checkout equipment (ACE) for spacecraft operations be consolidated. KSC pointed out there was a supplemental agreement with MSC for General Electric to provide system engineering support to ACE/spacecraft operations. Both the KSC Apollo Program Manager and the Director of Launch Operations considered that merging the two GE efforts into a single task order under KSC administrative control would have advantages. The proposal listed two:

1. A single interface would exist between KSC and all local GE AEC/spacecraft operations.
2. Through more efficient use of personnel, the contractor should be able to reduce the manpower level and still be responsive to the demands of the Apollo program.

Gilruth replied Nov. 1 to KSC Director Kurt H. Debus that MSC had evaluated advantages of transferring certain ACE/spacecraft responsibilities to KSC and had also considered advantages of continuing the existing system. These advantages were:

1. "To maximize manpower utilization, the current ACE management philosophy provides only optimum manpower for each operational site. A central support group, located at Houston, supplies the required support to any site experiencing special peak activity. This philosophy has created maximum management flexibility."
2. "The original intent in establishing ACE-S/C checkout philosophy was to assure standardization in checkout procedures and/or program unity from factory checkout through launch activities. By continuing to have all GE ACE-S/C site personnel responsible to the central design/engineering group located in Houston, this continuity is assured."
3. "Logistics support to KSC ground stations is unified under the present management control. Personnel responsible for providing logistics support to KSC ground stations are administratively linked to the personnel at KSC requiring the support."
4. "MSC currently provides reliability support, configuration management support, engineering support, management support and logistics support to all ACE-S/C ground stations. By continuing the present contractual arrangement we avoid the possibility of costly duplication in these areas."

Gilruth said that it was the MSC intent to support system engineering requirements in ACE/spacecraft areas and that further support in these areas was normally supplied by the spacecraft contractor.

"Actually it has been our impression that GE/MSFC ACE/spacecraft support at KSC and all other locations was sufficient to meet all requirements. . . . It is our opinion that the existing ACE/spacecraft management organization is required to assure optimum fulfillment of the Apollo program."

Ltrs., Debus to Gilruth, Oct. 13, 1966; Gilruth to Debus, Nov. 1, 1966.

October 19

Marshall Space Flight Center Director Wernher von Braun wrote MSC Director Robert R. Gilruth that MSFC had spent a considerable effort in planning the transfer of study and development tasks in the lunar exploration program to MSC. Von Braun said, "We feel it is in the spirit of the MSFC Hideaway Management Council Meeting held on August 13-15, 1966, to consider the majority of our Lunar Exploration Work Program for transfer to MSC in consonance with Bob Seamans' directive which designates MSC as the Lead Center for lunar science." He added that MSFC had formulated a proposal which it felt was in agreement with the directives and at the same time provided for management interfaces between the two Centers without difficulty.

Briefly MSFC proposed to transfer to MSC:

1. planning for Apollo Applications lunar traverses;
2. lunar surface geological, geophysical, geochemical, biological, and biomedical experiments; and
3. emplaced scientific station experiments.

MSFC proposed to retain

1. the local scientific survey module and related mobility efforts,
2. Apollo Applications program lunar drill,
3. lunar surveying system, and
4. lunar flying device (one man flying machine).

He added that MSFC had been working in specific areas of scientific technology that promised to furnish experiments that could be used on the lunar surface or from lunar orbit as well as from a planetary vehicle for planetary observations. Among these were radar and laser altimetry and infrared spectroscopy.

Von Braun said that Ernst Stuhlinger of the Research Projects Laboratory had discussed the proposed actions for transfer of functions to MSC, and MSC Experiments Program Manager Robert O. Piland had indicated his general agreement, pending further consideration. He asked that Gilruth give his reaction to the proposal and said, "It would be very helpful if our two Centers could present a proposal to George Mueller [OMSF] on which we both agree."

Ltr., von Braun to Gilruth, Oct. 19, 1966.

October 19

Apollo-Saturn 204 was to be the first manned Apollo mission, NASA announced through the manned space flight Centers. The news release, prepared at NASA Hq., said the decision had been made following a Design Certification Review Board meeting held the previous week at OMSF. The launch date had not been determined. Crewmen for the flight would be Virgil I. Grissom, command pilot; Edward H. White II, senior pilot; and Roger B. Chaffee, pilot. The backup crew would be James A. McDivitt, command pilot; David R. Scott, senior pilot; and Russell L. Schweickart, pilot. The AS-204 spacecraft would be launched by an uprated Saturn I launch vehicle on its earth-orbital mission "to demonstrate spacecraft and crew operations and evaluate spacecraft hardware performance in earth orbit."

TWX, NASA Hq. M-N-311 to KSC, MSC, MSFC, Oct. 19, 1966.

October 21

MSC's ASPO Manager Joseph F. Shea proposed to KSC Apollo Program Manager John G. Shinkle that - because the program was moving into the flight phase and close monitoring of the hardware configuration was important - they should plan work methods in more detail. He reminded Shinkle that he had named Walter Kapryan Assistant Program Manager "to provide the technical focal point . . . to maintain the discipline for the total spacecraft"; therefore Shea would like to transfer the chairman of the Apollo Configuration Control Panel from Shinkle's organization to Kapryan effective Nov. 1, 1966.

Ltr., Shea to Shinkle, Oct. 21, 1966.

October 21

Langley Research Center informed MSC that the Apollo Visibility Study requested by MSC would be conducted. Langley mockups could be used along with an SLA panel to be provided by MSC from Tulsa North American. The proposed study would be semistatic, with the astronaut seated in the existing CM mockup and viewing the S-IVB/SLA mockup. The positions of the mockups would be varied manually by repositioning the mockup dollies, and the astronaut would judge the separation distance and alignment attitude. The study was expected to start at the end of October or early November and last two or three weeks.

Ltr., Director, LaRC, to MSC, Attn: Robert R. Gilruth "Apollo Visibility Study," Oct.21, 1966.

October 24

MSC established a committee to investigate several nearly catastrophic malfunctions in the steam generation system at the White Sands Test Facility. The system was used to pump down altitude cells in

LM propulsion system development. Committee members were Joseph G. Thibodaux, chairman; Hugh D. White, secretary; Harry Byington, Henry O. Pohl, Robert W. Polifka, and Allen H. Watkins, all of MSC.

Memo, MSC Director to distr., "Committee for investigation of malfunctioning steam generation system at White Sands Test Facility, New Mexico," Oct. 24, 1966.

October 25

Propellant tanks of service module 017 failed during a pressure test at North American Aviation, Downey, Calif. The planned test included several pressure cycles followed by a 48-hour test of the tanks at the maximum operating pressure of 165 newtons per square centimeter (240 pounds per square inch). Normal operating pressure was 120 newtons per square centimeter (175 pounds per square inch). After 1 hour 40 minutes at 165 newtons the failure occurred.

SM 017 (designed for SA-501) had been pulled for this test after cracks had been detected in the tanks of SM 101. SM 017 had been previously proof-tested a short time (a matter of minutes) at 220 newtons per square centimeter (320 pounds per square inch).

A team was set up at North American Aviation to look into the failure and its possible impact on the Saturn IB and Saturn V Apollo missions. MSC had two observers on the team, which was to make its findings and recommendations available by November 4.

North American Aviation identified the problem as stress-corrosion cracking resulting from use of methanol as a test liquid at pressures causing above threshold stresses. No tanks subjected to methanol at high stress levels would be used. Freon and isopropyl alcohol, respectively, were recommended for test fluids in the oxidizer and fuel systems, with the stipulation that the equipment had not previously seen propellant and would receive a hot gaseous nitrogen purge after completion of the cold flow operation.

Note, Frank Magliato, NASA Hq., to NASA Administrator and Deputy Administrator, "Test Failure of Service Module 017," Oct. 26, 1966; TWX, Dale D. Myers, NA, to J. F. Shea, MSC, Nov. 11, 1966.

October 27

Owen E. Maynard, Chief of the MSC Missions Operations Division, said the flight operations plan had proposed communication constraints be resolved by reducing the accessible landing area on the lunar surface to a region permitting continuous communication with no restriction on vehicle attitude during descent and ascent. Maynard said, "Such a proposal is not acceptable." Contending interests were the desire to maintain communications in the early part of the descent powered flight and to avoid the definition of attitude restrictions in this region.

Acknowledging that both of these were desirable objectives, Maynard said that mission planning should

be based on access to previously defined Apollo zones of interest and to designated sites within those zones with vehicle attitude maneuvers to provide communications when required.

Memo, Maynard to distr., "LM communication capability during lunar descent and ascent," Oct. 27, 1966.

November 4

NASA Apollo Program Director Samuel C. Phillips indicated his concern to MSC over the extensive damage to a number of fuel cell modules from operational errors during integrated system testing. Phillips pointed out that in addition to the added cost there was a possible impact on the success of the flight program. He emphasized the importance of standardizing the procedures for fuel cell activation and shutdown at North American Aviation, MSC, and KSC to maximize learning opportunities.

TWX, MAT-91, NASA Hq., to MSC, Attn: Joseph F. Shea, "Fuel Cell Operation Failures," Nov. 4, 1966.

November 6 - December 6

Lunar Orbiter II was launched at 6:21 p.m. EST from Launch Complex 13 at Cape Kennedy, to photograph possible landing sites on the moon for the Apollo program. The Atlas-Agena D booster placed the spacecraft in an earth-parking orbit and, after a 14-minute coast, injected it into its 94-hour trajectory toward the moon. A midcourse correction maneuver on November 8 increased the velocity from 3,051 to 3,133 kilometers per hour. At that time the spacecraft was 265,485 kilometers from the earth.

The spacecraft executed a deboost maneuver at 3:26 p.m., November 10, while 352,370 kilometers from the earth and 1,260 kilometers from the moon and traveling at a speed of 5,028 kilometers per hour. The maneuver permitted the lunar gravitational field to pull the spacecraft into the planned initial orbit around the moon. On November 15, a micrometeoroid hit was detected by one of the 20 thin-walled pressurized sensors.

The spacecraft was transferred into its final close-in orbit around the moon at 5:58 p.m. November 15 and the photo-acquisition phase of *Lunar Orbiter II*'s mission began November 18. Thirteen selected primary potential landing sites and a number of secondary sites were to be photographed. By the morning of November 25, the spacecraft had taken 208 of the 211 photographs planned and pictures of all 13 selected potential landing sites. It also made 205 attitude change maneuvers and responded to 2,421 commands.

The status report of the *Lunar Orbiter II* mission as of November 28 indicated that the first phase of the photographic mission was completed when the final photo was taken on the afternoon of November 25. On November 26, the developing web was cut with a hot wire in response to a command from the earth.

Failure to achieve the cut would have prevented the final readout of all 211 photos. Readout began immediately after the cut was made. One day early, December 6, the readout terminated when a transmitter failed, and three medium-resolution and two high-resolution photos of primary site 1 were lost. Full low-resolution coverage of the site had been provided, however, and other data continued to be transmitted. Three meteoroid hits had been detected.

Memos, Lunar Orbiter Program Manager to NASA Administrator, "Lunar Orbiter II Post Launch Report #1" through "#15," Nov. 7, 8, 14, 16, 17, 21, 25, and Dec. 9, 1966 (Mission Operation Reports S-814-66-02).

November 9

NASA Associate Administrator for Manned Space Flight George E. Mueller reported on technical feasibility and cost tradeoffs of real-time television coverage of Apollo missions. Deputy Administrator Robert C. Seamans, Jr., had requested an evaluation during a July 8 program review. Highlights of the report were:

- Lunar missions would be the most complex attempted in manned space flight. Even with optimum training, astronaut capabilities would be heavily taxed and availability of real-time TV coverage could provide an opportunity in trouble-shooting spacecraft anomalies or in performing scientific experiments.
- To transmit TV video to Mission Control Center in Houston, scan conversion from the Apollo format to the standard commercial format would be required as well as a communications capability. For the lunar mission, implementation at Goldstone and Madrid would provide 62- to 91-percent TV coverage with an estimated initial investment of \$500,000 and an operating cost of \$1,200,000 per year, based on four seven-day missions per year with 8 to 14 hours a day possible coverage for each station.
- The most optimistic minimum procurement and installation time for the first unit would be 10 months and, to provide real-time TV for the first lunar mission, the system should be exercised at least one mission before AS-504. Mueller recommended approval for additional equipment and communication services necessary for live TV coverage from the Goldstone, Calif., and Madrid, Spain, stations.

Seamans approved the proposal on November 17, with the following condition, which was later transmitted to MSC Director Robert R. Gilruth: "Before NASA commitments of any sort are made to the networks for Apollo capsule TV coverage, the plans and procedures must be approved by the Administrator."

Ltr., NASA Associate Administrator for Manned Space Flight to Deputy Administrator, "Real Time TV Coverage of Apollo Missions," Nov. 9, 1966; approval, with condition, by Seamans, Nov. 17, 1966; NASA Routing Slip to MSC Director Robert R. Gilruth from Jack T. McClanahan, Chief, Apollo Mission Requirements, OMSF, received at MSC Dec. 12, 1966.

November 22

Perkin-Elmer Corp., Norwalk, Conn., and Chrysler Corp., Detroit, Mich., were authorized about \$250,000 each to continue studies of optical technology for NASA. The nine-month extension of research by the two companies was to evaluate optical experiments for possible future extended Apollo flights. The proposed experiments included control of optical telescope primary mirrors, telescope temperature control, telescope pointing, and laser propagation studies.

NASA News Release 66-300, Nov. 22, 1966.

November 25

MSC was requested by NASA Hq. to take the following actions:

1. Delete all experiments assigned to AS-205.
2. Assign experiment M005 (Bioassays Body Fluid, modified version) to AS-205/208.
3. Assign experiment M006 (Bone Demineralization) to AS-205/208.
4. Assign experiment M011 (Cytogenic Blood Studies) to AS-205/208.
5. Assign experiment M023 (Lower-Body Negative Pressure) to AS-205/208.
6. Redesignate experiments assigned to AS-207/208 to AS-205/208.

TWX, NASA Hq. to MSC (APO-CCB Directive No. 80), Nov. 25, 1966.

November 29

MSC's Director of Flight Crew Operations Donald K. Slayton said that the Block I flight crew nomenclature was suitable for the AS-204 mission, but that a more descriptive designation was desirable for Block II flights. Block I crewmen had been called command pilot, senior pilot, and pilot. Slayton proposed that for the Block II missions the following designations and positions be used: commander, left seat at launch with center seat optional for the remainder of the CSM mission, and left seat in the LM; CSM pilot, center seat at launch with left seat optional for remainder of mission; and LM pilot in the right seat of both the CSM and LM.

Memo, Slayton to distr., "Block II Apollo flight crew designation," Nov. 29, 1966.

December 5

In response to a request from Apollo Program Director Samuel C. Phillips on November 21, MSC reported its evaluation of Atlantic versus Pacific Ocean prime recovery areas for all Saturn V Apollo missions. MSC said that a change of recovery area to the Atlantic for AS-501 and AS-502 would cause some schedule slip and compromise of mission objectives and would not necessarily save recovery ship

effort. For AS-503 and similar nonlunar missions, adjustments could be made to the mission profile to result in a prime recovery in the Atlantic area. Secondary support would be necessary in the Pacific, however. The report stressed that confining recovery to the Atlantic area for lunar missions would severely curtail the number of launch windows available.

In a December 30 letter to MSC, KSC, and MSFC, the Apollo Program Director referred to the study and said it had been determined that plans for Pacific recovery for the AS-501 and AS-502 missions were justified.

Ltrs., Christopher C. Kraft, Jr., MSC Director of Flight Operations, and Joseph F. Shea, Manager, ASPO, to NASA Hq., Attn: S. C. Phillips, "Atlantic Recovery," Dec. 5, 1966; Apollo Program Director, Office of Manned Space Flight, to MSC, KSC, and MSFC, "Atlantic Versus Pacific Recovery for Saturn V/Apollo Missions," Dec. 30, 1966.

December 5

During reassembly of LM Simulator (LMS) 1 at Houston, MSC personnel discovered that the digital-to-analog conversion equipment was not the unit used during the preship tests at Binghamton, N.Y.; it was apparent the unit had never been checked out, because at least five power-buss bars were missing. The unit had not checked out in the preship tests, and at the simulator readiness review test on October 14 Grumman had been authorized to replace the defective digital-to-analog core memory after the unit arrived at Houston. MSC questioned whether the delivery requirement of LMS-1 had been met and asked Grumman to explain why the switch was made without MSC knowledge and what steps Grumman expected to take to correct the situation.

TWX, MSC LM Project Officer to Grumman LM Program Manager, Dec. 5, 1966.

December 6

MSC Director of Flight Crew Operations Donald K. Slayton pointed out to ASPO Manager Joseph F. Shea that LM-to-CSM crew rescue was impossible. Slayton said

1. there was no way for the portable life support system and crewman to traverse from the LM front hatch to the CSM side hatch in zero-g docked operations, because there was no restraint system or tether attach points in the vicinity of the CSM hatch to permit the crewman to stabilize himself and work to open the hatch; and
2. there was no way to control the Apollo inner hatch (35-43 kilograms) to ensure that it would not inadvertently damage its seals, the spacecraft wiring, or the pressure bulkhead.

Slayton added that several spacecraft changes, additional training hardware for valid thermal testing, zero-g simulator demonstration, and crew training effort would be required to permit extravehicular crew rescue from LM to CSM. Until this total rescue capability was implemented, manned LM to CSM

operations would constitute an unnecessary risk for the flight crew.

Memo, Slayton to Shea, "Apollo EVA," Dec. 6, 1966.

December 6

Langley Research Center reported on its November study of visibility from the CSM during extraction of the LM from the S-IVB stage. The study had been made in support of the AS-207/208A mission, with assistance of MSC and North American Aviation personnel, to

1. determine if the CSM pilot could detect the signal indicating that the CSM had detached from the S-IVB,
2. determine if he could recognize a misalignment between the CSM/LM combination and the S-IVB during withdrawal, and
3. investigate simple aid techniques to make the pilot's task easier.

Results indicated that

1. LM docking did not provide adequate indication of detachment of the LM from the S-IVB, but
2. in misalignment tests subjects could recognize errors as small as two to three degrees in yaw and five to seven centimeters in lateral translation except when the CSM/LM was yawed right and translated left relative to the S-IVB.

The configuration of the model used prevented studying pitch, roll, or vertical translation misalignments.

Jack E. Pennington, "Results of Apollo Transposition Withdrawal Study," Langley Working Paper No. 335, Dec. 6, 1966.

December 7

In a memo to Apollo Program Director Samuel C. Phillips, Associate Administrator for Manned Space Flight George E. Mueller approved assignment of experiment S068, Lunar Meteoroid Detection, to the Apollo Program Office for implementation, provided adequate funding could be identified in the light of relative priority in the total science program. The experiment had been recommended by the Manned Space Flight Experiment Board (MSFEB) for a lunar mission. Also, as recommended by the MSFEB, the following experiments would be placed on the earliest possible manned space flight: S015 (Zero g, Single Human Cells); S017 (Trapped Particles Asymmetry); S018 (Micrometeorite Collection); and T004 (Frog Otolith Function).

Memo, Mueller to Phillips, "Experiment Assignments," Dec. 7, 1966.

December 7

Associate Administrator for Manned Space Flight George E. Mueller requested Leonard Reiffel, NASA Hq., "to be thinking about an appropriate name for the Lunar Receiving Laboratory - a descriptive kind of name rather than one that doesn't signify exactly what it is."

Note, Mueller to Reiffel (telecon), "Lunar Receiving Laboratory," Dec. 7, 1966.

December 13

The number one lunar landing research vehicle (LLRV) test vehicle was received at MSC December 13, 1966. Its first flight at Ellington Air Force Base following facility and vehicle checkout was expected about February 1, 1967, with crew training in the vehicle to start about February 20. A design review was held at Buffalo, N.Y., during the week of January 2, 1967, in connection with Bell Aerospace Company's contract for three lunar landing training vehicles (LLTVs) and associated equipment. No major design changes in the vehicle baseline configuration were requested. Crew training in helicopters and in the Lunar Landing Research Facility at Langley Research Center and the LLRV fixed base simulator was continuing.

Memo, Director of Flight Crew Operations, MSC, to Deputy Director, MSC, "LLRV/TV Monthly Progress Report," Jan. 19, 1967.

December 15

MSC Director of Administration Wesley L. Hjernevik informed NASA Hq. that Frank Smith had told him on December 14 of his meeting with NASA management on Lunar Receiving Laboratory plans. Smith advised that MSC should take necessary actions immediately to begin operation of the LRL. MSC advised Headquarters that it planned to expand one of the two facility operation contracts at MSC to include the LRL and designate an LRL organization, staffed with qualified civil service personnel for immediate full-time operation.

TWX, Hjernevik to NASA Hq., "Lunar Receiving Laboratory Operations Plans," Dec. 15, 1966.

December 19

A meeting at NASA Hq. discussed plans for the Lunar Receiving laboratory, noting that some problems were time-critical and needed immediate attention. Attending were Robert C. Seamans, Jr., Willis B. Shapley, George E. Mueller, Homer E. Newell, and Francis B. Smith, all of NASA Hq.; and Robert R. Gilruth, George M. Low, and Wesley L. Hjernevik of MSC.

The group agreed on the following interim actions:

1. Continued efforts to develop clearer definition of tasks that should be initiated to ensure the LRL would be ready for operation in time to handle returned lunar samples.
2. Creation of a task group at MSC to prepare for initial operation of the LRL. The task group would consist of MSC personnel plus a few new hires in critical skill areas.
3. Extension of the existing MSC support contract to provide minimum LRL technical and engineering support needed during the next few months.
4. Development of a clearer definition of the role and method of operation of the U.S. Public Health Officer to provide for more effective use of his recommendations for quarantine requirements.

On December 21, Shapley informed Mueller and Newell that NASA Administrator James E. Webb and Deputy Administrator Seamans had approved the proposed actions.

Memos, Smith to Webb and Seamans, "December 19th meeting to discuss plans for the Lunar Receiving Laboratory," Dec. 19, 1966; Shapley to Mueller and Newell, "Lunar Receiving Laboratory," Dec. 21, 1966.

December 22

Lewis L. McNair, MSFC Chairman of the Flight Mechanics Panel, told Calvin H. Perrine, Jr., MSC, that the Guidance and Performance Sub-Panel had been unable to reach an agreement on venting the liquid-oxygen (LOX) tank of the Saturn V S-IVB stage during earth parking orbit. McNair pointed out that MSFC did not want a programmed LOX vent and that MSC did. He added that the issue must be resolved in order to finalize the AS-501 attitude maneuver and venting timeline.

Ltr., McNair to Perrine, Dec. 22, 1966.

December 22

In a memo to Donald K. Slayton, MSC Deputy Director George M. Low indicated that he understood George E. Mueller had stated in executive session of the Management Council on December 21 that he had decided a third lunar module simulator would not be required. Low said, "This implies that either the launch schedule will be relieved or missions will be so identical that trainer change-over time will be substantially reduced."

Memo, Low to Slayton, "Third LM Mission Simulator," Dec. 22, 1966.

December 22

NASA announced crew selection for the second and third manned Apollo missions. Prime crew for AS-205/208 would be James A. McDivitt, commander; David R. Scott, CM pilot; and Russell L. Schweickart, LM pilot. The backup crew would be Thomas P. Stafford, commander; John W. Young, CM pilot; and Eugene A. Cernan, LM pilot. The crew for AS-503, the first manned mission to be

launched by a Saturn V, would be Frank Borman, commander; Michael Collins, CM pilot; and William A. Anders, LM pilot. The backup crew would be Charles Conrad, Jr., commander; Richard F. Gordon, Jr., CM pilot; and Clifton C. Williams, Jr., LM pilot.

NASA News Release 66-326, "NASA Names Crews for Apollo Flights," Dec. 22, 1966.

December 23

Handling and installation responsibilities for the LM descent stage scientific equipment (SEQ) were defined in a letter from MSC to Grumman Aircraft Engineering Corp. The descent stage SEQ was composed of three basic packages:

1. the Apollo Lunar Surface Experiments Package (ALSEP) compartment 1, which included the ALSEP central station and associated lunar surface experiments;
2. ALSEP compartment 2, composed of the radioisotope thermoelectric generator (RTG) and Apollo lunar surface drill (ALSD); and
3. the RTG fuel cask, thermal shield, mount and RTG fuel element.

The following definition of responsibility for handling and installation had been derived:

1. The SEQ would be installed in the LM descent stage while the LM was in the LM landing gear installation stand before LM-SLA mating, with the exception of the RTG fuel cask, thermal shield, mount and fuel element, and the ALSD.
2. The RTG fuel cask, thermal shield, mount and fuel element and the ALSD would be installed in the LM descent stage during prelaunch activities at the launch site.
3. Grumman would be responsible for SEQ installation with the exception of the RTG fuel element. The ALSEP contractor, Bendix Aerospace Systems Division, would provide the installation procedure and associated equipment. Bendix would also observe the installation operation and NASA would both observe and inspect it.
4. The Atomic Energy Commission (AEC) would be responsible for handling and installing the RTG fuel element. Bendix would provide procedures and associated equipment. Grumman and NASA would observe and inspect this operation. If for any reason the RTG fuel element was required to be removed during prelaunch operations, the AEC would be responsible for the activity. Removal procedures would be provided by Bendix. MSC requested that Grumman's planned LM activities at Kennedy Space Center reflect these points of definition.

Ltr., MSC to Grumman, "Contract NAS 9-1100, Handling and installation responsibilities for the LM descent stage Scientific Equipment (SEQ)," Dec. 23, 1966.

December 23

NASA Administrator James E. Webb approved establishment of a Science and Applications Directorate

at MSC. The new directorate would plan and implement MSC programs in space science and its applications, act as a focal point for all MSC elements in these programs, and serve as the Center's point of contact with the scientific community. In addition to the Director's office, the new directorate would encompass an Advanced Systems Office, Lunar Surface Project Office, Space Physics Division, Applications Plans and Analysis Office, Applications Project Office, Lunar and Earth Sciences Division, and Test and Operations Office. In a letter on January 17, 1967, NASA Associate Administrator George E. Mueller told MSC Director Robert R. Gilruth the new Directorate was "another significant milestone in your effort to support the Agency and the scientific community in the exploration of space. . . ."

Organization Chart, MSC, Dec. 23, 1967; ltr., Mueller to Gilruth, Jan. 17, 1967.

December 26

Donald K. Slayton said there was some question about including extravehicular activity on the AS-503 mission, but he felt that, to make a maximum contribution to the lunar mission, one period of EVA should be included. Slayton pointed out that during the coast period (simulating lunar orbit) in the current flight plan the EVA opportunity appeared best between hour 90 and hour 100. Two primary propulsion system firings would have been accomplished and the descent stage of the LM would still be attached.

Slayton specified that EVA should consist of a crewman exiting through the LM forward hatch and making a thorough orbital check of the LM before reentering through the same hatch. He said EVA on AS-503 would provide:

1. flight experience and confidence in LM environmental-control-system performance during cabin depressurization;
2. flight confidence in the Block II International Latex Corp. pressure garment assemblies;
3. orbital time-line approximation of cabin depressurization times, forward hatch operation, flight crew egress procedures, and LM entry following a simulated lunar EVA;
4. visual inspection and photography of LM landing gear for possible damage during withdrawal from the S-IVB stage;
5. external inspection and photography of the LM to record window and antenna contamination caused by SLA panel pyrotechnic deployment;
6. inspection and photography of descent engine skirt and adjacent areas for evidence of damage from two descent propulsion system firings;
7. inspection and photography of possible damage to the upper LM caused by the SM reaction control system during withdrawal;
8. possible additional data regarding EVA metabolic rates, etc., as applied to the Block II pressure garment assembly; and
9. additional orbital confidence in the portable life support system operational procedures.

Memo, Slayton to Technical Assistant for Apollo, "AS-503 Mission," Dec. 26, 1966.

December 30

Homer E. Newell, NASA Associate Administrator for Space Science and Applications, pointed out to MSC Director Robert R. Gilruth that during a program review he was made aware of difficulties in the development of the Apollo Lunar Surface Experiments Package. The problems cited were with the lunar surface magnetometer, suprathemal ion detector, passive seismometer, and the central station transmitter receiver. Newell, who had been briefed on the problems by NASA Hq. ALSEP Program Manager, W. T. O'Bryant, said: "I felt they were serious enough to warrant giving you my views in regard to the importance of having the ALSEP with its planned complement of instruments aboard the first Apollo lunar landing mission. It is essential that basic magnetic measurements be made on the lunar surface, not only for their very important planetological implications, but also for the knowledge which will be gained of the lunar magnetosphere and atmosphere as the result of the combined measurements from the magnetometer, solar wind spectrometer, and suprathemal ion detector."

MSC Deputy Director George M. Low, in a January 10 letter to Newell, thanked him and said he would discuss the problems with Newell more fully after receiving a complete review of the ALSEP program from Robert O. Piland.

Low wrote Newell on April 10, 1967, that there had been schedule slips in the program plan devised in March 1966 - primarily slips associated with the lunar surface magnetometer, the suprathemal ion detector, and the central station receiver and transmitter. "In each case, we have effected a programmatic workaround plan, the elements of which were presented to Leonard Reiffel of OMSF and William O'Bryant of your staff on December 5, 1966, and in subsequent reviews of the subject with them as the planning and implementation progressed. . . ."

Ltrs., Newell to Robert R. Gilruth, Dec. 30, 1966; Low to Newell, Jan. 10, 1967; and Low to Newell, Apr. 10, 1967.

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Part 1 (E)

Preparation for Flight, the Accident, and Investigation

January 1967

1967

January 3

B. Kaskey, Bellcomm, Inc., gave NASA Apollo Program Director Samuel C. Phillips three reasons why an AS-204 rescue or rendezvous with a biosatellite would be impracticable:

1. The Block I spacecraft hatch was not designed to open and reseal in space, therefore no extravehicular activity could be planned for AS-204.
2. The launch window for 204 was five hours on each day, set by lighting available for launch aborts and normal recovery; rendezvous would reduce the launch window to minutes.
3. More than half of the reaction control system propellant was committed because of the requirement that deorbit be possible on every orbit without use of the service propulsion system.

Phillips sent the information to ASPO Manager Joseph F. Shea at MSC.

Note, Kaskey to Phillips, NASA Hq., "Working Note," Jan. 3, 1967.

January 4

An MSC meeting selected a Flight Operations Directorate position on basic factors of the first lunar landing mission phase and initiated a plan by which the Directorate would inform other organizations of the factors and the operational capabilities of combining them into alternate lunar surface mission plans.

Flight Operations Director Christopher C. Kraft, Jr., conducted the discussion, with Rodney G. Rose, Carl Kovitz, Morris V. Jenkins, William E. Platt, James E. Hannigan, Bruce H. Walton, and William L. Davidson participating.

The major factors (philosophy) identified at the meeting were:

- "The astronauts should be provided with an extravehicular (EVA) timeline framework and objectives and then be given real time control of their own activities. This approach should better accommodate the first lunar surface unknowns than if rigorous activity control were attempted from earth."
- "The LM should always be in a position to get back into lunar orbit in the minimum time. Specifically the merits and feasibility of maintaining the LM platform powered up and aligned should be evaluated. Any other LM systems requiring start up time after powering down should be identified."
- "The constraints affecting the minimum time required to turn around and launch after LM landing and the time line should be determined. This time was estimated to two CSM orbits. The effects of Manned Space Flight Network (MSFN) support should be considered."
- The first EVA should be allocated to LM post landing inspection, immediate lunar sample collection, lunar environment familiarization, photographic documentation, and astronaut exploration prerogatives. Any second EVA would include deployment of ALSEP (Apollo Lunar Surface Experiments Package) and a more systematic geological survey. Therefore, a mission nominally planned for only one EVA would not have to include an ALSEP in the payload. Any flight operations benefits resulting from deletion of the ALSEP weight and deployment operations (such as replacing weight with more fuel) must be determined."

Other less important factors were discussed and several action items were assigned: Rose would be responsible for successful implementation of plans resulting from the meeting. Hannigan would determine the LM, portable life support system, and ALSEP systems constraints and determine if the ALSEP weight allowance could be beneficially applied to LM consumables. The Operations Analysis Branch would investigate the MSFN support.

Memo, Chief, Operations Analysis Br., MSC, to Chief, Flight Control Div., MSC, "Operations viewpoint on first lunar surface mission plan," Jan. 5, 1967.

January 4

Charles A. Berry, MSC Director of Medical Research and Operations, proposed establishment of an MSC management program for control of hazardous spacecraft materials, to provide confidence for upcoming long- duration Apollo missions while simultaneously saving overall costs. Berry pointed out that no unified program for control of potentially toxic or flammable spacecraft materials existed and, in the past, individual Program Offices had established their own acceptance criteria for toxicological safety and fire hazards.

Memo, Berry to Deputy Director, MSC, "Management Program for Control of Hazardous Spacecraft Materials," Jan. 4, 1967.

January 4

Director of Flight Crew Operations Directorate (FCOD) Donald K. Slayton discussed the 2TV-1 (thermal vacuum test article) manned test program in a letter to the ASPO Manager. Pointing out that FCOD was providing an astronaut crew for the vacuum test program in support of the AS-258 mission, Slayton said the FCOD objective was to test and evaluate crew equipment, stowage, and system operations procedures planned for Block II flights. Slayton acknowledged that this objective was not identical with ASPO's requirement for thermal and vacuum verification of integrated system design, but felt that it was of equal importance and should be given equal priority in planning the test. To achieve the FCOD objective, he requested that specific conditions be met in spacecraft configuration, test planning, and test conduct.

Ltr., Slayton to Manager, ASPO, "2TV-1 Manned Test Program," Jan. 4, 1967.

January 10

Apollo Program Director Samuel C. Phillips told NASA Associate Administrator for Manned Space Flight George E. Mueller that studies had been completed on the use of "direct translunar injection" (launch directly into a trajectory to the moon) as a mode of operation for lunar landing missions. The principal advantages would be potential payload increases and elimination of the S-IVB stage restart requirement. The disadvantage was that there would be no usable launch windows for about half of each year and a reduced number of windows for the remainder of the year. Phillips was confident the launch vehicle would have adequate payload capability, since Saturn V performance continued to exceed spacecraft requirements. Confidence in successful S-IVB restarts was also high. For the lunar missions, therefore, direct launch was considered as a fall-back position and the effort was concentrating on the parking orbit mode.

Ltr., Phillips to Mueller, "Saturn V Direct Lunar Injection," Jan. 10, 1967.

January 12

The NASA Western Support Office, Santa Monica, Calif., reported two accidents at North American plants, with no personal injuries:

- Apollo CM 2S-1 - being hoisted into a cradled position at North American Aviation's Space and Information Systems Division, Downey, Calif. - was dropped 1.8 meters onto a concrete floor Jan. 12. The first report was that the CM apparently suffered considerable damage.
- The S-II-5 interstage received possible structural damage when the protective metal roof covering of a handling fixture was struck during the swing opening of the six-story east door of Station 9 at the Seal Beach plant. The structural connections of the handling fixture to the interstage indicated damage. The S-II-5 interstage had been improperly parked within the swing opening of the east door.

Memo, William E. Lilly, NASA Hq., to George E. Mueller, NASA Hq., "Incident Reports: Damage to the Command Module 2S-1 and S-II-5 Interstage," Jan. 23, 1967.

January 19

Testing of CSM 012 at Downey, Calif., and KSC revealed numerous failures in the communications cable assembly caused by broken wiring, bent pins, and connector malfunctions. Certain design deficiencies in the system had been remedied by adding adapter cables in series with the cobra cable, but these additions had resulted in additional weak points in the system and in an unacceptably cumbersome cable assembly connected to crew members. For these reasons, Donald K. Slayton, Director of Flight Crew Operations, ruled the existing communications assembly unsafe for flight and requested that the biomedical tee adapter, cobra cable, sleep adapter, and noise eliminator be combined into one new cobra cable for CSM 012.

Memo, Slayton to Manager, ASPO, "Communications cables for Spacecraft 012," Jan. 18, 1967.

January 20

The Saturn 503 S-IVB stage exploded and was destroyed at the Douglas Sacramento, Calif., Test Facility at 4:25 p.m. PST during a countdown. The exercise had progressed to 10 seconds before simulated launch (about 8 minutes before S-IVB ignition) when the explosion occurred. Earlier that day the countdown had progressed to about 6 minutes past simulated launch when a problem with the GSE computer tape carrier head required a hold and a recycling in the countdown. No one was injured.

A Douglas Aircraft Company investigating team under Jack Bromberg started operations the next morning, and an MSFC-appointed investigating board chaired by Kurt Debus, KSC, began operating three days after the accident.

TWX, MSFC to addressees, "Explosion of S-IVB-503 Stage," Jan. 23, 1967.

January 23

The Lunar Mission Planning Board held its first meeting at MSC. Present, in addition to Chairman Robert R. Gilruth, were Charles A. Berry, Maxime A. Faget, George M. Low, Robert O. Piland, Wesley L. Hjernevik, and acting secretary William E. Stoney, Jr., all of MSC. Principal subject of discussion was the photography obtained by *Lunar Orbiter I* and *Lunar Orbiter II* and application of this photography to Apollo site selection. The material was presented by John Eggleston and Owen Maynard, both of MSC. *Orbiter I* had obtained medium-resolution photography of sites on the southern half of the Apollo area of interest; *Orbiter II* had obtained both medium- and high-resolution photographs of sites toward the northern half of the area. Several action items were assigned, with progress to be reported at the next meeting, including a definition of requirements for a TV landing aid

for the lunar module and a report on landing-site-selection restraints based on data available from *Lunar Orbiter I* and *II* only, and another on data from *Lunar Orbiter I, II, and III*.

Minutes of the Lunar Mission Planning Board, Jan. 23, 1967.

January 26

Apollo Program Director Samuel C. Phillips sent a message to the manned space flight Centers indicating that he wanted to supplement the findings of the S-IVB Accident Investigation Board with a review by the Crew Safety Panel of the possible impact on manned Apollo flights. He requested Crew Safety Panel members and any other necessary crew safety representatives to go to Sacramento, Calif., immediately, review the 20 January accident, and answer a number of questions:

1. What would have happened if a crew had been on board the space vehicle at the time of the accident?
2. What feasible methods were there within existing system capabilities to escape such an explosion? What other escape methods might be evolved beyond existing system capabilities?
3. How would the EDS (emergency detection system) have functioned if the accident had occurred on a manned flight? Should there be any changes to the EDS?
4. Should any changes be made to AS-204 to increase the probability of a safe escape?

Phillips said the panel's recommendations were needed by February 6 to help assess any impact on AS-204 and subsequent flights.

TWX, NASA Hq. to addressees, "S-IVB Stage Accident Investigation," Jan. 26, 1967.

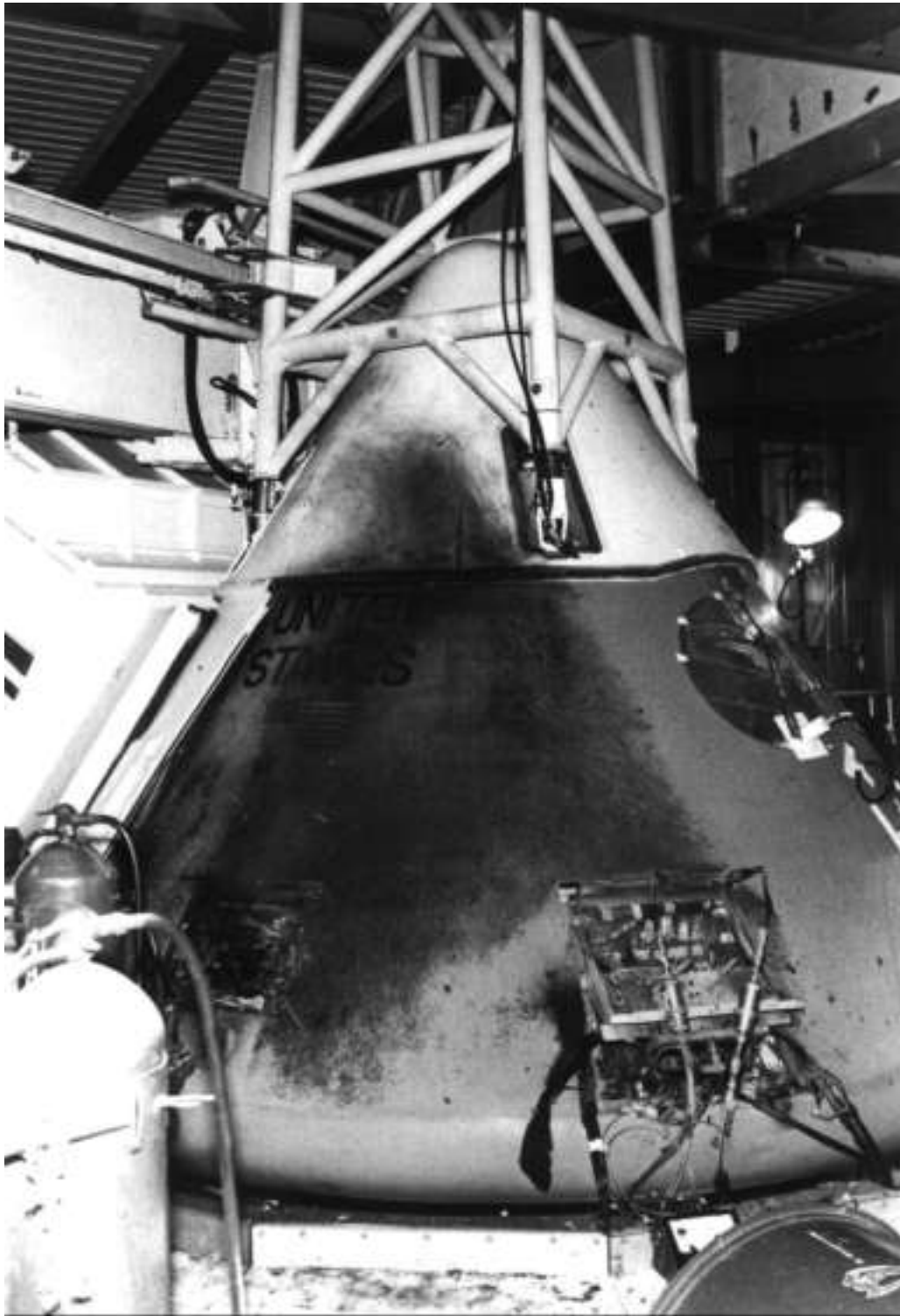
January 27

Representatives of 62 nations signed the space law treaty, "Treaty on Principles Covering the Activities of the States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies," at separate ceremonies in Washington, London, and Moscow. The treaty, which limited military activities in space, had been agreed upon by the U.S. and U.S.S.R. December 8, 1966, and unanimously approved by the United Nations General Assembly December 19. It was to become effective when ratified by the U.S., U.S.S.R., United Kingdom, and two other countries.

Astronautics and Aeronautics, 1967 (NASA SP-4008, 1968), p. 23; and text of treaty.

January 27

Fire sweeping through command module 012 atop its Saturn IB launch vehicle at Launch Complex 34, KSC, took the lives of the three-man crew scheduled for the first manned Apollo space flight.



Effects of the flash fire on CM 012, photographed shortly after the fatal January 27, 1967, Apollo 204 accident: exterior of the command module.

ASPO Manager Joseph F. Shea sent a flash report to NASA Hq.: "During a simulated countdown for mission AS-204 on January 27, 1967, an accident occurred in CM 012. This was a manned test with the prime astronaut crew on board. A fire occurred inside the command module resulting in the death of the

three astronauts and as yet undetermined damage to the command and service modules." The launch had been scheduled for February 21.

The Director, Armed Forces Institute of Pathology in Washington, was alerted during late evening and informed that the accident had taken the lives of astronauts Virgil I. Grissom, Edward H. White II, and Roger B. Chaffee.

Later that evening a request for autopsy support was received and three pathologists and a medical photographer were sent to Cape Kennedy on an Air Force aircraft. Team members were Col. Edward H. Johnston, USA; Cdr. Charles J. Stahl, USN; Capt. Latimer E. Dunn, USAF; and T/Sgt Larry N. Hale, USAF.

The postmortem examinations began at 11 a.m. January 28 at the USAF Bioastronautic Operational Support Unit and were completed at 1 a.m. the following day.

TWX, Shea to NASA Hq., Attn: Apollo Program Director, Jan. 28, 1967; Append. D, "Panel 11," *Report of Apollo 204 Review Board to the Administrator, National Aeronautics and Space Administration*, Apr. 5, 1967, p. D-11-13.

January 28

The Apollo 204 Review Board was established by NASA's Deputy Administrator Robert C. Seamans, Jr., to investigate the Apollo 204 accident that had killed the 204 prime crew January 27. The Board would report to the NASA Administrator.

Appointed to the Board were:

- Floyd L. Thompson, Director Langley Research Center, Chairman.
- Frank Borman, astronaut, MSC.
- Maxime A. Faget, Director of Engineering and Development, MSC.
- E. Barton Geer, Associate Chief of Flight Vehicles and Systems Division, LaRC.
- George Jeffs, Chief Engineer, Apollo, North American Aviation, Inc.
- Frank A. Long, President's Science Advisory Committee member, Vice President for Research and Advanced Studies, Cornell University.
- Col. Charles F. Strang, USAF, Chief of Missiles and Space Safety Division, Air Force Inspector General, Norton Air Force Base, Calif.
- George C. White, Jr., Director, Reliability and Quality, Apollo Program Office, NASA Hq.
- John Williams, Director of Spacecraft Operations, KSC.

George Malley, Chief Counsel, LaRC, was named to serve as counsel to the Board.

The Board was told it could call upon any element of NASA for support, assistance, and information,

and was instructed to:

- Review the circumstances surrounding the accident to establish the probable cause or causes and review the findings, corrective actions, and recommendations being developed by the program offices, field Centers, and contractors.
- Direct any further specific investigations necessary.
- Report its findings on the cause of the accident to the NASA Administrator as expeditiously as possible and release the information through the Office of Public Affairs.
- Consider the impact of the accident on all Apollo equipment preparation, testing, and flight operations.
- Consider all other factors related to the accident, including design procedures, organization, and management.
- Develop recommendations for corrective or other action based upon its findings and determinations.
- Document its findings, determinations, and recommendations and submit a final report to the Administrator, which would not be released without his approval.

Memo for the Apollo 204 Review Board from Seamans, Jan. 28, 1967.

January 28

The Chairman and several members of the Apollo 204 Review Board assembled at KSC and met with NASA Deputy Administrator Robert C. Seamans, Jr., Apollo Program Director Samuel C. Phillips, and other personnel from NASA Hq., KSC, and MSC. The officials were given a quick appraisal of circumstances surrounding the January 27 accident and actions taken after the fire. The meeting was followed by an initial general session of the Board in the Mission Briefing Room, an area assigned to the Board to conduct its business. The Board adjourned to visit the scene of the accident, Launch Complex 34, and then reconvened to plan the review.

"Board Proceedings," *Report of Apollo 204 Review Board to the Administrator, National Aeronautics and Space Administration*, Apr. 5, 1967, p. 3-13.

January 29

Astronaut Frank Borman briefed the Apollo 204 Review Board after his inspection of the damaged command and service modules. A main purpose of the inspection was to verify the position of circuit breakers and switches. In other major activities that day, the Pyrotechnic Installation Building was assigned to the Board to display the debris and spacecraft components after removal from Launch Complex 34; the Board began interviewing witnesses; and the Board Chairman asked NASA Associate Administrator for Manned Space Flight George E. Mueller for assistance in obtaining flame propagation experts to assist the Board. Experts might be obtained from Lewis Research Center, the Bureau of Mines, and the Federal Aviation Agency. The Board Chairman established an ad hoc committee to

organize task panels to make the accident investigation systematically. The committee was composed of John J. Williams, KSC; E. Barton Geer, LaRC; Charles W. Mathews, NASA, Hq.; John F. Yardley, McDonnell Aircraft Corp.; George Jeffs, North American Aviation, Inc.; and Charles F. Strang, USAF.

"Board Proceedings," p. 3-13.

January 30

Robert W. Van Dolah of the Bureau of Mines, I. Irving Pinkel of Lewis Research Center, and Thomas G. Horeff of the Federal Aviation Agency joined the Apollo 204 Review Board as consultants. Membership of the special ad hoc committee established January 29 to recommend special panels for the investigation was changed to Frank Borman and Maxime A. Faget, both of MSC; Charles W. Mathews, NASA Hq.; George Jeffs, North American Aviation, Inc.; John F. Yardley, McDonnell Aircraft Corp.; and John J. Williams, KSC, Chairman. Mathews outlined 19 recommended panels and the work objectives of each. A Board member was assigned to monitor each panel and to serve as a focal point through which the panels would report to the Board. Lt. Col. James W. Rawers (USAF) of the Range Safety Division Analysis Section presented an oral report on what Air Force Eastern Test Range personnel saw at the time of the accident. In other activities that day Faget introduced Alfred D. Mardel, MSC, who presented a briefing on data and sequence of events.

"Board Proceedings," p. 3-14.

January 31

Col. Charles F. Strang advised the Apollo 204 Review Board of an accident in an altitude chamber at Brooks Air Force Base, Tex., that morning. A flash fire had swept the oxygen-filled pressure chamber, killing Airman 2/C William F. Bartley, Jr., and Airman 3/C Richard G. Harmon. Col. Strang presented a short briefing on the circumstances and was asked by Chairman Floyd Thompson to provide follow-up information.

Lt. Col. William D. Baxter, Air Force Eastern Test Range representative to the Board, advised the group of existing Apollo spacecraft hazards, including:

- high-pressure oxygen bottles that might be pressurized to 335 newtons per square centimeter (485 pounds per square inch) and be subject to embrittlement;
- pyrotechnics on the service module; and
- a launch escape system with a 40-kilonewton (9,000-pound-thrust) rocket motor.

An engineering review was made of these hazards and it was agreed that these items must be removed before any work could proceed.

In other actions on January 31, the Chairman of Panel 4, Disassembly Activities, briefed the Board on

the Spacecraft Debris Removal Plan and the group approved the plan to the point of removing the astronauts' couches. In addition, Panel 19, Safety of Investigation Operations, was formed.

"Board Proceedings," pp. 3-14, 3-15; *Astronautics and Aeronautics, 1967* (NASA SP-4008, 1968), p. 29.

January 31

A TWX from NASA Headquarters to MSC, MSFC, and KSC ordered checkout and launch preparation of AS-501 to proceed as planned, except that the CM would not be pressurized in an oxygen environment pending further direction. If AS-501 support, facility, or work force should conflict with the activities of the AS-204 Review Board, the Board would be given priority.

TWX, Samuel C. Phillips to MSC, MSFC, and KSC, Jan. 31, 1967.

January 31

Funeral services were held for the Apollo crewmen who died in the January 27 spacecraft 012 (Apollo 204 mission) flash fire at Cape Kennedy. All three were buried with full military honors: Virgil I. Grissom (Lt. Col., USAF), and Roger B. Chaffee (Lt. Cdr., USN), in Arlington, Va., National Cemetery; and Edward H. White II (Lt. Col., USAF), at West Point, N.Y. Memorial services had been held in Houston January 29 and 30.

Astronautics and Aeronautics, 1967 (NASA SP-4008, 1968), pp. 27, 29.

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Part 1 (F)

Preparation for Flight, the Accident, and Investigation

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February 1

MSC management directed contractors and other government agencies to stop all MSC-related manned testing in environments with high oxygen content. The message dispatched stated: "Until further notice, each addressee and his subcontractors is directed to cease all MSC related manned testing in an environment containing high oxygen concentrations. This restriction applies to all tests in chambers, enclosures, spacecraft, space suits, and includes any other procedure which may require any human activity within a concentrated oxygen environment. Unmanned qualification and development tests may continue in accordance with established plans as long as the contractor can assure that human safety is not jeopardized.

"Waivers for test continuation due to urgent programmatic schedules and commitments will be granted only by the Director of MSC. Each addressee should review all test procedures and use of equipment for unmanned testing using concentrated oxygen under pressure to assure that the tests are necessary and will be conducted safely.

"This message is precautionary in nature. It should not be construed to imply that any preliminary conclusions have been reached in the investigation of the recent Apollo accident.

"Unmanned buildup and preparations should proceed as planned, so that testing can be resumed when this restriction is lifted. . . ."

TWX, George M. Low, MSC, to addressees, Feb. 1, 1967.

February 1

The task of removing the launch escape system from AS-204 was delayed until retrorockets and other

ordnance devices could be removed from the launch vehicle and spacecraft.

Apollo 204 Review Board Chairman Floyd L. Thompson appointed a committee of two Board members and three consultants to coordinate panel activities and to bring to the attention of the Board the actions requiring specific approval. This Panel Coordinating Committee was required to present daily activity reports to the Board. Thompson announced that an executive session (Board members) would be held at 4 p.m. daily.

"Board Proceedings," p. 3-15.

February 2

Command module 014 arrived from the North American Aviation plant in Downey, Calif., and was placed in the Pyrotechnic Installation Building at KSC. The module was to be used for training the technicians who would disassemble command module 012, the module in which the AS-204 fire had ignited. Before removal of any component from 012, the technicians were to perform similar tasks on 014, to become familiar with all actions required to remove any single component and minimize damage during removal. As a component was removed it was transported from the launch complex to the Pyrotechnic Installation Building. All equipment associated with the accident would also be placed in the PIB, including command module hardware and support equipment.

The Apollo 204 Review Board was informed that the most significant event in the investigation to date was the removal of the launch escape system from the command module, eliminating the greatest potential hazard to disassembly operations. With this task finished, members of the Fire Propagation Panel were expected to enter the command module the following day. Removal of the launch escape system also permitted extensive photographic coverage of the interior of the 012 command module.

Col. Charles F. Strang distributed copies of a status report of the January 31 accident at Brooks AFB, Tex., for the Board's information. NASA Deputy Administrator Robert C. Seamans attended the session.

"Board Proceedings," pp. 3-15, 3-16, 3-47.

February 2

MSC issued instructions to contractors and employees regarding release of information on any aspect of the AS-204 accident or investigation. The message said: "In accordance with the Apollo Failure Contingency Plan . . . and so this work may proceed rapidly and with complete integrity, all NASA and contractor employees are directed to refrain from discussing technical aspects of the accident outside of assigned working situations. This is meant to rule out accident discussion with other employees, family friends, neighbors and the like. All press information will be channeled through the Public Affairs Office.

TWX, MSC to distr., "MSC Posture on Apollo 204 Investigation," Feb. 2, 1967.

February 3

NASA Deputy Administrator Robert C. Seamans, Jr., reported to Administrator James E. Webb on progress of the Apollo 204 Review Board investigation of the January 27 spacecraft fire. Specific cause of the fire had not been determined from the preliminary review. Official death certificates for the three crew members listed cause of death as "asphyxiation due to smoke inhalation due to the fire." Webb released the report to Congress and the press.

Associate Administrator for Manned Space Flight George E. Mueller announced that the unmanned flights AS-206 (on uprated Saturn I) an AS-501 and AS-502 (first and second Saturn V launches) would proceed as scheduled in 1967. Manned flights were postponed indefinitely.

"Board Proceedings," p. 3-47; NASA News Releases 67-21 and 67-22, Feb. 3, 1967.

February 3

In memoranda for the Apollo 204 Review Board, NASA Deputy Administrator Seamans noted changes in the Board:

- Frank A. Long, President's Scientific Advisory Committee member and Vice President for Research and Advanced Studies at Cornell University, was no longer a member of the Board, effective February 1.
- Robert W. Van Dolah, Research Director for the Explosive Research Center of the Bureau of Mines, Department of the Interior, was appointed to the Board effective February 1.
- George Jeffs - Chief Engineer, Apollo, North American Aviation, Inc. - was consultant rather than member of the Board effective February 2.

Seamans also amplified and documented the oral instructions given to the Chairman January 28, 1967:

- The Chairman was to establish procedures for the organization and operation of the Board as he found most effective, and the procedures were to be part of the Board's records.
- Board members were to be appointed or removed by the Deputy Administrator after consultation with the Chairman as necessary for the Board's effective action.
- The Chairman could establish procedures to ensure the execution of his responsibility in his absence.
- The Chairman was to appoint or designate representatives, consultants, experts, liaison officers, observers, or other officials as required to support Board activities. He was to define their duties and responsibilities as part of the Board's records.
- The Chairman was to advise the Deputy Administrator periodically on the organization, procedures, and operations of the Board and its associated officials.
- The Chairman was to ensure that the counsel to the Board maintained memoranda records

covering areas of possible litigation.

Memos, Seamans to Apollo 204 Review Board, Feb. 3, 1967.

February 3

The Apollo 204 Review Board Chairman requested that a document be written to establish procedures for entry into CM 012. Coordination of requirements and priorities would be controlled by the Panel Coordinating Committee, and entry into the CM by Frank Borman, MSC, or his delegated representative.

A display showing the sequence of events immediately preceding and following the accident was prepared from telemetry data and placed in the Mission Briefing Room. Time span of the display was from 6:30 p.m. to 6:33 p.m., January 27. Significant information was included on communications, instrumentation, electrical power, environmental control, guidance and navigation, and stabilization and control.

Borman reported that the debris removal plan approved by the Board was progressing satisfactorily and that the next phase would use protective plywood covers for the couches to permit detailed examination of the command module interior.

Homer Carhart, Chief of Fuels Research, Chemistry Division, Naval Research Laboratory, was assigned to the Fire Propagation Panel. Board Chairman Floyd Thompson made the following appointments as Representatives of the Board: C. H. Bolender and Charles W. Mathews, both of NASA Hq.; Joseph F. Shea and G. Fred Kelly, MSC; Rocco Petrone, KSC; and William D. Baxter, Air Force Eastern Test Range.

"Board Proceedings," pp. 3-16, 3-17.

February 4

Apollo 204 Review Board Chairman Floyd L. Thompson established an Advisory Group to support the Board in its investigation. The group consisted of representatives, consultants, liaison officers, observers, and secretariat and would report to the Board Chairman.

Duties were defined as follows:

- Representative; represent a major element of NASA or other government agency having programs and activities associated with the Apollo Program.
- Consultant; serve as an adviser to the Review Board by providing opinions, information, and recommendations, as appropriate, based on his field of competence.
- Observer; acquire information relative to his area of expertise and normal responsibility.
- Secretariat; provide administrative, secretarial, clerical, and other supporting services to the

Review Board.

The following were designated to the Advisory Group by Thompson:

Representatives:

C. H. Bolender, NASA Hq., representing the Apollo Program Director;

Charles W. Mathews, Director, Apollo Applications Program, NASA Hq.;

Rocco A. Petrone, Director, Launch Operations, KSC;

Joseph F. Shea, ASPO Manager, MSC;

Lt. Col. William D. Baxter, USAF, Chief, Range Safety Office, Air Force Eastern Test Range;

G. F. Kelly, Flight Medicine Branch, Center Medical Office, MSC.

Consultants:

Frank A. Long, Vice President for Research and Advanced Studies, Cornell University;

John Yardley, Technical Director, Astronautics Co., Division of McDonnell Co.;

George W. Jeffs, Chief Engineer, Apollo Program, North American Aviation, Inc., or alternate R. L. Benner, Assistant Chief Engineer, Apollo Program, North American Aviation, Inc.;

Irving Pinkel, Chief, Fluid Systems Research Division, Lewis Research Center;

Thomas G. Horeff, Propulsion Program Manager, Engineering and Safety Division, Aircraft Development Service, Federal Aviation Agency;

Homer Carhart, Chief, Fuels Branch, Chemistry Division, Naval Research Laboratory;

John S. Leak, Chief, Technical Services, Engineering Division, Bureau of Safety, Civil Aeronautics Board.

Liaison Officer: Duncan Collins, Special Adviser, Secretary of the Air Force, Skylab Program.

Observers:

All MSC astronauts;

John D. Hodge, MSC;

P. A. Butler, USAF;

W. Dugan, USAF;

George E. Mueller, NASA Hq.;

Samuel C. Phillips, NASA Hq.;

Kurt H. Debus, KSC;

Paul C. Donnelly, KSC;

John W. King, KSC;

H. E. McCoy, KSC;

R. E. Moser, KSC;

W. P. Murphy, KSC;

G. Merritt Preston, KSC;

J. G. Shinkle, KSC;

A. F. Siefert, KSC;

W. Williams, KSC.

Secretariat:

Ernest Swieda, Executive Secretary.

Memo for Record, Floyd L. Thompson, "Establishment of Apollo 204 Review Board Advisory Group," Feb. 4, 1967.

February 4

Maxime Faget, MSC, distributed a draft report on the use of internal and external power on the command module for the information of the Apollo 204 Review Board.

Scott Simpkinson, MSC, Chairman of the Disassembly Activities Panel, presented the disassembly schedule. He expected removal of the couches from command module 012 by 5 a.m., followed by installation of the false floor by 12 noon on February 5. The false floor had previously been installed in command module 014 as a training exercise.

Frank Borman, MSC, was granted release of the impounded flight suits of the backup crew, for egress testing. The Board was to observe the test February 5. "Board Proceedings," p. 3-17.

Lt. Col. William D. Baxter, Air Force Eastern Test Range, reported to the Apollo 204 Review Board that copies of statements by 90 witnesses of the January 27 fire had been transcribed. George Jeffs of North American Aviation announced that an NAA and AiResearch team had arrived to inspect the 012 command module and to propose further action on the environmental control unit and system.

Col. Charles F. Strang, USAF, said Board Chairman Floyd Thompson had asked that the "Life Sciences" portion of the final report include an analysis of the escape system, with redesign recommendations. The system fell within the purview of the Ground Emergency Procedures Review Panel, the In-Flight Fire Emergency Provisions Review Panel, the Design Review Panel, and the Medical Analysis Panel. G. Fred Kelly, MSC, was asked to coordinate findings.

"Board Proceedings," p. 3-18.

February 7

The Senate Committee on Aeronautical and Space Sciences met in executive session to hear NASA testimony on the Apollo 204 fire. NASA Deputy Administrator Robert C. Seamans, Jr., said the cause of the accident had not yet been found. Corrective actions under study included choices of CM cabin and suit atmospheres, improved accessibility into and out of the CM cabin, and procedures to minimize the possibility of fires and to extinguish fires if they should occur.

Charges that the Apollo program was taking chances with lives in the effort to beat the U.S.S.R. to the moon were "completely unfounded; . . . before every one of our manned flights, as well as our ground test simulations, we have taken stock to be sure that there is nothing . . . undone or . . . done, that would in any way increase the risk to the astronauts." The astronauts had been party to decisions and part of the review process to make sure this was true. Associate Administrator for Manned Space Flight George E. Mueller emphasized that the Apollo program had been "paced at a deliberate pace"; it was the longest research and development program the U.S. had ever undertaken.

MSC Chief of Center Medical Programs Charles A. Berry testified that the cabin atmosphere used in the Apollo program - 100 percent oxygen at pressure of 3.5 newtons per square centimeter (5 pounds per square inch) - was based on extensive research over more than 10 years. The one-gas selection was based on tradeoffs among oxygen toxicity, hypoxia, spacecraft leakage, weight, and system reliability. And cabins had been purged with oxygen at some 10.3 newtons per square centimeter (15 pounds per square inch) during the prelaunch period for all manned launches since 1960 and all spacecraft vacuum chamber tests in Mercury, Gemini, and Apollo programs - primarily to prevent astronauts from getting the bends.

Three previous fires had occurred in the pure oxygen environment, but these had been in simulators and

caused by test equipment and procedures that would not be used in spacecraft.

The three-door hatch, requiring 90 seconds to open, was used for the first time on CM 012, which had an inner pressure hull and an outer shell to carry the structural loads of reentry into the atmosphere on a return from the moon. Danger of a fast-opening escape hatch's accidentally opening in space - as the Mercury program's Liberty Bell hatch had opened after splashdown in July 1961 - had to be considered. Research on cabin accessibility, ongoing before the 204 accident, was now intensified.

Senate Committee on Aeronautical and Space Sciences, Apollo Accident: Hearing, 90th Cong., 1st sess., pt. 1, Feb. 7, 1967.

February 7

Irving Pinkel, of Lewis Research Center and the Fire Propagation Panel, presented a preliminary report to the Apollo 204 Review Board. The report described the areas of the command module most damaged by the January 27 fire, the most probable fire paths, and the combustible materials in the CM. The oxygen in the CM would permit burning of only 5.4 to 6.8 kilograms of material. Solid combustibles in the CM included plastics in the nylon, polyurethane, and silicone rubber classes. The liquid-coolant ethylene glycol could also become a fuel if it escaped from the closed coolant system.

The technical team from AiResearch and North American Aviation (under NASA supervision) completed inspection of the CM 012 spacecraft environmental control unit, preparatory to removal.

Panel 21 was formed for service module disposition. It would plan and execute SM activities and obtain Board approval for demating the command and service modules.

"Board Proceedings," p. 3-19.

February 7

Floyd L. Thompson, Chairman of the Apollo 204 Review Board, formally established 21 task panels to support the investigation. He appointed a Board member as monitor for each panel.

Duties of the panels were to:

- Perform all functions within their respective statements of work as approved by the appropriate Board monitors.
- Submit work plans through the Panel Coordination Committee to the Review Board for approval.
- Provide reports to the Review Board, when required, on the progress of work.
- Work with each other under the guidance of the Panel Coordination Committee.

Following are the names of the panels and the panel chairman and Board monitors assigned to each panel.

Apollo 204 Review Board Task Panels

Panel No.	Panel Title	Panel Chairman	Board Monitor
1	S/C and GSE Configuration	J. Goree, MSC	J. Williams, KSC
2	Test Environments	W. Hoyler, MSC	G. White, NASA Hq.
3	Sequence of Events	D. Arabian, MSC	M. Faget, MSC
4	Disassembly Activities	S. Simpkinson, MSC	F. Borman, MSC
5	Origin & Propagation of Fire	F. Bailey, MSC	R. Van Dolah
6	Historical Data	T. J. Adams, MSC	G. White, NASA Hq.
7	Test Procedures Review	D. Nichols, KSC	J. Williams, KSC
8	Materials Review	W. Bland, MSC	M. Faget, MSC
9	Design Reviews	R. Williams, MSC	G. White, NASA Hq.
10	Analysis of Fracture Areas	P. Glynn, MSC	B. Geer, LaRC
11	Medical Analysis	G. Kelly, MSC	F. Thompson, LaRC; G. Malley, Counsel
12	Witness Statements	N. Vaughn, MSC	G. Strang, USAF; G. Malley, Counsel
13	Ground Emergency Provisions	G. Page, KSC	F. Borman, MSC
14	Security of Operations	C. Buckley, KSC	C. Strang, USAF
15	Board Administrative Procedures	A. Griffin, KSC	B. Geer, LaRC
16	Special Tests	G. Stoops, MSC	M. Faget, MSC
17	Final Board Report	K. Hinchman, USAF	C. Strang, USAF
18	Integration Analysis	A. Mardel, MSC	M. Faget, MSC
19	Safety of Investigation Operations	J. Atkins, KSC	B. Geer, LaRC
20	In-flight Fire Emergency Provisions Review	J. Lovell, MSC	F. Borman, MSC
21	Service Module Disposition	W. Petynia, MSC	J. Williams, KSC

Memo for Record, Floyd L. Thompson, "Establishment of Apollo 204 Review Board Panels," Feb. 7, 1967.

February 7

MSC Director Robert R. Gilruth asked LaRC Director Floyd Thompson to conduct a study at Langley to familiarize flight crews with CM active docking and to explore problems in CM recontact with the LM and also LM withdrawal. MSC would provide astronaut and pilot-engineer support for the study. Apollo Block II missions called for CM active docking with the LM and withdrawal of the LM from the S-IVB stage, requiring development of optimum techniques and procedures to ensure crew safety and to minimize propellant utilization. LM withdrawal was a critical area because of clearances, marginal flight crew visibility, and mission constraints. Previous simulations at LaRC indicated the possibility of using the Rendezvous Docking Simulator.

Ltr., Gilruth to Thompson, Feb. 7, 1967.

February 8

MSC ASPO Manager Joseph Shea reviewed with George Jeffs of North American Aviation a deficiency in the mission control programmer (MCP) in spacecraft 017. Certain diodes - intended to prevent propagation of a single-point failure into redundant circuitry - had been omitted from the flight unit. The diodes appeared on MCP schematics but had been omitted from the hardware because of problems in ground testing. A fix appeared mandatory before flight. The MCP unit in spacecraft 020 would be similarly modified before final integrated tests, to confirm that the design change had not introduced other problems.

Shea requested a full explanation from North American "as to how the schematics and/or drawings being used by the responsible design review engineers did not reflect the as built conditions." A report detailing the loopholes in North American procedures that permitted such a condition and the corrective actions taken to prevent such incidents in the future was requested no later than March 1.

Memo, Shea to distr., Feb. 8, 1967.

February 10

William W. Petynia, MSC, was given ASPO responsibility for use of the spacecraft 012 service module in nonflight support of the Apollo program when the Apollo 204 Review Board released the SM from - further investigation. It was to be used in subsystem tests or tests of the complete module.

Memo, Petynia to Assistant Manager, ASPO, and Head, Apollo Support Office, "Disposition of the SC 012 Service Module," Feb. 10, 1967.

February 10

NASA Deputy Administrator Robert C. Seamans, Jr., and members of his staff were briefed at KSC on aspects of the Apollo 204 investigation: final report, fire propagation, photographic control, data

integration, and medical analysis. The group also visited the Pyrotechnic Installation Building and other areas under the control of the Apollo 204 Review Board.

Board Chairman Floyd Thompson announced that the panel reports would be signed by the panel chairmen only and that the Board monitors assigned to the panels would be responsible for ensuring that minority views be given proper consideration. In the event that serious differences were not resolved, they were to be included in the panel reports for the Board's consideration.

"Board Proceedings," pp. 3-20, 3-51 through 3-53.

February 10

The Board of Inquiry into the January 20 S-IVB-503 explosion at the Douglas Sacramento Test Facility identified the probable cause as the failure of a pressure vessel made with titanium-alloy parent-metal fusion welded with commercially pure titanium. The combination, which was in violation of specifications, formed a titanium hydride intermetallic that induced embrittlement in the weld nugget, thus significantly degrading the capabilities of a weldment to withstand sustained pressure loads. The Board recommended pressure limitations for titanium-alloy pressure vessels.

TWX, NASA Hq. to MSC, KSC, and Grumman, Feb. 8, 1967; TWX NASA Hq. to MSFC, MSC, KSC, "Pressure Limitation on Titanium Alloy Pressure Vessels," Feb. 10, 1967; ltr., William Teir, MSFC, to MSC, Attn: Joseph F. Shea, "Titanium Pressure Vessels," Feb. 10, 1967.

February 10

Apollo 204 Review Board Chairman Floyd Thompson requested the NASA Office of Manned Space Flight, MSFC, KSC, and MSC to furnish a detailed description of their responsibilities, organizational relationships, and alignment in the Apollo program. Robert W. Van Dolah (Bureau of Mines), Chairman of the Origin and Propagation of Fire Panel, was asked to prepare a report on fire propagation by February 15 for submission to NASA Deputy Administrator Robert C. Seamans, Jr.

Specially built tables had been placed in the Pyrotechnic Installation Building to display items from CM 012 for inspection without handling.

The Board also decided to ask that special studies of the spacesuits be made by the manufacturer and the MSC Crew Systems Division, to provide expert opinions on possible contributing factors to the fire and information for future spacesuit design.

"Board Proceedings," p. 3-21.

February 14

NASA Deputy Administrator Robert C. Seamans, Jr., gave Administrator James E. Webb a second interim report on the Apollo 204 Review Board investigation: "At this time there has been no determination as to the source of the ignition itself," but the fire apparently had varied considerably in intensity and direction and might have had more than one phase. All three crew spacesuits had been burned through, although extent of damage varied. Spacecraft disassembly was proceeding carefully, with detailed mapping and photography. Webb released the report to the press February 15.

"Board Proceedings," pp. 3-51 through 3-53; NASA News Release 67-28, Feb. 15, 1967.

February 14

Selected Apollo 204 Review Board members and panel chairmen were instructed to prepare an interim report on actions to date. The Board was to review the report February 19 for a briefing of NASA Deputy Administrator Seamans on February 22. Robert W. Van Dolah presented a report on findings by the Origin and Propagation of Fire Panel, for submission to Seamans.

Command module 012 was scheduled for removal from its launch vehicle February 17 because of satisfactory progress in removing systems from it.

"Board Proceedings," p. 3-21.

February 15

The Apollo 204 Review Board received a detailed briefing on the anomalies recorded before and during the CM 012 fire. The following anomalies were transmitted by the command module telemetry system to several recording stations:

1. communication difficulties,
2. high flow rate in oxygen system,
3. disruption of alternating current,
4. telemetry readings from a disconnected gas chromatograph connector, and
5. change in the gimbal angle of the inertial measurement unit, which might indicate movement in the command module.

The Board asked additional testing and analysis.

"Board Proceedings," p. 3-22.

February 16

NASA Deputy Administrator Robert C. Seamans, Jr., informed Associate Administrator for Manned

Space Flight George E. Mueller that, in view of the interim nature of schedule outlook for manned uprated Saturn I and Saturn V missions, he had decided to show these missions as "Under Study" in the Official NASA Flight Schedule for February 1967. As soon as firm approved dates for the missions were available the schedule would be updated. He said that all participants in the Apollo program should be advised that - except for unmanned missions 206, 501, and 502 - official agency schedule commitments had not been made and certainly could not be quoted until management assessments of the program had been completed and schedules approved by the Office of the Administrator.

Memo, Seamans to Mueller, "Official NASA Apollo Schedules for Manned Missions," Feb. 16, 1967.

February 17

The Apollo 204 Review Board classified the materials in and around spacecraft 012 into three categories. Categories A and B were materials that had significant bearing on the results of the findings or were considered relevant to the investigation. Category C was essentially material not involved in the event, or only affected as a consequence of the event. Most of the Category C material would, at the time of its designation, be released to the program office for disposition and use within what might be termed normal program channels.

Memo, Joseph F. Shea, MSC, to distr., "Policy with respect to the use of material released from Apollo 204 Review Board jurisdiction," Feb. 16, 1967.

February 17

Command module 012 was separated from the service module and moved to the Pyrotechnic Installation Building for further disassembly and investigation.

"Board Proceedings," p. 3-22.

February 20

The Apollo 204 Review Board approved a plan to remove the spacecraft 012 service module from the launch vehicle on February 21. The service module was to be taken to the Manned Spacecraft Operations Building at KSC for detailed examination and testing. Board Chairman Floyd Thompson directed that a plan be developed to release Launch Complex 34 from impoundage and to return it to KSC for normal use after the SM was removed. Preparations were being made to remove the aft heatshield from the command module to permit inspection of the CM floor from the lower side.

"Board Proceedings," p. 3-23.

February 20

Kenneth S. Kleinknecht was designated Chairman of the CSM Configuration Control Panel in the Apollo Spacecraft Program Office, MSC. He would have authority to approve CSM changes within the limits outlined in the ASPO Configuration Management Plan.

Memo, Manager, ASPO, to distr., "CSM Configuration Control Panel Chairman," Feb. 20, 1967.

February 21

Apollo program officials were briefed on significant information, tentative findings, and preliminary recommendations developed by the Apollo 204 Review Board. Those present included George E. Mueller, Samuel C. Phillips, C. H. Bolender, Frank A. Bogart, and Julian B. Bowman, all of NASA Hq.; Robert R. Gilruth, George M. Low, and Christopher C. Kraft, Jr., all of MSC; Kurt H. Debus, KSC; and Wernher von Braun, MSFC.

Ashmun Brown, Office of Chief Counsel, KSC, was assigned to assist the counsel to the Board.

"Board Proceedings," pp. 3-23, 3-24.

February 22

A formal briefing on progress of the Apollo 204 Review Board was presented to NASA Deputy Administrator Robert C. Seamans, Jr., David Williamson of Seamans' staff, and Charles A. Berry, Joseph F. Shea, Donald K. Slayton, and Walter M. Schirra, Jr., all of MSC.

In a general session of the Board, Chairman Floyd Thompson stated that 1,500 persons were giving direct support to the accident investigation. This number, considered to be conservative, consisted of 600 persons from NASA, Air Force, Navy, Department of the Interior and other government agencies, and 900 from industry and universities.

"Board Proceedings," p. 3-24.

February 23

Apollo Program officials, headed by NASA Associate Administrator for Manned Space Flight Mueller, briefed Deputy Administrator Seamans, Apollo 204 Review Board members, and those present at the February 22 briefing. The presentation included a status report on the Apollo program, on special tests being conducted and planned as a result of the January 27 fire, and on proposed actions on the tentative Review Board findings.

Board Chairman Floyd Thompson, LaRC; Robert Van Dolah, Bureau of Mines; and Frank Borman, MSC, accompanied Seamans to Washington the following day, to brief Administrator James E. Webb

on the tentative findings and preliminary recommendations of the Board (see February 25).

The spacecraft-lunar module adapter (SLA) was removed from the launch vehicle and moved to the Manned Spacecraft Operations Building for examination.

"Board Proceedings," pp. 3-24, 3-25, 3-55 through 3-59.

February 23

William A. Lee was redesignated from Assistant Program Manager, Apollo Spacecraft Program Office, to Manager for the LM, ASPO, at MSC. Lee would be responsible for the management of the lunar module program, including MSC relations with Grumman and other supporting industrial concerns. Lee would report to ASPO Manager Joseph F. Shea and would assist him in the following areas:

1. Directing the design, development, and fabrication program contracted by NASA with Grumman.
2. Directing and planning detailed system engineering and system integration functions for the project, including review of engineering design work and system engineering studies by the contractor.
3. Development of the program of ground and flight tests at White Sands Missile Range, MSC, and KSC.
4. Monitoring contractors' operations to ensure adherence to specifications, to identify and solve problems which might impede the development of systems or subsystems.
5. Directing subordinate functional chiefs on all vehicle problems in the project and resolving or securing resolution of major technical, flight, and program problems.
6. Chairing the Change Control Panel for LM.

Manned Spacecraft Center Announcement, 67-34, "Manager for Lunar Module Apollo Spacecraft Program Office," Feb. 23, 1967.

February 25

NASA Administrator James E. Webb released a statement and Deputy Administrator Robert C. Seamans' third interim report on the Apollo 204 Review Board investigation, including tentative findings and preliminary recommendations.

Webb said the risk of fire in the 012 command module had been greater than recognized when procedures were established for the January 27 manned test that had ended in a fatal flash fire. Successful Mercury and Gemini flight experience with pure oxygen atmospheres and the difficulty of keeping dropped items out of complex wiring and equipment had led to placing Velcro pads, covers over wire bundles, and nylon netting in the CM cabin. Although mostly of low combustion material, they were not arranged to provide barriers to the spread of fire. Soldered joints also had melted, and leaked oxygen and fluids had contributed to the fire. The capsule rupture caused flames to rush over and around

astronaut couches to the break, preventing the crew from opening the hatch. And the environmental control unit would require careful examination and possible redesign.

Seamans reported an electrical malfunction was the most likely source of ignition of the fire, which apparently had three distinct phases. Principal preliminary recommendations of the Review Board were:

- Combustible material in the CM should be replaced whenever possible by nonflammable materials, all nonmetallic materials should be arranged to maintain fire breaks, oxygen or combustible liquid systems should be made fire resistant, and full flammability tests should be conducted with a mockup of each new configuration.
- A more rapidly and more easily operated CM hatch should be designed.
- On-the-pad emergency procedures should be revised to recognize the possibility of cabin fire.

The Board also suggested some subsystems and procedures could be improved for safety. It did not recommend that cabin atmosphere for operations in space be changed from pure oxygen at pressure of 3.5 newtons per square centimeter (5 pounds per square inch), but did recommend that tradeoffs between one-gas and two-gas atmospheres be reevaluated and that pressurized oxygen no longer be used in prelaunch operations.

"Board Proceedings," pp. 3-55 through 3-59; NASA News Release 67-38, Feb. 25, 1967.

February 27

NASA officials testified in an open hearing of the Senate Committee on Aeronautical and Space Sciences on the Apollo 204 fire. MSC Chief of Center Medical Programs Charles A. Berry reported that the cause of the three astronauts' deaths could be refined to asphyxiation from inhalation of carbon monoxide, bringing unconsciousness in seconds and death rapidly thereafter. The astronauts were believed to have become unconscious 18 to 20 seconds after the fire began.

Associate Administrator for Manned Space Flight George E. Mueller said NASA was introducing a three-pronged effort to prevent fire in the future: it would continue to minimize the possibility of ignition but would recognize the possibility would always exist, would seek to eliminate the chance of propagation if a fire began, and would seek to minimize consequences of a fire to the crew. Newly developed nonflammable materials would be used wherever possible and would be arranged to maintain fire breaks. Systems would be made more fire- and heat-resistant. The new CM cabin would be verified by full boilerplate flame tests. Design work was under way on a new unified hatch - a single integrated hatch to replace the double hatch and permit emergency exit in two seconds, yet remain safely sealed in flight. Emergency procedures were being revised. Spacecraft system design and qualification were being thoroughly reviewed. Alternative cabin atmospheres for checkout and launch were being studied, but during flight itself pure oxygen at 3.5-newtons-per-square-centimeter (5-pounds-per-square-inch) pressure still appeared safest for crews, with best balance among fire hazard, system reliability, and physiological risks.

First Apollo Block II spacecraft - CSM 101, the next in line at North American Aviation - was to incorporate all changes determined necessary by the investigation.

Senate Committee on Aeronautical and Space Sciences, *Apollo Accident: Hearings*, 90th Cong., 1st sess., pt. 2, Feb. 27, 1967.

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Part 1 (G)

Preparation for Flight, the Accident, and Investigation

March 1 through March 16, 1967

1967

March 1

Apollo 204 Review Board Chairman Floyd Thompson announced that the NASA Deputy Administrator had signed a memorandum February 27 designating the Director, Langley Research Center, custodian of the Review Board material.

Maxime Faget, MSC, presented a plan for screening equipment removed from the CM. The plan was intended to reduce the effort and time required to investigate and analyze the equipment. The Board agreed that the Panel Coordination Committee would establish an ad hoc committee to perform the screening.

"Board Proceedings," p. 3-25.

March 2

MSC ASPO reported to NASA Hq. that, because of many wiring discrepancies found in Apollo spacecraft 017, a more thorough inspection was required, with 12 main display control panels to be removed and wiring visually inspected for cuts, chafing, improper crimping, etc. The inspection, to begin March 2, was expected to take three or four days.

The two crates containing the mission control programmer (MCP) for CSM 017 had been delivered to Orlando, Fla., February 26 with extensive damage. Damage indicated that one crate might have been dropped upside down; its internal suspension system was designed for right-side-up shock absorption. The second crate contained holes that might have been caused by a fork lift. The MCP was returned to Autonetics Division of North American Aviation for inspection; barring dynamic programmer problems, the equipment was expected to be returned to KSC by March 7. The crates bore no markings such as "This Side Up" or "Handle with Care."

Ltr., Assistant Manager, ASPO to NASA Hq., Attn: Samuel C. Phillips, "ASPO Weekly Project Status Report to MSF," March 2, 1967.

March 3

The Apollo 204 Review Board decided to classify all material from command module 012 as Category A or Category B items. Category A would include all items that were damaged or identified as suspect or associated with anomalies. Category B would include items that appeared to be absolved of association with the January 27 accident; these would be available to the Apollo Program Office for use in nondestructive tests, but the Board would require copies of all test reports. Frank Borman, MSC, announced that disassembly of the command module was scheduled for completion by March 10.

"Board Proceedings," p. 3-26.

March 6

Although the final recommendations of the Apollo 204 Review Board were not yet in hand, MSC Deputy Director George M. Low believed the program "should start preparing a set of criteria which must be followed before we can resume testing in an oxygen environment. These criteria can then be used either to allow us to sign waivers on our testing embargo, or to go forward with additional messages, permitting testing, provided our criteria are met." He said the criteria would probably differ for:

1. spacesuit testing,
2. testing in oxygen chambers, and
3. testing within spacecraft.

"They would probably include such things as the exact environment within and outside the enclosure; the type of flammable material; safety precautions and procedures; and emergency procedures."

Memo, Low, MSC, to A. C. Bond, MSC, "Resumption of testing in an oxygen environment," March 6, 1967.

March 7

During a House Committee on Science and Astronautics hearing on NASA's FY 1968 authorization, NASA Administrator James E. Webb replied to questions by Congressmen John W. Wydler, Edward J. Gurney, and Emilio Q. Daddario about the impact of the Apollo 204 accident on schedules for accomplishing the lunar landing. Webb said:

"As the man asked by President Kennedy and later by President Johnson to take the responsibility for

this program, I have provided to you information showing the need for the 12 Saturn I-B's and the 15 Saturn V vehicles, and have stated that if we could get the kind of developed performance out of these vehicles on the early flights that would give us confidence that we could turn some of the earlier flights loose to go to the Moon, we might do this earlier than later.

"I have stated that if it took all 15 Saturn V's to complete the mission, it would not be done in this decade.

"Now the charts that you have seen this morning show that we are going to exercise the Apollo Command Module, the Service Module, and the Lunar Excursion Module around the Earth with the Saturn I-B vehicle, and that we will be doing this in this year and next year.

"It also shows that if we can fully test out and be very sure of the performance of the Saturn V vehicle with all of the equipment that is riding on it, we would put men into the third or more likely the fourth vehicle. Now that vehicle will have on it everything necessary to go to the Moon. But I cannot tell you today that it will be turned loose to the Moon even if everything on it is perfect, because my judgment as Administrator is that we are going to exercise this equipment around the Earth more than that before we start for the Moon.

"On the other hand, if everything is working perfectly, it would be logical to start; whether we get halfway and come back, I don't know. But many people who are very optimistic have assumed that because you plan now before any large rocket has ever flown to put all the equipment on the fourth flight that you are going to completely succeed and therefore you will in fact turn that loose to the Moon next year.

"I do not believe so, and have so stated time and time again, publicly and to this committee.

"I would like to say one other thing. In order to mobilize this effort to make everything fit together, we have prepared schedules that have target dates on them, and the target date for flying the fourth Saturn V has been in the summer or early fall of 1968. So many people have said, 'What is the earliest time you could go, isn't that really your target?' Well, obviously we want to go as soon as we can, and obviously if everything worked perfectly, this vehicle would be fully equipped to go. But my own judgment is that if we get this done by the end of 1969, we will be very, very fortunate; that the chance that we will do so, the odds that we will do so, the possibility of doing all the work necessary is less this year than it was last. And I testified at this table last year that it was less at that time than it had been the previous year. So we have had in my judgment some accumulation of difficulties which make the problem of doing it in this decade more difficult. But it is still not out of the picture, and shall I say, not impossible, although almost impossible to think of a 1968 date."

House Committee on Science and Astronautics, *1968 NASA Authorization: Hearings*, pt. 1, 90th Cong., 1st sess., Feb. 28, March 1, 2, 7, 8, 9, 1967, pp. 186-87.

March 7

The aft heatshield was removed from CM 012. A close inspection disclosed that the rupture in the floor extended about two-thirds of the circumference, a rupture much greater than originally estimated.

"Board Proceedings," p. 3-27.

March 8

Maxime A. Faget, MSC, presented the Apollo 204 Review Board a follow-up report on analysis of the arc indication on the lower-equipment-bay junction-box cover plate. The plate had been delivered to the KSC Material Analysis Laboratory and, in addition to the analysis of the arc indication, molten material found on the bottom of the plate would also be analyzed.

"Board Proceedings," p. 3-27.

March 8

NASA Associate Administrator for Manned Space Flight George E. Mueller stated that the February completion of MSFC studies of the Saturn V launch vehicle's payload and structural capability would permit an official revision of the payload from 43,100 kilograms to 44,500 kilograms; the CM weight would be revised from 5,000 to 5,400 kilograms; and the LM from 13,600 to 14,500.

Memo, Mueller to Seamans, "Weights of Major Apollo Flight Systems for Official Quotation," March 8, 1967.

March 10

J. Thomas Markley, Assistant Manager of ASPO, pointed out that within a few weeks MSC would face sustaining engineering problems. Many subcontractors not affected by the January 27 Apollo 204 accident would be phasing out of work; also many of them would be out of business long before the major flight program would start. He asked, "How do we now retain that talent for some necessary period of time?" He requested that Systems Engineering define requirements for retaining the technical capability for the overall systems, as well as the unique subsystem capability potentials that might need to be retained. He requested the package be prepared for his review by April 3.

Memo, Markley to John B. Lee, R. W. Williams, and J. G. McClintock (all of MSC), "Sustaining Engineering," March 10, 1967.

March 13

The Apollo 204 Review Board met with chairmen of Panels 12, 16, 19, and 20 (see February 7 and following entries) for critical review of their draft final reports. The reports were accepted subject to editorial corrections. The Witness Statements Panel (Panel 12) task had been to collect all data from witnesses of the 204 accident, including both eyewitnesses and console monitors, and to prepare the data for publication as appendix to the formal report. The panel also was to analyze the sequence of events and summarize any testimony that was contradictory to the main data.

Eyewitnesses and television and audio monitors from 18 agencies and contractors had been queried. Responses from 590 persons totaled 572 written and 40 recorded statements - adding up to 612 statements obtained (some persons submitted more than one statement or were interviewed twice). The sequence of events, as reconstructed from witness statements, follows:

Between 6:31:00 and 6:31:15 p.m. EST Jan.27, 1967

Witnesses in launch vehicle aft interstage, Level A-2:

Felt two definite rocking or shaking movements of vehicle before "Fire" report. Unlike vibrations experienced in past from wind, engine gimbaling, or equipment input.

Witnesses on Levels A-7 and A-8:

Heard "Fire" or "Fire in Cockpit" transmissions. Heard muffled explosion, then two loud whooshes of escaping gas (or explosive releases). Observed flames jet from around edge of command module and under White Room.

TV monitors:

Heard "Fire" or "Fire in Cockpit" transmissions. Observed astronaut helmet, back, and arm movements; increase of light in spacecraft window; and tonguelike flame pattern within spacecraft. Observed flame progressing from lower left corner of window to upper right; then spreading flame filled window, burning around hatch openings, lower portion of command module, and cables.

Between 6:31:15 and 6:33 p.m. EST

Witnesses on Levels A-7 and A-8:

Repeated attempts to penetrate White Room for egress action. Fought fires on CM, SM, and in White Room area.

TV monitors:

Observed smoke and fire on Level A-8. Progressive reduction of visibility of spacecraft hatch on TV monitor because of increasing smoke.

Between 6:33 and 6:37 p.m. EST

Repeated attempts to remove hatch and reach crew. Spacecraft boost protective cover removed by North American personnel J. D. Gleaves and D. O. Babbitt. Spacecraft outer hatch removed by North American personnel J. W. Hawkins, L. D. Reece, and S. B. Clemmons. Spacecraft inner

hatch opened and pushed down inside by Hawkins, Reece, and Clemmons, approximately 6:36:30 p.m. EST. No visual inspection of spacecraft interior possible because of heat and smoke. No signs of life.

Between 6:37 and 6:45 p.m. EST

Remains of fires extinguished. Fire and medical support arrived. Fireman J. A. Burch, Jr., and North American technician W. M. Medcalf removed spacecraft inner hatch from spacecraft. Examination of crew and verification of condition.

Between 6:45 p.m. EST Jan. 27 and 2:00 a.m. EST Jan. 28

Service structure cleared. Photographs taken. Crew removed. Complex and area under secure conditions. Personnel from Washington and Houston arrived and assumed control.

In its final report to the Review Board the panel indicated it believed that all persons with pertinent information regarding the accident had been queried.

"Board Proceedings" and Append. D, "Panels 12 thru 17," *Report of Apollo 204 Review Board to the Administrator, National Aeronautics and Space Administration*, April 5, 1967, pp. 3-28, 3-29, and D-12-3 through D-12-12.

March 13

The report of the Apollo 204 Review Board's In-flight Fire Emergency Provisions Review Panel (No. 20) listed seven findings and accompanying determinations. The panel had been charged with reviewing the adequacy of planned inflight fire emergency procedures and other provisions, as well as determining that emergency procedures existed for all appropriate activities. Among findings and determinations were:

- **Finding** - An inflight fire procedure was published and available to the Apollo 204 crew. The procedure was analyzed with reference to the Apollo 204 CM 012 configuration.
- **Determination** - Existing inflight fire procedures were deficient in the following areas:
 1. Turning off the cabin fans should be the first item of the procedural check list. This might help prevent the spread of fire by minimizing cabin air currents.
 2. The procedure should have specified the length of time to keep the cabin depressurized to ensure the fire had been extinguished and that all materials had cooled to below their ignition temperature.
- **Finding** - The command module depressurization time to drop from 3.5 to 0.4 newtons per square centimeter (from 5 to 0.5 pounds per square inch) could vary from 1 minute 45 seconds to 3 minutes 20 seconds, according to the flight-phase ambient temperature.
- **Determination** - The depressurization time was too slow to combat a cabin fire effectively

"Board Proceedings" and Append. D, "Panels 19 thru 21," *Report of Apollo 204 Review Board*, pp. 3-29 and D-20-3 through D-20-9.

March 13

The Special Tests Panel (No. 16) report to the Apollo 204 Review Board summarized activities from January 31 to February 23, when it had been merged with Panel 18. Panel 16 had been established to coordinate tests by other groups into an overall coordinated test plan. For example, flammability would be tested at several locations and the panel would ensure coordination. Major tests such as mockups of actual configurations and boilerplate destructive combustion tests would be considered by the panel. (See March 31 for Panel 18 report).

"Board Proceedings" and Append. D, "Panels 12 thru 17," *Report of Apollo 204 Review Board*, pp. 3-29 and D-16-3.

March 14

The Service Module Disposition Panel (No. 21) report accepted by the Apollo 204 Review Board said test results had failed to show any SM anomalies due to SM systems and there was no indication that SM systems were responsible for initiating the January 27 fire.

Panel 21 had been charged with planning and executing SM activities in the Apollo 204 investigation, beginning at the time the Board approved the command module demate. The task was carried out chiefly by Apollo line organizational elements in accordance with a plan approved by the Board and identifying documentation and control requirements.

The panel's major activities had been:

- Demating the service module and service module-lunar module adapter from the launch vehicle and moving them to the Manned Spacecraft Operations Building.
- Inspecting the exterior and interior areas of the service module.
- Making detailed system tests of all service module systems that were mechanically or electrically connected to the command module at the time of the accident.

"Board Proceedings," and Append. D, "Panels 19 thru 21," *Report of Apollo 204 Review Board*, pp. 3-29 and D-21-3 through D-21-6.

March 14

Apollo Program Director Samuel C. Phillips appointed a team to make a special audit of quality control and inspection. The audit would encompass Apollo spacecraft operations at Downey, Calif., KSC, and

elsewhere as required and would consider both contractor and government activities to determine if problems or deficiencies existed and recommend corrective action. The team was to use to the maximum extent the results of quality and inspection audit activities already under way at MSC and KSC.

Specifically, the team was to

1. review inspection standards for compatibility with Apollo program requirements, the degree to which these standards had been reduced to effective instructions and criteria for use by individual inspectors, and consistency between sites;
2. evaluate at each activity the program for selection, training, and evaluation of quality control and inspection personnel;
3. evaluate the adequacy of follow-up, closeout action and treatment by management of reported discrepancies in quality reports, failure reports, and program action requests;
4. evaluate the effectiveness of materials and parts control in ensuring that all materials and parts in end items as well as those used in processing and testing were in accordance with drawings and specifications; and
5. evaluate methods used to ensure quality of product from vendors and subcontractors.

Phillips named Rod Middleton of NASA OMSF to chair the team. Other members were Willis J. Willoughby, OMSF; Martin L. Raines, White Sands Test Facility; John Berkebile, MSFC; John D. Dickenson, KSC; and Jeff Adams and Robert Blount, MSC. Phillips requested a report by March 31.

TWX, NASA Hq. to MSC, MSFC, KSC, and White Sands Test Facility, March 14, 1967.

March 15

CSM 017 was in hold because of numerous discrepancies found in the spacecraft (see also March 2). Of 1,368 "squawks" concerning exposed wiring, 482 had been resolved by March 14. Spacecraft mechanical mating with the launch vehicle was projected for April 29 (but see also April 10 and June 20).

Ltr., Assistant Manager, ASPO, MSC, to NASA Hq., Attn: Samuel C. Phillips, "Weekly Project Status Report to MSF," March 15, 1967.

March 15

MSC informed Kennedy Space Center that, on release of the 012 service module from further investigation, the MSC Apollo Spacecraft Program Office would use it for program support. ASPO was establishing tests and test locations and asked KSC to deactivate SM systems and store the SM in a remote area for up to four weeks.

TWX, J. Thomas Markley, Assistant Manager ASPO, MSC, to Eugene McCoy, KSC, March 15, 1967.

March 15

MSC Director of Flight Crew Operations Donald K. Slayton requested that a rendezvous of the CSM with its launch vehicle S-IVB stage be a primary objective of the Apollo 2 mission [i.e., Apollo 7; Slayton apparently wanted to acknowledge only scheduled manned flights in the sequentially numbered Apollo missions]. He stated that the exercise could be conducted after the third darkness without interference with normal spacecraft checkout. "We believe a rendezvous with the booster on the first manned Apollo mission would be compatible with developing lunar mission capability at the earliest opportunity and request its incorporation into the primary mission objective." A memorandum from Flight Operations Director Christopher C. Kraft, Jr., on April 18 recognized "the need for CSM active rendezvous early in the Apollo flight program, but recommends that rendezvous not be considered during the first day of the Apollo 7 [the official flight designation for the first manned flight] mission. . . ." and presented four reasons:

1. the initial manned flight should concentrate on systems,
2. there was a reasonable probability that system problems or other unknowns would cause cancellation of rendezvous activity,
3. the early part of a first-of-a-kind mission was open-ended, and
4. crew and flight control experience was limited in updating and preparing for contingency deorbit, which would be further complicated by maneuvering effects on the orbit.

The Flight Operations Directorate recommended "that any rendezvous activity be scheduled after a minimum of one day of orbital flight, and that it be limited to a simple equiperiod exercise with a target carried into orbit by the spacecraft."

Memos, Director of Flight Crew Operations to Manager, ASPO, "Rendezvous exercise for the Apollo 2 Mission," March 15, 1967; Director of Flight Operations to Manager, ASPO, and Director of Flight Crew Operations, "Proposed rendezvous exercise for the Apollo 7 mission," April 18, 1967.

March 16

LeRoy E. Day, NASA OMSF, suggested to Apollo Program Director Samuel C. Phillips that, "if we are going to achieve a tight schedule of redesign and test activity as a result of AS-204 [accident], a number of changes in our mode of operation may be necessary." He recommended a concerted effort to systematize and discipline the scheduled reporting system between OMSF, ASPO, and the contractor. Day further suggested monthly "Black Saturday Reviews" by ASPO with OMSF participation. The reviews would be detailed and cover all spacecraft activities and should be given against the same set of baselines as all program reviews. Slips against such schedules would have to be thoroughly reviewed and a recovery plan developed.

Note, Day to Phillips, "Spacecraft redesign/test activity," March 16, 1967.

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Part 1 (H)

Preparation for Flight, the Accident, and Investigation

March 16 through April 5, 1967

1967

March 16

The Apollo 204 Review Board accepted the final report of its Administrative Procedures Panel (No. 15). The panel had been established February 7 to establish and document such activities as control of spacecraft work, logging and filing exhibits, logging Board activities, scheduling meetings, preparing agendas, and arranging for secretarial services and reproduction. During the investigation into the January 27 spacecraft fire, the panel had:

- Issued 25 Board administrative procedures.
- Established the administrative and Secretarial Support Office, which had provided support in two shifts seven days a week, unless otherwise required, with some additional third-shift support.
- Established the Photographic Data Control Center to correlate and distribute photographs and maintain a film library.
- Processed letters, telegrams, and telephone messages received offering assistance, recommendations, and comments.
- Periodically issued approved schedules of work.
- Established the Audio Magnetic Tape Library to control 0.64centimeter voice-transmission tape recordings about spacecraft 012 during the Space Vehicle Plugs-Out Integrated Test.

"Board Proceedings" and Append. D. "Panels 12 thru 17," *Report of Apollo 204 Review Board*, pp. 3-29 and D-15-3 through D-15-5.

March 18

The Apollo 204 Review Board accepted the final report of the Fracture Areas Panel (No. 10). The panel had been charged with inspecting spacecraft 012 for structural failures in the January 27 fire and analyzing them from the standpoint of local pressure, temperature levels, direction of gas flow, etc.

The panel inspected the spacecraft structures while they were still at Launch Complex 34 and continued through removal of the CM heatshield. Structural damage reports were made coinciding with spacecraft disassembly phases. As major subsystems were removed from the spacecraft they were visually inspected. Buckles, fractures, cracks, melted areas, localized arcing or pitting in metal components, and obvious direct wire shorts were noted and documented.

Panel findings and determinations included:

Finding

Spacecraft data during the Plugs-Out Test gave indications from which a spacecraft pressure history could be estimated.

Determination

1. The CM cabin structure had ruptured at 6:31:19.4 (± 0.1) p.m. EST January 27 at an estimated minimum cabin pressure of 20 newtons per sq cm (29 psia).
2. The CM cabin structure had sustained cabin pressure in excess of its designed ultimate pressure of 8.9 newtons-per-sq-cm (12.9-psi) differential (19 newtons per sq cm; 27.6 psia). Cabin pressure at rupture probably reached 20 to 26 newtons per sq cm (29 to 37.7 psia).
3. The estimated average gas temperature at rupture exceeded 644 kelvins (700 degrees F).

Finding

The CM cabin ruptured in the aft bulkhead adjacent to its juncture with the aft sidewall.

Determination

The failure occurred because of excessive meridional tensile stress in the inner face sheet at the junction of the weld land to the thinner face sheet. The fracture originated on the right-hand side of the command module.

Finding

The CM cabin structure was penetrated in the aft bulkhead beneath the environmental control unit and the aft sidewall.

Determination

1. The loss of structural integrity at these penetrations occurred after the primary rupture.
2. Failure of the water glycol and oxygen lines near the environmental control unit resulted in local burning and melting of the adjacent structure.

Finding

The aft heatshield stainless-steel face sheets were melted and eroded.

Determination

The temperature of the flame and gas exiting from the fracture origin exceeded 1640 K (2500 degrees F).

"Board Proceedings" and Append. D, "Panels 6 thru 10," *Report of Apollo Review Board*, pp. 3-30 and D-10-3 through D-10-7.

March 18-19

The final report of the Spacecraft and Ground Support Equipment Configuration Panel (No. 1) was accepted by the Apollo 204 Review Board. The panel had been assigned the task of documenting the physical configuration of the spacecraft and ground support equipment immediately before and during the January 27 fire, including equipment, switch position, and nonflight items in the cockpit. The panel was also to document differences from the expected launch configuration and configurations used in previous testing (such as altitude-chamber testing).

During the investigation the panel had discovered a number of items which might have had relevance to flame propagation:

- An engineering order, released at North American Aviation's Downey facility on January 20, provided direction to inspect the polyurethane foam in specified areas and coat the silicone rubber to meet flammability requirements. The direction was not recorded in the configuration verification record as of the start of the Space Vehicle Plugs-Out Integrated Test and was not accomplished on spacecraft 012. This item was considered as possibly significant in terms of fuel for the fire and a medium for flame propagation.
- Polyethylene bags covered the hose fitting for the drinking water dispenser and the battery-instrumentation cable and connectors and transducer, which were placed on the aft bulkhead near the batteries. The bags were made of nonflight materials.
- Two polyurethane pads, covered with Velostat, were stowed over couch struts. The pads were placed in the spacecraft to protect the struts, wiring, and aft bulkhead during the planned emergency egress at the end of the test. These items were of nonflight material and were not documented by quality inspection records.
- Three packages of switching checklists from the Operational Checkout Procedure and one package of system malfunction procedures, in a manila folder, were stowed on the crew couches and on a shelf. These items were on unqualified paper and, while required for the test, they were not documented by quality inspection records.
- Nylon protective sleeves were covering all three crewmen's oxygen umbilicals. These sleeves were nonflight items.
- Three ground-support-equipment window covers had been temporarily installed to protect the windows and were nonflight items in the spacecraft at the time of the accident. Another such cover for the side hatch window was removed by the crew and stowed inside the command module. These covers were of nylon fabric; flight covers were made of aluminized Mylar.
- Velcro pile had been installed to protect the Velcro hood on the command module floor. It would have been removed before the flight.
- "Remove before flight" streamers installed in the command module interior were additional nonflight items.
- Polyethylene zipper tubing, installed to protect hand controller cables, was a nonflight item and was additional material in the command module.

The panel's summary of findings and determinations included:

Finding

Eighty engineering orders effective for spacecraft 012 had not been carried out at the time of the accident. Of these, twenty were specified to be completed after the test; four did not affect configuration.

Determination

Test requirements had no defined relationships with the open status of 56 engineering orders. The reason not all work items and engineering orders were closed was late receipt of changes or further work scheduled to be completed before launch.

Finding

Items not documented by quality inspection records had been placed on board the spacecraft during preparation for the Space Vehicle Plugs- Out Integrated Test.

Determination

Procedures for controlling entry of items into the spacecraft were not strictly enforced.

"Board Proceedings" and Append. D, "Panels I thru 4," *Report of Apollo 204 Review Board*, pp. 3-30 and D-1-5 through D-1-19.

March 18-19

The Apollo 204 Review Board accepted the final report of the Security Operations Panel (No. 14). The panel had been assigned to review existing security practices at KSC and supporting areas for adequacy and recommend any needed changes. Practices included access control, personnel sign-in requirements, buddy systems, and background investigation requirements.

The panel's report submitted six findings and determinations, which included:

Finding

KSC security personnel or uniformed security personnel had been assigned to all locations requiring safeguarding measures, including launch vehicle stages and spacecraft from the time of arrival at KSC until the time of the January 27 accident.

Determination

The number of KSC and uniformed security personnel members used was adequate.

Finding

The Apollo Preflight Operations Procedures - dated October 17, 1966, and January 24, 1967 - for access control of test and work areas, required that<

1. access controls to spacecraft work areas be exercised by the contractor;
2. the contractor maintain a log of all personnel permitted access during off-shift and nonwork periods; and
3. the contractor control and log command module ingress and egress.

Determination

The procedures established in the Apollo Preflight Operations Procedures were not followed for spacecraft 012 in that

1. the contractor failed to exercise adequate access controls on the fifth, sixth, and seventh spacecraft levels;
2. the contractor failed to maintain an off-shift log; and
3. the command module ingress-egress log was inadequately maintained.

"Board Proceedings" and Append. D, "Panels 12 thru 17," *Report of Apollo 204 Review Board*, pp. 3-30 and D-14-3 through D-14-7.

March 18-20

The Apollo 204 Review Board accepted the final report of its Origin and Propagation of Fire Panel (No. 5). The panel task had been to "conduct inspections, chemical analyses [and] spectrographic analysis of spacecraft, parts or rubble, or use any other useful techniques to establish point of [the CM 012] fire origin, direction and rate of propagation, temperature gradients and extremes. The nature of the fire, the type of materials consumed, the degree of combustion shall be determined."

Following an intensive study - which considered ignition sources, description, and course of the fire - the panel listed 10 findings and determinations in its final report, including:

Finding

Severe damage to wiring was found at the bottom of the power equipment bay along the aft bulkhead. Evidence of arcing was found and damage was less severe in the right-hand direction of this bay.

Determination

Electrical arcing in the extreme lower left-hand corner of this bay could have provided a primary ignition source.

Finding

Right-hand portions of the left-hand equipment bay were severely damaged. Wiring, tubing, and components in the carbon dioxide absorber compartment and oxygen/water panel compartment were burned and melted. Penetrations in the aft bulkhead and pressure vessel wall were observed. The carbon dioxide absorber compartment showed heavy fire damage; failure was due to pressure overload and melting caused by the fire in this area.

Determination

Electrical arcing in the right-hand portion of this bay could have provided a primary ignition source.

Finding

Evidence of electrical arcs from conductor to conductor and from conductor to structure were found.

Determination

No arc could be positively identified as the unique ignition source. Three were found that had all the elements needed to cause the disaster. Two of these showed evidence of poor engineering and installation.

"Board Proceedings" and Append. D, "Panel 5," *Report of Apollo 204 Review Board*, pp. 3-30 and D-5-3 through D-5-15.

March 19

The final report of the Ground Emergency Provisions Panel (Panel 13) accepted by the Apollo 204 Review Board submitted 14 findings and determinations. The panel had been charged with reviewing the adequacy of planned ground procedures for the January 27 spacecraft 012 manned test, as well as determining whether emergency procedures existed for all appropriate activities. The review was to concentrate on activity at the launch site and to include recommendations for changes or new emergency procedures if deemed necessary.

The panel approached its task in two phases. First, it reviewed the emergency provisions at the time of the CM 012 accident, investigating

1. the procedures in published documents,
2. the emergency equipment inside and outside the spacecraft, and
3. the emergency training of the flight crew and checkout test team.

Second, the panel reviewed the methods used to identify hazards and ensure adequate documentation of safety procedures and applicable emergency instructions in the operational test procedures.

Findings and determinations included:

Finding

The applicable test documents and flight crew procedures for the AS- 204 Space Vehicle Plugs-Out Integrated Test did not include safety considerations, emergency procedures, or emergency equipment requirements relative to the possibility of an internal spacecraft fire during the operation.

Determination

The absence of any significant emergency preplanning indicated that the test configuration (pressurized 100-percent-oxygen cabin atmosphere) was not classified as potentially hazardous.

Finding

The propagation rate of the fire in the accident was extremely rapid. Removal of the three spacecraft hatches, from either the inside or the outside, for emergency exit required a minimum of 40 to 70 seconds, respectively, under ideal conditions.

Determination

Considering the rapid propagation of the fire and the time constraints imposed by the spacecraft hatch configuration, it is doubtful that any amount of emergency preparation would have precluded injury to the crew before egress.

Finding

Procedures for unaided egress from the spacecraft were documented and available. The AS-204

flight crew had participated in a total of eight egress exercises employing those procedures.

Determination

The 204 flight crew was familiar with and well trained in the documented emergency crew procedures for effecting unaided egress.

Finding

The spacecraft pad work team on duty at the time of the accident had not been given emergency training drills for combating fires in or around the spacecraft or for emergency crew egress. They were trained and equipped only for a normal hatch removal operation.

Determination

The spacecraft pad work team was not properly trained or equipped to effect an efficient rescue operation under the conditions resulting from the fire.

Finding

Frequent interruptions and failures had been experienced in the overall communications system during the operations preceding the accident. At the time the accident occurred, the status of the system was still under assessment.

Determination

The status of the overall communications was marginal for the support of a normal operation. It could not be assessed as adequate in the presence of an emergency condition.

Finding

Emergency equipment provided at the spacecraft work levels consisted of portable carbon dioxide fire extinguishers, rocket-propellant-fuel-handler's gas masks, and 4.4-centimeter-diameter fire hoses.

Determination

The existing emergency equipment was not adequate to cope with the conditions of the fire. Suitable breathing apparatus, additional portable carbon dioxide fire extinguishers, direct personnel evacuation routes, and smoke removal ventilation were significant items that would have improved the reaction capability of the personnel.

Finding

Under the existing method of test procedure processing at KSC, the safety offices reviewed only the procedures noted in the operational checkout procedure outline as involving hazards. Official approval by KSC and Air Force Eastern Test Range Safety was given after the procedure was published and released.

Determination

The scope of contractor and KSC Safety Office participation in test procedure development was loosely defined and poorly documented. Post-procedure-release approval by the KSC Safety Office did not ensure positive and timely coordination of all safety considerations.

"Board Proceedings"; Append. A, "Board Minutes"; and Append. D, "Panels 12 thru 17," in *Report of Apollo 204 Review Board*, pp. 3-28 through 3-30, A-1 12, and D-13-3 through D-13-13.

March 19

The Materials Work Panel (Panel 8, also referred to as Materials Review' Panel) in its final report

accepted by the Apollo 204 Review Board cited a number of findings on flammable materials in spacecraft 012. The panel's task had included the following, from its detailed work statement:

- "Assemble, summarize, compare and interpret requirements and data describing the flammability of nonmetallic materials exposed to the crew bay environment of the spacecraft and in related applications.
- "Specify and authorize performance of tests and/or analyses to furnish additional information as to flammability characteristics of these materials alone, and in combination with fluids known or postulated to have been in the spacecraft 012 cabin.
- "Panel No. 8, in support of Panel No. 5 (Origin and Propagation of Fire) shall interpret and implement the requirements for analyses of debris removed from the spacecraft."

Panel 8 classified its findings in six categories: Materials Configuration; Routine Materials Test; Fire Initiation Special Investigation; Fire Propagation Special Investigation; Materials Installation Criteria and Controls; and Technical Data and Information Availability. The findings and determinations included:

Finding

Complete documentation identifying potentially combustible nonmetallic materials in spacecraft 012 was not available in a single readily usable format. A total of 2,528 different potentially combustible nonmetallic materials that were probably used on spacecraft 012 was found by a review of available documentation.

Determination

The program for identifying and documenting nonmetallic materials used in the spacecraft, including their weights and surface areas, was not adequate.

Finding

Raschel Knit, Velcro, Trilock, and polyurethane foams burn about twice as fast (in the downward direction) in oxygen at a pressure of 11.4 newtons per sq cm (16.5 psia) as at 3.5 newtons per sq cm (5 psia).

Determination

The primary fuels for the fire burned more than twice as fast in the early stages of the spacecraft 012 fire in accident conditions (pressure of 11.4 newtons per sq cm) as in the space flight atmosphere for which they were evaluated (3.5 newtons per sq cm).

Finding

Surface and bulk damage of materials in spacecraft 012 varied from melting and blistering of aluminum alloys, combustion of Velcro, and burning of Teflon wire insulation to slight surface damage and melting of nylon fabrics.

Determination

The fire filled the spacecraft interior. The most intense heat was in the lower left front area around the environmental control unit. Surface temperatures in excess of 800 kelvins (1,000 degrees F) were reached in areas such as the front and left side of the spacecraft. Surface temperatures were less than 500 K (400 degrees F) in isolated pockets above the right-hand couch.

Finding

The rate of flame propagation, the rate of pressure increase, the maximum pressures achieved, and the extent of conflagration in 3.5 newtons-per-sq-cm (5-psia) oxygen boilerplate tests was much less severe than observed in the 11.4-newton (16.5-psia) oxygen boilerplate tests. Burning or charring was limited to approximately 29 percent of the nonmetallic materials by oxygen depletion.

Determination

The conflagration that occurred in spacecraft 012 at a pressure of 11.4 newtons per sq cm would be far less severe and slower in a spacecraft operating with an oxygen environment at 3.5 newtons, if additional large quantities of oxygen are not fed into the fire.

Finding

North American Aviation materials selection specification requires that a material pass only a 500 K (400 degrees F) spark-ignition test in oxygen at 10.1 newtons per sq cm (14.7 psia).

Determination

NAA criteria for materials flammability control were inadequate.

Finding

No flammability criteria or control existed covering nonflight items installed in CM 012 for test.

Determination

Lack of control of nonflight material could have contributed to the fire.

Finding

The NASA materials selection criteria required that a material pass a 500 K (400 degrees F) spark-ignition test and a 1.27-an-per-sec combustion rate (measured downward in oxygen at 3.5 newtons per sq cm). Raschel Knit and Velcro (hook) pass this test.

Determination

The NASA criteria for materials flammability were not sufficiently stringent.

Finding

The system for control of nonmetallic materials use at MSC during the design and development of government furnished equipment used in CM 012 depended on identification of noncompliance with criteria by the development engineers.

Determination

The NASA materials control system was permissive to the extent that installation or use of flammable materials were not adequately reviewed by a second party.

Finding

Nonmetallic materials selection criteria used by North American and NASA were not consistent. The NASA criteria, although more stringent, were not contractually imposed on the spacecraft contractor.

Determination

Materials were evaluated and selected for use in CM 012 using different criteria. Application of the NASA criteria to the command module would have reduced the amount of the more flammable materials (Velcro and Uralane foam).

Finding

Alternate materials that are nonflammable or significantly less flammable than those used on spacecraft 012 were available for many applications.

Determination

The amount of combustible material used in command modules can be limited.

Finding

Current information and displays of the potentially flammable materials configuration of spacecraft 012 were not available before the fire.

Determination

Maintenance of data and displays at central locations and test sites for management visibility and control of flammable materials is feasible and useful.

"Board Proceedings"; Append. A, "Board Minutes"; and Append. D, "Panels 6 thru 10," in *Report of Apollo 204 Review Board*, pp. 3-30, A-112, and D-8-3 through D-8-35.

March 20

NASA announced it would use the Apollo-Saturn 204 launch vehicle to launch the first lunar module on its unmanned test flight. Since the 204 vehicle was prepared and was not damaged in the Apollo 204 fire in January, it would be used instead of the originally planned AS-206.

NASA News Release 67-67, March 20, 1967.

March 20

The Deputy Administrator of NASA designated Langley Research Center custodian of all materials dealing with the investigation and review of the January 27 Apollo 204 accident. Review Board Chairman Floyd Thompson, LaRC, who had the responsibility of determining the materials to be included in the final repository, determined that the following categories of materials were to be preserved:

1. Reports, files, and working materials;
2. Medical reports;
3. Spacecraft 012 command module, its systems, components, and related drawings.

Category 1 materials would be stored at LaRC, Category 2 at MSC, and Category 3 at KSC.

In other actions Robert W. Van Dolah, Chairman of the Origin and Propagation of Fire Panel, reported on a test being conducted in CM 014 to attempt to establish the amount of static electricity that might be generated by a suited crewman; and members of the Board met with MSC Director Robert R. Gilruth and members of his staff, as well as management and engineering personnel of North American Aviation, for a presentation concerning solder joints in the CM.

"Board Proceedings," pp. 3-30, 3-31.

March 21

Final report of the Disassembly Activities Panel (No. 4) was accepted by the Apollo 204 Review Board. Panel 4 had been assigned to develop procedures for disassembly of spacecraft 012 for inspection and failure analysis. Disassembly was to proceed step by step in a manner permitting maximum information to be obtained without disturbing the evidence - in both the cockpit and the area outside the pressure hull. Cataloging documentary information within the spacecraft and displaying the removed items were a part of the required procedures.

Procedures followed included the following actions:

- Immediately after the January 27 accident, NASA KSC Security placed Launch Complex 34 under additional security. Special guards were assigned to the service structure and to the adjustable level at the entrance of the CM. Controls were established for personnel access to the service structure and the CM.
- After the accident, before disturbing any items in the spacecraft, a series of photographs was taken. A step-by-step photography method was established as a standard operating procedure for the Disassembly Activities Panel.
- The first step toward an orderly disassembly was to ensure safe working conditions at the spacecraft. A meeting with KSC and Air Force Eastern Test Range Safety personnel established procedures and safety rules.
- After the couches were removed, a special false floor was suspended from the couch strut fittings to provide access to the entire inside of the spacecraft without disturbing any evidence. The false floor was fabricated from aluminum angles supporting 2-centimeter-thick, 46-centimeter plexiglass squares.
- The Review Board appointed a Panel Coordination Committee to carry out new procedures to ensure closely controlled and coordinated equipment removal.

The Disassembly Activities Panel cataloged and displayed the 1,261 items removed from spacecraft 012 during the investigation. The Pyrotechnics Installation Building (PIB) at KSC was assigned as an area in which components removed from the command module could be placed in bonded storage yet still be available for inspection by investigative personnel. The following areas were established in the PIB:

1. **Bond room** - a bonded area to receive components as they were removed from CM 012. This area was provided with a receiving table; 10 storage cabinets for small components; and areas for large components and items associated with the investigation but not from the command module itself.
2. **Astronaut equipment room and work room** - an area in which the spacesuits and other government furnished crew equipment were investigated.
3. **Bonded display area** - an area in which components could be displayed under controlled conditions to permit investigators to examine CM 012 components visually.
4. **Command module 012 work area** - The command module was placed in a supporting ring

within an existing workstand in the PIB and remained in this area until the aft heatshield was removed. The CM was then transferred to a standard support ring in the north end of the building. Technicians continued the disassembly activities while the CM was in these areas.

5. **Spacecraft 014 CM** - Spacecraft 014 CM (identical in configuration to spacecraft 012) was shipped to KSC on February 1 to assist the Apollo 204 Review Board in the investigation. This CM was placed in the PIB and was used for practicing difficult removals of CM 012 components.
6. **Mockup No. 2** - Mockup No. 2, a full-scale plywood command module, was brought to KSC and placed in the PIB February 8. The mockup had been configured with Velcro, debris traps, couch positioning, etc., to duplicate CM 012 configuration at the time of the fire.
7. **Half-scale mockup** - A half-scale mockup of the CM interior was placed in the bonded display area February 8 to display half-scale interior surface photographs taken after the fire in CM 012.

"Board Proceedings," and Append. D, "Panels 1 thru 4," *Report of Apollo 204 Review Board*, pp. 3-31 and D-4-3 through D-4-8.

March 25

The Apollo 204 Review Board accepted the final report of its Test Environment Panel (Panel 2). Panel 2 had been assigned responsibility for the history of all test environments encountered by spacecraft 012 that were considered germane to system validation from a fire hazard standpoint, including qualification testing of systems and subsystems. The panel was particularly to emphasize qualification tests in pure oxygen with regard to pressures, temperature, time of exposure, and simulation of equipment malfunctions. It was also to indicate any deficiencies in the test program related to the problem; comparison with previous tests of appropriate flight, house, or boilerplate spacecraft; and documentation of any problems encountered which related to fire hazard.

The panel reviewed all tests pertinent to the investigation. The qualification tests were reviewed at MSC, covering more than 1,000 documents. Vehicle tests were reviewed at North American Aviation's Downey, Calif., facility, covering more than 500 documents. Summaries of these efforts were reviewed by the panel at KSC to determine any test program deficiencies.

The final report of the panel included six findings and determinations. Among them were:

Finding

Not all crew compartment equipment had been tested as explosion proof.

Determination

Testing of possible ignition sources had been insufficient.

Finding

Some CM equipment exhibited arcing or shorting either during certification or during spacecraft 012 testing. There was no positive way to determine from the records reviewed whether spacecraft anomalies (possibly caused by an arc or a short) were reviewed by system engineers and the test conductor before a test.

Determination

Review of possible ignition sources before manned testing was inadequate.

Finding

Not all equipment installed in CM 012 at the time of the accident was intended for flight (some components were installed for test purposes only).

Determination

The suitability of this equipment in the CM for this test was not established.

"Board Proceedings" and Append. D, "Panels 1 thru 4," *Report of the Apollo 204 Review Board*, pp. 3-32 and D-2-3 through D-2-8.

March 25 - April 24

NASA Hq. Office of Manned Space Flight informed KSC, MSFC, and MSC of approved designations for Apollo and Apollo Applications missions:

1. all Apollo missions would be numbered sequentially in the order flown, with the next mission to be designated Apollo 4, the following one Apollo 5, etc., and
2. the Apollo Applications missions would be designated sequentially as AAP-1, AAP-2, etc. The number designations would not differentiate between manned and unmanned or uprated Saturn I and Saturn V missions.

In a letter to George E. Mueller, OMSF, on March 30, MSC Deputy Director George M. Low offered two suggestions, in keeping with the intent of the NASA instruction yet keeping the designation Apollo 1 for spacecraft 012. NASA Hq. had approved that designation before the January 27 fire claimed the lives of Astronauts Virgil I. Grissom, Edward H. White II, and Roger B. Chaffee; and their widows requested that the designation be retained. The suggestions were:

3. Consider the AS-201, 202, and 203 missions part of the Saturn I (as opposed to uprated Saturn I) series; reserve the designation Apollo 1 for spacecraft 012; and number the following flights Apollo 2, etc., or
4. Designate the next flight Apollo 4, as indicated by Headquarters, but apply the scheme somewhat differently for missions already flown. Specifically, put the Apollo 1 designation on spacecraft 012 and then, for historic purposes, designate 201 as mission 1-a, 202 as mission 2 and 203 as mission 3.

A memorandum to the NASA space flight Centers, North American Aviation, and certain Headquarters personnel from the NASA Assistant Administrator for Public Affairs on April 3 stated that the Project Designation Committee had approved the Office of Manned Space Flight's recommendations and that Mueller had begun implementation of the designations.

On April 24, OMSF further instructed the Centers that AS-204 would be officially recorded as Apollo 1, "first manned Apollo Saturn flight - failed on ground test." AS-201, AS-202, and AS-203 would not be

renumbered in the "Apollo" series, and the next mission would be Apollo 4.

TWX, Mueller, NASA OMSF, to KSC, MSFC, MSC, "Apollo and AAP Mission Designation," March 25 and April 24, 1967; ltr., Low to Mueller, March 30, 1967; memo, Julian Scheer, NASA Assistant Administrator for Public Affairs, to distr., April 3, 1967.

March 27

A meeting at MSC considered fire detection systems and fire extinguishers. Participants were G. M. Low, K. S. Kleinknecht, A. C. Bond, J. N. Kotanchik, J. W. Craig, M. W. Lippitt, and G. W. S. Abbey. Craig and Lippitt had visited Wright Field, Ohio, and from their findings the following conclusions were reached:

1. no fire detection system was available for incorporation into the Apollo spacecraft;
2. a reliable system would be desirable, but the system must not give false alarms when used in a closed spacecraft environment and yet must give adequate warning of fire;
3. two kinds of systems appeared to be in varying states of development - systems using infrared or ultraviolet sensors and systems sensing ionized particles or condensation nuclei in the atmosphere;
4. a work statement should be prepared, with the help of personnel at Wright Field, for the purpose of receiving specific proposals on available systems; and
5. the ultimate goal should be to develop a system ready for flight use within six months.

Memo for the Record, George M. Low, "Fire detection/extinguishment," March 27, 1967.

March 28

Apollo 204 Review Board Chairman Floyd Thompson asked for a report on the Pyrotechnic Installation Building activity. Disassembly of spacecraft 012 had been completed March 27. Of 1,261 items logged through the bond room for display to Board and panel personnel, about 1,000 items were from the CM.

The final report of the Screening Committee was distributed to the Board by George T. Sasseen, KSC, for review. Sasseen stated that the following items would be retained as Category A (items damaged or identified as suspect or associated with anomalies).

- Lower equipment bay junction box cover plate
- Command pilot's torso harness
- Velcro and Raschel netting
- Static inverter 2
- Main display control panel 8
- Instrumentation data distribution panel J800/J850
- Octopus cable.

Maxime A. Faget, MSC, advised the Board that the lithium hydroxide cartridge had been sent to MSC for analysis. Hubert D. Calahan, OMSF, was appointed courier to handcarry the item to MSC and Richard S. Johnston, MSC, was designated the Board's witness for the analysis. MSC's Crew Systems Laboratory was to make the analysis and report to the Board. The analysis was to identify contaminants to determine the quantity of carbon dioxide in the lithium hydroxide.

William D. Mangan, Langley Research Center, joined the legal staff supporting the Board.

"Board Proceedings," pp. 3-32, 3-33.

March 29

At the request of the Manager of the MSC Lunar Surface Programs Office, NASA Associate Administrator for Space Science and Applications Homer E. Newell considered alternate Array B configurations of the Apollo Lunar Surface Experiments Package to alleviate a weight problem. Instead of a single array, he selected two configurations for ALSEP III and ALSEP IV:

ALSEP III Experiments:

Passive Seismic, Heat Flow (w/Lunar Drill), Cold Cathode Gauge, and Charged Particle Lunar Environment.

ALSEP IV Experiments:

Passive Seismic, Active Seismic, Suprathermal Ion Detector/Cold Cathode Gauge, and Charged Particle Lunar Environment.

Newell requested that both configurations be built but that, if program constraints permitted the fabrication of only one array for ALSEP II and IV, ALSEP III should be given the preference. The Apollo Program Director concurred in the Newell recommendation.

Ltr., Apollo Program Director, NASA Hq., to R. O. Piland, MSC, March 29, 1967.

March 29-30

The Apollo Site Selection Board meeting at NASA Hq. March 29 heard MSC presentations on lunar landing site selection constraints, results of the *Orbiter II* screening, and reviews of the tasks for site analysis. MSC made recommendations for specific sites on which to concentrate during the next four months and recommended that the landing sites for the first lunar landing mission be selected by August 1. The Board accepted the recommendations. A Surveyor and Orbiter meeting the following day considered the targeting of the Surveyor C mission and the Lunar Orbiter V mission. MSC representatives at the two meetings were John Eggleston and Owen E. Maynard.

Memo, Chief, Mission Operations Div., MSC, to Manager, ASPO, "Trip Report - Apollo Site Selection

Board and Surveyor/Orbiter Utilization Committee Meetings," April 20, 1967.

March 29 - April 4

H. C. Creighton, A. R. Goldenberg, and Guy N. Witherington, all of KSC, inspected spacecraft 101 wire bundles March 29 at the request of CSM Manager Kenneth S. Kleinknecht of MSC. Kleinknecht had asked that they give him a recommendation as to whether the bundles should be removed or whether they could be repaired in place. On April 4, they reported to Kleinknecht that time had not been sufficient to determine the complete status of the wiring. A superficial inspection about five-percent complete had indicated some serious discrepancies, for which they made some recommendations, but they recommended a more detailed inspection of the spacecraft 101 wire bundles.

Memo, Creighton, Goldenberg, and Witherington to Kleinknecht, "Condition of Spacecraft 101 Wire Bundles," April 4, 1967.

March 30

The Apollo 204 Review Board accepted the report of its Sequence of Events Panel (No. 3), which had been charged with analyzing data from immediately before and during the January 27 fire, including digital, analog, voice communications, and photography. The data was required to display significant events as they occurred with the precise time tag. Time histories of all continuous or semicontinuous recorded parameters and correlation of parameter variations and events were to be recorded, as well as interpretation of the analysis results. Where pertinent, normal expected variations were to be compared with those actually obtained.

Panel 3 had served as a separate panel from January 31 through February 23, when it was merged with the Integration Analysis Panel (No. 18). Panel 3 reported one finding and one determination:

Finding

The data recorded from the spacecraft and ground instrumentation system during the Spacecraft Plugs-Out Test were found to be valid except for three brief dropouts after 6:31:17 EST, January 27 (13 seconds after the pilot reported "fire in the cockpit"). All onboard data transmission ended about 6:31:22 EST.

Determination

The onboard instrumentation system functioned normally before and during the initial phase of the fire. There were no indicated malfunctions in any of the instrumentation sensors during this period.

"Board Proceedings" and Append. D, "Panels 1 thru 4," *Report of Apollo 204 Review Board*, pp. 3-33 and D-3-3 through D-3-6.

March 30

The Apollo 204 Review Board met with its Test Procedures Review Panel (Panel No. 7) to complete acceptance of the panel's final report. The panel had been established February 7 to document test procedures actually employed during the day of the January 27 accident and to indicate deviations between planned procedures and those used. The panel was to determine changes that might alleviate fire hazard conditions or that might provide for improved reaction or corrective conditions and review the changes for applicability to other tests.

Among the panel's findings and determinations were:

Finding

209 pages of the 275-page Operational Checkout Procedure (OCP) were revised and released on the day before the test. However, less than 25 percent of the line items were changed.

Approximately one percent of the change was due to errors in technical content in the original issue of the procedure. In addition, 106 deviations were written during the test.

Determination

Neither the revision nor the deviations were known to have contributed specifically to the incident. The late timing of the change release, however, prevented test personnel from becoming adequately familiar with the test procedure before use.

Finding

During the altitude chamber tests, the cabin was pressurized at pressures greater than sea level with an oxygen environment two and a half times as long as the cabin was pressurized with oxygen before the accident during Plugs-Out Test.

Determination

The spacecraft had successfully operated with the same cabin conditions in the chamber for a greater period of time than on the pad up to the time of the accident.

Finding

Troubleshooting the communication problem was not controlled by any one person, and was at times independently run from the spacecraft, Launch Complex 34 Blockhouse, and the Manned Spacecraft Operations Building. Communications switching, some of which was not called out in OCP, was performed without the control of the Test Conductor.

Determination

The uncontrolled troubleshooting and switching contributed to the difficulty experienced in attempting to assess the communication problem.

Finding

KSC was not able to ensure that the spacecraft launch operations plans and procedures adequately satisfied, in a timely way, the intent of MSC. Changes in spacecraft testing by KSC could not be kept in phase with the latest requirements of MSC. Prelaunch checkout requirements were not formally transmitted to KSC from MSC.

Determination

Prelaunch-test-requirements control for the Apollo spacecraft program was constrained by slow response to changes, lack of detailed KSC-MSO inter-Center agreements, and lack of official NASA-approved test specifications applicable to prelaunch checkout.

Finding

The decision to perform the Plugs-Out Test with the flight crew, closed hatch, and pure oxygen cabin environment made on October 31, 1966, was a significant change in test philosophy.

Determination

There was no evidence that this change in test philosophy was made so late as to preclude timely incorporation into the test procedure.

"Board Proceedings" and Append. D, "Panels 6 thru 10," *Report of Apollo 204 Review Board*, pp. 3-33 and D-7-3 through D-7-13.

March 30

The Apollo 204 Review Board was scheduled to review the final report of its Historical Data Panel (Panel No. 6). The panel had been assigned to assemble, summarize, and interpret historical data concerning the spacecraft and associated systems pertinent to the January 27 fire. The data were to include such records as the spacecraft log, failure reports, and other quality engineering and inspection documents. In addition the panel prepared narratives to reflect the relationship and flow of significant review and acceptance points and substantiating documentation and presented a brief history of prelaunch operations performed on spacecraft 012 at Kennedy Space Center.

In its final report to the Review Board the Historical Data Panel submitted eight findings and determinations. Among them were:

Finding

The Ingress-Egress Log disclosed several instances where tools and equipment were carried into the spacecraft, but the log did not indicate these items had been removed.

Determination

Maintenance of the Ingress-Egress Log was inadequate.

Finding

Inspection personnel did not perform a prescheduled inspection with a checklist before hatch closing.

Determination

Inspection personnel could not verify specific functions during that period.

Finding

At the time of the spacecraft 012 shipment to KSC, the contractor submitted an incomplete list of open items. A revision of that list significantly and substantially enlarged the list of open items.

Determination

The true status of the spacecraft was not identified by the contractor.

"Board Proceedings" and Append. D, "Panels 6 thru 10," *Report of Apollo 204 Review Board*, pp. 3-33 and D-6-3 through D-6-7.

March 30

The Apollo 204 Review Board accepted the final report of its Design Review Panel (No.9), whose duty had been to conduct Critical Design Reviews of systems or subsystems that might be potential ignition sources within the Apollo command module cockpit or that might provide a combustible condition in either normal or failed conditions. The panel was also to consider areas such as the glycol plumbing configuration; electrical wiring and its protection, physical and electrical; and such potential ignition sources as motors, relays, and corona discharge. Other areas would include egress augmentation and the basic cabin atmosphere concept (one-gas versus two-gas).

The contemplated spacecraft configuration for the next scheduled manned flight (spacecraft 101, Block II) was significantly different from that of spacecraft 012 (Block I), in which the January 27 fire had occurred. Therefore, both configurations were to be reviewed - the Block I configuration as an aid in determining possible sources for the fire, the Block II to evaluate the system design characteristics and potential design change requirements to prevent recurrence of fire.

The panel's final report to the Review Board contained findings on ignition and flammability, cabin atmosphere, review of egress process, and review of the flight and ground voice communications. Among them were:

Finding

Flammable, nonmetallic materials were used throughout the spacecraft. In the Block I and Block II spacecraft design, combustible materials were contiguous to potential ignition sources.

Determination

In the Block I and Block II spacecraft design, combustible materials were exposed in sufficient quantities to constitute a fire hazard.

Finding

The spacesuit contained power wiring to electronic circuits. The astronauts could be electrically insulated.

Determination

Both the power wiring and potential for static discharge constituted possible ignition sources in the presence of combustible materials. The wiring in the suit could fail from working or bending.

Finding

Residues of RS89 (inhibited ethylene glycol/water solution) after drying were both corrosive and combustible. RS89 was corrosive to wire bundles because of its inhibitor.

Determination

Because of the corrosive and combustible properties of the residues, RS89 coolant could, in itself, provide all of the elements of a fire hazard if it leaked onto electrical equipment.

Finding

Water/glycol was combustible, although not easily ignited.

Determination

Leakage of water/glycol in the cabin would increase risk of fire.

Finding

Deficiencies in design, manufacture, and quality control were found in the postfire inspection of the wire installation.

Determination

There was an undesirable risk exposure, which should have been prevented by both the contractor and the government.

Finding

The spacecraft atmosphere control system design was based on providing a pure oxygen environment.

Determination

The technology was so complex that, to provide diluent gases, duplication of the atmosphere control components as well as addition of a mechanism for oxygen partial-pressure control would be required. These additions would introduce additional crew-safety failure modes into the flight systems.

Finding

Sixty seconds were required for unaided crew egress from the CM. The hatch could not be opened with positive cabin pressure above approximately 0.17 newtons per sq cm (0.25 psi). The vent capacity was insufficient to accommodate the pressure buildup in the Apollo 204 spacecraft.

Determination

Even under optimum conditions emergency crew egress from Apollo 204 spacecraft could not have been accomplished in sufficient time.

Finding

During the January 27 Apollo 204 test, difficulty was experienced in communicating from ground to spacecraft and among ground stations.

Determination

The ground system design was not compatible with operational requirements.

"Board Proceedings" and Append. D, "Panels 6 thru 10," *Report of Apollo 204 Review Board*, pp. 3-33 and D-9-3 through 3-9-13.

March 31

The Integration Analysis Panel (No. 18) was rewriting its final report to the Apollo 204 Review Board. Panel 18 had been assigned to review information from all task groups and make the final technical integration of the evidence. Panels 3 and 16 had been merged with Panel 18 on February 23. In its final report to the Review Board, Panel 18 listed:

Findings

Several arcing indications were observed in the CM left front sector and a voltage transient was noted in all three phases of AC Bus 2. This transient was most closely simulated by a power interruption or short circuit on DC Bus B. Physical evidence and witness statements indicated the progress of the fire to be from the left side of the spacecraft. Simulations and tests indicated that combustion initiation by electrostatic discharge or chemical action was not probable. No physical evidence of prefire overheating of mechanical components or heating devices was found.

Determinations

No single ignition source could be conclusively identified. The most probable initiator was considered to be the electrical arcing or shorting in the left front sector of the spacecraft. The location best fitting the total available information was that where environmental control system instrumentation power wiring ran into the area between the environmental control unit and the oxygen panel.

Finding

All spacecraft records were reviewed by the various panels and the results were screened by Panel 18.

Determination

No evidence was found to correlate previously known discrepancies, malfunctions, qualification failures or open work items with the source of ignition.

Finding

At the time of the observed fire, data including telemetry and voice communications indicated no malfunctioning spacecraft systems (other than the live microphone).

Determination

Existing spacecraft instrumentation was insufficient by itself to provide data to identify the source of ignition.

"Board Proceedings" and Append. D, "Panel 18," *Report of Apollo 204 Review Board*, pp. 3-33 and D-18-3 through D-18-51.

March 31

The final report of the Medical Analysis Panel (No. 11) to the Apollo 204 Review Board was processed for printing. The panel had been assigned to provide a summary of medical facts with appropriate medical analysis for investigation of the January 27 fire. Examples were cause of death, pathological evidence of overpressure, and any other areas of technical value in determining the cause of accident or in establishing corrective action.

The panel report indicated that at the time of the accident two NASA physicians were in the blockhouse monitoring data from the senior pilot. Upon hearing the first voice transmission indicating fire, the senior NASA physician turned from the biomedical console to look at the bank of television monitors. When his attention returned to the console the bioinstrumentation data had stopped. The biomedical engineer in the Acceptance Checkout Equipment (ACE) Control Room called the senior medical officer for instructions. He was told to make the necessary alarms and informed that the senior medical officer was leaving his console. The two NASA physicians left the blockhouse for the base of the umbilical tower and arrived there shortly before ambulances and a Pan American physician arrived at 6:43 p.m. The three physicians went to the spacecraft; time of their arrival at the White Room was estimated to be 6:45 p.m. EST.

By this time some 12 to 15 minutes had elapsed since the fire began. After a quick evaluation it was

evident that the crew had not survived the heat, smoke, and burns and it was decided that nothing could be gained by attempting immediate egress and resuscitation.

Panel 11's 24 findings included:

Finding

Biomedical data at the time of the accident were received from only the senior pilot. The data consisted of one lead of electrocardiogram, one lead of phonocardiogram, and impedance pneumogram (respiration). The data was received by telemetry and from the onboard medical data acquisition system.

Determination

This configuration was normal for the test.

Finding

At 6:31:04 p.m. there was a marked change in the senior pilot's respiratory and heart rates on the biomedical tape. There was also evidence of muscle activity in the electrocardiogram and evidence of motion in the phonocardiogram. The heart rate continued to climb until loss of signal.

Determination

This physiological response is compatible with the realization of an emergency situation.

Finding

Voice contact with the crew was maintained until 6:31:22.7

Determination

At least one crew member was conscious until that time.

Finding

Hatches were opened at approximately 6:36 p.m. and no signs of life were detected. Three physicians looked at the suited bodies at approximately 6:45 p.m. and decided that resuscitation efforts would be to no avail.

Determination

Time of death could not be determined from this finding.

Finding

"The cause of death of the Apollo 204 Crew was asphyxia due to inhalation of toxic gases due to fire. Contributory cause of death was thermal burns."

Determination

It could be concluded that death occurred rapidly and that unconsciousness preceded death by some increment of time. The fact that an equilibrium had not been established throughout the circulatory system indicated that blood circulation stopped rather abruptly before an equilibrium could be reached.

Finding

Panel 5 had estimated that significant levels (more than two percent) of carbon monoxide were in the spacecraft atmosphere by 6:31:30 p.m. EST. By this time at least one spacesuit had failed, introducing cabin gases to all suit loops.

Determination

The crew was exposed to a lethal atmosphere when the first suit was breached.

Finding

The distribution of carbon monoxide in body organs indicated that circulation stopped rather abruptly when high levels of carboxyhemoglobin reached the heart.

Determination

Loss of consciousness was caused by cerebral hypoxia due to cardiac arrest from myocardial hypoxia. Factors of temperature, pressure, and environmental concentrations of carbon monoxide, carbon dioxide, oxygen, and pulmonary irritants were changing at extremely rapid rates. It was impossible from available information to integrate these variables with the dynamic physiological and metabolic conditions they produced, to arrive at a precise statement of the time when consciousness was lost and when death supervened. Loss of consciousness was estimated as at between 15 and 30 seconds after the first suit failed. Chances of resuscitation decreased rapidly thereafter and were irrevocably lost within 4 minutes.

Finding

The purge with 100-percent oxygen at above sea-level pressure contributed to the propagation of fire in the Apollo 204 spacecraft.

Determination

The oxygen level was the planned cabin environment for testing and launch, since prelaunch denitrogenation was necessary to forestall the possibility of the astronauts' suffering the bends. A comprehensive review of operational and physiological tradeoffs of various methods of denitrogenation was in progress.

"Board Proceedings" and Append. D, "Panel 11," *Report of Apollo 204 Review Board*, pp. 333 and D-11-3 through D-11-9.

March 31

ASPO Manager Joseph F. Shea requested that the White Sands Test Facility be authorized to conduct the descent propulsion system series tests starting April 3 and ending about May 1. The maximum expected test pressure would be 174 newtons per sq cm (253 psia), normal maximum operating pressure. The pressure could go as high as 179 newtons per sq cm (260 psia) according to the test to be conducted.

Required leak check operations were also requested at a maximum pressure of 142 newtons per sq cm (206 psia), with a design limit of 186 newtons per sq cm (270 psia). The test fluids would be compatible with the titanium alloy at the test pressures. The test would be conducted in the Altitude Test Stand, where adequate protection existed for isolating and containing a failure. MSC Director Robert R. Gilruth approved the request the same day.

Memo, Shea to Gilruth, "Request for authorization to conduct a pressure test," March 31, 1967.

April 1

In reply to a request from NASA Hq., CSM Manager Kenneth S. Kleinknecht told Apollo Program

Director Samuel C. Phillips that replacement of the service module 017 oxidizer tank was based on a double repair weld of the method 2 kind in that tank. This kind of repair, he said, resulted in a weld chemistry similar to the weld on the S-IVB helium bottle that had failed, as had only recently been determined by examination of the secondary-propulsion-system tank repair weld. There was insufficient proof that titanium hydride concentrations could not occur in the double method-2 repair weld, and replacement of the tank would preclude any question as to the integrity of the tank. The decision was delayed as long as possible in the hope of developing technical justification of weld integrity. When that was not achieved and there was little confidence that justification could be developed in the near future, the decision was made directing the tank change. The activity would not cause additional schedule time loss, as it was already necessary to repeat the spacecraft integrated test because of wiring rework.

Ltr., Kleinknecht to Phillips, "Delay in Direction to Effect Service Module Tank Change," April 1, 1967.

April 5

The mission profile for the first manned Apollo flight would be based on that specified in Appendix AS-204 in the Apollo Flight Mission Assignments Document dated November 1966, the three manned space flight Centers were informed. Apollo Program Director Samuel C. Phillips said the complexity of the mission was to be limited to that previously planned, and therefore consideration of a rendezvous exercise would be dependent upon the degree of complication imposed on the mission. "There will be no additions that require major new commitments such as opening a CM hatch in space or exercising the docking subsystem."

TWX, Phillips to MSC, MSFC, and KSC, "First Manned Mission," April 5, 1967.

April 5

The Apollo 204 Review Board transmitted its final formal report to NASA Administrator James E. Webb, each member concurring in each of the findings, determinations, and recommendations concerning the January 27 spacecraft fire that took the lives of three astronauts.



The Apollo 204 Review Board studied Apollo spacecraft 014 (above) in its investigation of the January 27, 1967, fire in the similar CM 012 (below, photographed after the fire). The interior view shows the forward section of the left-hand equipment bay, below the environmental control unit in each spacecraft. The DC power cable crosses over aluminum tubing and under a lithium hydroxide access door (removed in the photo of the damaged CM 012). The board determined this was the area of the most probable initiator of the fire.

During the review the Board had adhered to the principle that reliability of the CM and the entire system involved in its operation was a requirement common to both safety and mission success. Once the CM had left the earth's environment the occupants were totally dependent on it for their safety. It followed that protection from fire as a hazard required much more than quick egress. Egress was useful only during test periods on earth when the CM was being readied for its mission and not during the mission itself. The risk of fire had to be faced, but that risk was only one factor pertaining to CM reliability that must receive adequate consideration. Design features and operating procedures intended to reduce the fire risk must not introduce other serious risks to mission success and safety.

The House Committee on Science and Astronautics' Subcommittee on NASA Oversight held hearings on the Review Board report April 10-12, 17, and 21 and May 10. Senate Committee on Aeronautical and Space Sciences hearings were held April 11, 13, and 17 and May 4 and 9 (see May 9-10, 1967, and Appendix 8).

Findings, determinations, and recommendations of the Apollo 204 Review Board were:

Finding

1. A momentary power failure occurred at 6:30:55 p.m. EST (23:30:55 GMT).
2. Evidence of several arcs was found in the postfire investigation.
3. No single ignition source of the fire was conclusively identified.

Determination

The most probable initiator was an electrical arc in the sector between the -Y and +Z spacecraft axes. The exact location best fitting the total available information was near the floor in the lower forward section of the left-hand equipment bay where environmental control system instrumentation power wiring led into the area between the environmental control unit and the oxygen panel. No evidence was discovered that suggested sabotage.

Finding

1. The CM contained many classes of combustible material in areas contiguous to possible ignition sources.
2. The test was conducted with a 100-percent oxygen atmosphere at 11.5 newtons per sq cm (16.7 psia).

Determination

The test conditions were extremely hazardous.

Recommendation

The amount and location of combustible materials in the CM must be severely restricted and controlled.

Finding

1. The rapid spread of fire increased pressure and temperature, rupturing the CM and creating a toxic atmosphere. "Death of the crew was from asphyxia due to inhalation of toxic gases due to fire. A contributory cause of death was thermal burns."
2. Non-uniform distribution of carboxyhemoglobin was found by autopsy.

Determination

Autopsy data led to the medical opinion that unconsciousness occurred rapidly and that death followed soon thereafter.

Finding

Because of internal pressure, the CM inner hatch could not be opened before rupture of the CM.

Determination

The crew was never capable of effecting emergency egress because of the pressurization before the rupture and their loss of consciousness soon after rupture.

Recommendation

The time required for egress of the crew should be reduced and the operations necessary for

egress be simplified.

Finding

The organizations responsible for planning, conducting, and safety of this test failed to identify it as being hazardous. Contingency preparations to permit escape or rescue of the crew from an internal CM fire were not made.

1. No procedures for this kind of emergency had been established either for the crew or for the spacecraft pad work team.
2. The emergency equipment in the White Room and on the spacecraft work levels was not designed for the smoke condition resulting from a fire of this nature.
3. Emergency fire, rescue, and medical teams were not in attendance.
4. Both the spacecraft work levels and the umbilical tower access arm contained features such as steps, sliding doors, and sharp turns in the egress paths which hindered emergency operations.

Determination

Adequate safety precautions were neither established nor observed for this test.

Recommendations

1. Management should continually monitor the safety of all test operations and ensure the adequacy of emergency procedures.
2. All emergency equipment (breathing apparatus, protective clothing, deluge systems, access arm, etc.) should be reviewed for adequacy.
3. Personnel training and practice for emergency procedures should be given regularly and reviewed before a hazardous operation.
4. Service structures and umbilical towers should be modified to facilitate emergency operations.

Finding

Frequent interruptions and failures had been experienced in the overall communication system during the operations preceding the accident.

Determination

The overall communication system was unsatisfactory.

Recommendation

1. The ground communication system should be improved to ensure reliable communications among all test elements as soon as possible and before the next manned flight.
2. A detailed design review should be conducted on the entire spacecraft communication system.

Finding

1. Revisions in the Operational Checkout Procedure for the test were issued at 5:30 p.m. EST January 26, 1967 (209 pages), and 10:00 a.m. EST January 27, 1967 (4 pages).
2. Differences existed between the ground test procedures and the inflight checklists.

Determination

Neither the revision nor the differences contributed to the accident. The late issuance of the revision, however, prevented test personnel from becoming adequately familiar with the test procedure before use.

Recommendations

- 1. Test procedures and pilot's checklists that represent the actual CM configuration should be published in final form and reviewed early enough to permit adequate preparation and participation of all test organizations.**
- 2. Timely distribution of test procedures and major changes should be made a constraint to the beginning of any test.**

Finding

The fire in CM 012 was subsequently simulated closely by a test fire in a full-scale mockup.

Determination

Full-scale mockup fire tests could be used to give a realistic appraisal of fire risks in flight-configured spacecraft.

Recommendation

Full-scale mockups in flight configuration should be tested to determine the risk of fire.

Finding

The CM environmental control system design provided a pure oxygen atmosphere.

Determination

This atmosphere presented severe fire hazards if the mount and location of combustibles in the CM were not restricted and controlled.

Recommendations

- 1. The fire safety of the reconfigured CM should be established by full-scale mockup tests.**
- 2. Studies of the use of a diluent gas should be continued, with particular reference to assessing the problems of gas detection and control and the risk of additional operations that would be required in the use of a two-gas atmosphere.**

Finding

Deficiencies existed in CM design, workmanship and quality control, such as:

- 1. Components of the environmental control system installed in CM 012 had a history of many removals and of technical difficulties, including regulator failures, line failures, and environmental control unit failures. The design and installation features of the environmental control unit made removal or repair difficult.**
- 2. Coolant leakage at solder joints had been a chronic problem.**
- 3. The coolant was both corrosive and combustible.**
- 4. Deficiencies in design, manufacture, installation, rework, and quality control existed in the electrical wiring.**
- 5. No vibration test was made of a complete flight-configured spacecraft.**
- 6. Spacecraft design and operating procedures required the disconnecting of electrical connections while powered.**
- 7. No design features for fire protection were incorporated.**

Determination

These deficiencies created an unnecessarily hazardous condition and their continuation would imperil any future Apollo Operations.

Recommendations

- 1. All elements, components, and assemblies of the environmental control system**

- should be reviewed in depth to ensure its functional and structural integrity and to minimize its contribution to fire risk.
2. The design of soldered joints in the plumbing should be modified to increase integrity or the joints should be replaced with a more structurally reliable configuration.
 3. Deleterious effects of coolant leakage and spillage should be eliminated.
 4. Specifications should be reviewed; three-dimensional jigs should be used in manufacture of wire bundles; and rigid inspection at all stages of wiring design, manufacture, and installation should be enforced.
 5. Flight-configured spacecraft should be vibration tested.
 6. The necessity for electrical connections or disconnections with power on within the crew compartment should be eliminated.
 7. The most effective means of controlling and extinguishing a spacecraft fire should be investigated. Auxiliary breathing oxygen and crew protection from smoke and toxic fumes should be provided.

Finding

An examination of operating practices showed the following examples of problem areas:

1. The number of open items at the time of shipment of the CM 012 was not known. There were 113 significant engineering orders not accomplished at the time CM 012 was delivered to NASA; 623 engineering orders were released subsequent to delivery. Of these, 22 were recent releases that were not recorded in configuration records at the time of the accident.
2. Established requirements were not followed with regard to the pretest constraints list. The list was not completed and signed by designated contractor and NASA personnel before the test, even though oral agreement to proceed was reached.
3. Formulation of and changes in prelaunch test requirements for the Apollo spacecraft program were responsive to changing conditions.
4. Noncertified equipment items were installed in the CM at time of test.
5. Discrepancies existed between NAA and NASA MSC specifications regarding inclusion and positioning of flammable materials.
6. The test specification was released August 1966 and was not updated to include accumulated changes from release date to the January 27 test date.

Determination

Problems of program management and relations between Centers and with the contractor had led to some insufficient responses to changing program requirements.

Recommendation

Every effort must be made to ensure the maximum clarification and understanding of the responsibilities of all organizations in the program, the objective being a fully coordinated and efficient program.

Report of Apollo 204 Review Board to the Administrator, National Aeronautics and Space Administration, April 5, 1967, transmittal letter and pp. 6-1 through 6-3 ; House Committee on

Science and Astronautics, Subcommittee on NASA Oversight, *Investigation into Apollo 204 Accident: Hearings, 90th Cong., 1st sess., vols. 1-3, April 10, 11, 17, 21, May 10, 1967*; Senate Committee on Aeronautical and Space Sciences, *Apollo Accident: Hearings, 90th Cong., 1st sess., pts. 3-7, April 11, 13, and 17, May 4 and 9, 1967.*

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Part 2 (A)

Recovery, Spacecraft Redefinition, and First Manned Apollo Flight

April 1967

1967

April 6

A program of biology training for lunar mission crews was formulated as part of a comprehensive Block II Training Plan being reviewed by the Flight Crew Operations Directorate at MSC. The program was to provide flight crews with rudimentary facts about microbial life forms, an understanding of the bioscientific importance of lunar exploration, and training in collection of lunar samples (biological requirements) and the various aspects of the quarantine program. The biology training was to be divided into five lecture and demonstration sessions, with one field trip to observe desert ecology.

Memo, Director of Flight Crew Operations to Special Assistant to the Director, "Bioscience training of lunar mission crews," April 6, 1967.

April 7

Joseph F. Shea, MSC Apollo Spacecraft Program Office Manager, was appointed NASA Deputy Associate Administrator for Manned Space Flight, with responsibility for technical aspects of the program.

George M. Low, MSC Deputy Director, would succeed Shea as ASPO Manager. Changes were to be effective April 10.

MSC Announcement 67-51, "Key Personnel Change," April 7, 1967.

April 8

A flash report sent to the NASA Apollo Program Director by ASPO Manager George M. Low at MSC

informed him that all the fuel-cell gaseous- nitrogen titanium-alloy tanks were suspected of having contaminated welds. The problem was detected during an acceptance test. Preliminary investigation revealed the weld had become contaminated during girth weld repair, because of incomplete purging of the tank's interior. All rewelded tanks were therefore liable to be contaminated and records were inadequate to identify which tanks had been rewelded. The following actions had been directed by Low for use on spacecraft 017 and 020:

1. cyclic and proof pressure test at pressures well above normal operating followed by x-ray and dye penetrant inspection on replacement tanks for spacecraft 017 fuel cells; and
2. removal of the spacecraft 017 tanks and replacement with tanks subjected to (1) above was planned.

It was expected that this could be accomplished without removal of the fuel cells, and the replacement of the three tanks was not expected to affect the 017 schedule.

TWX, Low to NASA Hq., April 8, 1967.

April 8

MSC Structures and Mechanics Division Chief Joseph N. Kotanchik had strongly recommended that all B-nuts already installed in spacecraft be loosened to relieve any residual strain on nearby solder joints, ASPO Manager George M. Low informed CSM Manager Kenneth S. Kleinknecht. Kotanchik thought the leaks found in spacecraft 012 at KSC and in spacecraft 101 during test were most likely caused by creep. Loosening all joints, replacing them with voishan washers, and then retorquing them with procedures known not to cause strain, should be given serious consideration. Low pointed out this would also accomplish Kleinknecht's desires of being sure that all joints were torqued to proper limits.

Memo, Low to Kleinknecht, "Creep of solder joints," April 8, 1967.

April 10

MSC informed NASA Hq. that the spacecraft 017 inertial measurement unit (IMU) was being removed to replace capacitors that were suspect after a number of failures with qualified mylar capacitors. Replacement was expected to delay mechanical mating of the spacecraft and launch vehicle an estimated two days. The guidance and navigation subsystem would be retested during the integrated spacecraft system tests with the launch vehicle simulator. Headquarters was also advised that all other IMUs in the program had been retrofitted to eliminate the suspect capacitor. Five days later, CSM Manager Kenneth Kleinknecht told KSC that MSC understood that the original impact had been increased to five days, but asserted the change was still mandatory.

TWXs, George M. Low, MSC, to S. C. Phillips, NASA OMSF, April 10, 1967; Kleinknecht, MSC, to KSC, April 15, 1967.

April 10

MSC ASPO Manager George M. Low told Sydney C. Jones, Jr., MSC Communications and Power Branch, that he wanted to establish two task teams on CSM electrical systems. The first team would study the wiring harnesses on spacecraft 2TV-1 and 101 and all subsequent spacecraft to determine actions needed to save the harnesses as installed. Low asked: "Can a sufficient number of nylon wire bundle ties be replaced to meet the requirements of our new materials specification? Can silicone rubber padding and chafing guards be replaced? What fixes must be incorporated to meet requirements of the recent inspection activities? Has the harness been mistreated in recent months, as was mentioned to me by some of the astronauts? How about water glycol spillage in 101?" The task team was to include members from the Engineering and Development and Flight Crew Operations Directorates, the Flight Safety Office, and the Reliability, Quality, and Test Division. Low asked firm recommendations concerning the harnesses in spacecraft 2TV-1 and 101 by April 15 if possible.

The second task team would study flammable materials used with all other electrical systems. Low referred "specifically to the RTV [room temperature vulcanizing] used on the backs of circuit-breaker panels and elsewhere; the circuit breakers themselves; the electroluminescent panels; and any other materials generally associated with the electrical system." Low said Structures and Mechanics Division (SMD) had done some very promising work with coatings for the circuit-breaker panels but these coatings might not be applied to some of the panels because of the open mechanical elements of many of the switches. He recommended that Jones ask representatives from SMD, the Instrumentation and Electronics Systems Division, and the Flight Safety Office to work with him. Low asked Jones to let him know by April 12 when it would be possible to make specific recommendations as to what needed to be done.

Memo, Low to Jones, "Task Team assignments," April 10, 1967.

April 10

George Low requested William M. Bland, MSC, to take action on two recommendations made by MSC Director Robert R. Gilruth:

1. Take stereo color photos of all spacecraft areas before they were closed out. This procedure had been invaluable during the Apollo Review Board's activities at KSC, and the same technique, applied during the manufacturing process of current spacecraft, might help answer questions raised subsequent to the closeout of an area and thereby save time.
2. Make additional requirements for the use of cover plates over spacecraft wire bundles. Greater use of cover plates during manufacturing, test, and perhaps even flight would prevent damage during subsequent activities.

Memo, Low to Bland, "Stereo photographs of spacecraft activities," April 10, 1967.

April 10

An investigation at Grumman compared flammability characteristics of blankets representative of the external LM vehicle insulation with those of unshielded mylar blankets. When subjected to identical ignition sources, the mylar specimens burned during all phases of testing. Localized charring and perforation were the only visible signs of degradation in specimens simulating the LM shielding. The conclusion was that the protection of mylar blankets by H-Film in the LM configuration effectively decreased the likelihood of ignition from open flame or electrical arcing.

LM Engineering Memo, LMO-562-11, to addressees from B. Bell, "Flammability Characteristics of LM Thermal Shielding," April 10, 1967; ltr., E. Stern to MSC, Attn: R. Wayne Young, "Contract NAS 9-1100, Flammability Characteristics of LM Thermal Shielding," April 17, 1967.

April 14

NASA Hq. informed the Directors of the manned space flight Centers that responsibility for approval of pressure vessel tests was being returned to normal Center management channels. Because of the failure of the 503 launch vehicle S-IVB stage and other pressure vessel problems, testing had been restricted by the office of the Apollo Program Director. The Program Director now returned to the Center Directors "responsibility for approving pressurization tests of pressure vessels in spacecraft modules, launch vehicle stages, and ground support equipment within their Apollo program responsibilities."

TWX, Apollo Program Director to Center Directors, "Responsibility for Approval of Tests and Pressure Vessels," April 14, 1967.

April 14

CM mockup tests by the Structures and Mechanics Division at the MSC Thermochemical Test Area had shown that significant burning occurred in oxygen environments at a pressure of 11.4 newtons per square centimeter (16.5 psia). The tests, in which most of the major crew bay materials had been replaced by Teflon or Beta cloth, consisted of deliberately igniting crew bay materials sequentially in two places. The Division recommended that operation with oxygen at 11.4 newtons in the crew compartment be eliminated and that either air or oxygen at 3.5 newtons per sq cm (5 psia) be used. In reply, the ASPO Manager pointed out that "Dr. Gilruth has indicated a strong desire to avoid the use of air on the pad which requires subsequent spacecraft purges. Accordingly, we should maintain the option of launching with a pure oxygen cabin environment until such time as additional tests indicate it would not be feasible."

Memos, Chief, MSC Structures and Mechanics Div., to Manager, ASPO, "Use of 16.5 psia oxygen as a cabin environment," April 14, 1967; Manager, ASPO, to Joseph N. Kotanchik, "Command and Service Module environment at launch," April 18, 1967.

April 17

A meeting at MSC considered requirements of the Apollo flight program before the first lunar landing mission. Present were C. H. Perrine, MSC Mission Operations Division, and Christopher C. Kraft, Jr., Sigurd A. Sjoberg, John D. Hodge, Eugene F. Kranz, Morris V. Jenkins, and Robert E. Ernull, all of Flight Operations Directorate. Most significant opinions resulting from the meeting were:

- Demonstrations of extravehicular transfer and CSM rescue of LM were not considered prerequisite to manned LM earth-orbital operations separated from the CSM.
- A rendezvous exercise on Apollo 7 (CSM 101) with a "pod" would be worth attempting some time after the first day of the mission.
- Unmanned burns of the LM ascent and descent propulsions systems, including fire-in-the-hole burns, were considered prerequisites to manning those functions. This prerequisite included manning of descent propulsion system burns.
- Three manned earth-orbital flights of the CSM and LM in joint operations, plus a single CSM-alone flight, were considered the minimum number of missions in the primary program before the first potential lunar mission.
- Although a lunar orbit mission should not be a step in the primary program, it should be part of the contingency plan in the event the CSM achieved lunar-mission capability before the LM did. The gains in operational experience were considered sufficient to justify the risk of such a mission.
- Saturn V launch vehicles should be manned (i.e., should launch manned spacecraft) as soon as possible.
- There was some question about the "manability" of LM-2.

Memo for File, Perrine, "Meeting with FOD on Apollo Flight Program," April 17, 1967.

April 18

ASPO Manager George M. Low pointed out to MSC Director of Engineering and Development Maxime A. Faget that apparently no single person at MSC was responsible for spacecraft wiring. Low said he would like to discuss naming a subsystem manager to follow this general area, including not only the wiring schematics, circuitry, circuit-breaker protection, etc., but also the detailed design, engineering, fabrication, and installation of wiring harnesses.

Memo, Low to Faget, "Subsystem manager for spacecraft wiring," April 18, 1967.

April 18

NASA Apollo Program Director Samuel C. Phillips signed a directive defining the requirements, responsibilities, and inter-Center coordination necessary for development, control, and execution of test and checkout plans and procedures for preparing and launching Apollo-Saturn space vehicles at KSC.

Memo, Chief, Apollo Program Planning, NASA OMSF, to distr., "Apollo Weekly Status Report," April 21, 1967.

April 20-26

A fire broke out in the Bell Aerosystems Test Facility, Wheatfield, N.Y., at 2:30 a.m. April 20. Early analysis indicated the fire was started by overpressurization of the ascent engine's propellant-conditioning system, which caused the system relief valve to dump propellant into an overflow bucket. The bucket in turn overflowed and propellant spilled onto the floor, coming into contact with a highly oxidized steel grating. Contact was believed to have initiated combustion and subsequently an intense, short-duration fire. The fire began in the test facility building near the altitude chamber and fuel tanks and spread to the inside of the altitude chamber. Among the effects of the fire on the program were

1. about four weeks' requirement to repair the LM ascent engine test facility,
2. tests delayed accordingly, and
3. delay of the acceptance test of the LM-2 ascent engine.

On April 26, a small localized fire occurred in Test Cell No. 3G at the Bell Aerosystems Test Center in Porter, N.Y. Preliminary reports indicated that a LM ascent engine bipropellant valve had been tested as a valve injector assembly but was not connected to an injector at the time of the fire. This valve was being purged with nitrogen on the fuel side and water on the oxidizer side in preparation for flushing. A very small quantity of fuel had spilled from the valve during hookup to the flush stand. When the water started to flush through the oxidizer side, a loose connector allowed oxidizer to come in contact with the spilled fuel and the fire resulted. No one was injured; damage was estimated at \$250.

ASPO Manager George Low received a message from NASA Hq. May 3 expressing concern that the two fires within one week might be symptomatic of inadequate test procedures and personnel training, which could lead to a more serious accident. Headquarters requested results of the investigations and notice of corrective action taken to prevent future incidents.

TWXs, Low to NASA Hq., Attn: Apollo Program Director, April 26, 1967; NASA Hq. to Low, May 3, 1967.

April 21

NASA Associate Administrator for Manned Space Flight George E. Mueller instructed NASA Apollo Program Director Samuel C. Phillips, MSC Director Robert R. Gilruth, and KSC Director Kurt H. Debus to review all findings and recommendations of the Apollo 204 Review Board and assign responsibility to an appropriate person for

1. program office evaluation of the findings and recommendations,

2. the action to be taken on each finding or recommendation,
3. the date on which this action was to be completed, and
4. the preparation of a report closing out the accident.

Upon completion of items (1) and (2) above, the responsible subsystem or system manager was to review his evaluation and planned actions with the Chairman of the Board panel responsible for determining the findings and recommendations, to be sure that they had been properly interpreted. Appropriate certification of facts would be signed by the panel Chairman.

Mueller specified that "Review Boards at the two Centers, either assisting or set up for this review, should review the above actions with respect to the findings and recommendations of the 204 Review Board; and to each other to be sure that we have a consistent and adequate approach to the problems and that the statement of actions and the actions themselves are feasible, and are clearly enough expressed so as to be unambiguous in content."

The above actions were to be completed by April 28 and reported to NASA Hq. in a form that could be presented to Congress. (See May 9-10 entry.)

Memo, Mueller to Phillips, Gilruth, and Debus, April 21, 1967.

April 25

Samuel C. Phillips, NASA Apollo Program Director, formed a task group under the direction of Harold Russell of NASA Hq. to begin preparation of a detailed inspection standards publication.

The task force would use pictures and discrepancy reports, the Apollo 204 Review Board report, and special inspections of spacecraft 012, 014, 017, 020, and 101 and LM-1.

During preparation of the uniform set of manned space flight standards, the quality control and inspection standards Centers had previously imposed upon their contractors would not be changed without approval of the Apollo Program Office. Phillips estimated that the project might be completed in about a month.

TWX, Phillips to Robert R. Gilruth, MSC, Kurt H. Debus, KSC, and Wernher von Braun, MSFC, April 25, 1967.

April 26

Because of the amount of flammable material in spacecraft 017 and 020, MSC decided to purge these two spacecraft on the pad with gaseous nitrogen. The total amount of oxygen in the spacecraft at time of reentry would not exceed 14 percent. No tests would be conducted on these spacecraft with hatches closed when men were in the spacecraft.

TWX, ASPO Manager to NASA Hq., Attn: Apollo Program Director, April 26, 1967.

April 27

NASA Task Team - Block II Redefinition, CSM, was established by ASPO. The team - to be in residence at North American Aviation during the redefinition period - was to provide timely response to questions and inputs on detail design, overall quality and reliability, test and checkout, baseline conditions, configuration control, and schedules.

Astronaut Frank Borman was named Task Team Manager and group leaders were: Design, Aaron Cohen; Quality and Reliability and Test and Checkout Procedures, Scott H. Simpkinson; Materials, Jerry W. Craig; Specifications and Configuration Control, Richard E. Lindeman; and Scheduling, Douglas R. Broome.

Memo, Manager, CSM, Apollo Spacecraft Program, to addressees, "Block II redefinition, command and service modules," April 27, 1967.

April 27

Astronaut Donn F. Eisele, a member of the Block II Wiring Investigating Team, wrote the ASPO Manager his reservations as to whether the wiring in spacecraft 101 could be salvaged and made safe for flight. "To render positive assurance of wiring integrity, strong consideration should be given to replacing the entire 101 harness with a new, like item-made to the same drawings as the present harness, but constructed and installed under more rigorous quality control measures; and using non-flammable materials. The replacement harness should be installed at the outset in protective trays and covers now being implemented at NAA [North American Aviation]. A wiring overlay could be installed later, to accommodate recent spacecraft design changes, if adequate space is provided in the protective trays, connector support provisions, etc. This should provide a harness of good quality and known condition to start with; and the protection and quality control measures should keep its integrity intact." (Eisele was the pilot on the Apollo 7 mission - the first manned Apollo mission and the one on which spacecraft 101 was used.)

Ltr., Eisele to ASPO Manager, "Spacecraft 101 wiring," April 27, 1967.

April 28 - May 16

Spacecraft delivery date and ground rule discussions were summarized by MSC ASPO Manager George M. Low in a letter to North American Aviation's Apollo Program Manager Dale D. Myers. Low referred to an April 23 letter from Myers and April 25 talks at Downey, Calif.

Basic was "an MSC ground rule that the first manned flight should be an open-ended mission; and that

2TV-1 (a test spacecraft) would be a constraint on that mission. I also stated that I would like to achieve a delivery date for Spacecraft 101 that is no later than November, 1967, and that all constraining tests on 2TV-1 should be completed one month before the flight of 101. I further stated that the proposed delivery dates for Spacecraft 103 and subsequent spacecraft were not good enough and that we should strive to achieve earlier dates.

"In summary, we did not agree with the basic ground rules stated in your April 23, 1967, letter. These ground rules essentially implied that 101 was to be limited to a six-orbit mission, and to be delivered as early as possible at the expense of all other spacecraft. Instead, we stated that it is NASA's position to achieve a balanced program involving the earliest possible deliveries when all spacecraft are considered and not just the first one."

A further exchange of letters May 8 and 16 reached agreement on target delivery dates and ground rules. Testing of thermal vacuum test vehicle 2TV-1 would be as originally planned except that extravehicular activities would not be included in tests constraining CSM 101. Delivery date was to be October 14. CSM 101 was to be delivered December 8 and would be launched on a Saturn IB to verify system performance. The mission was to be open-ended, up to 10 days, with no LM and no docking or EVA provisions included. New delivery date for CSM 103 was March 23, 1968. Ltrs., Low to Myers, April 28 and May 8, 1967; Myers to Low, May 16, 1967.

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Part 2 (B)

Recovery, Spacecraft Redefinition, and First Manned Apollo Flight

May 1967

1967

May 1

MSC estimated the effect of the Apollo 204 fire on program costs for FY 1967 and 1968, in reply to April 26 instructions from NASA Apollo Program.

Manager Samuel C. Phillips. Estimates were:

Command and service modules	\$25 million
Lunar module	\$21 million
Other	\$35 million
Total	\$81 million

Further, the program extension resulting from the accident would require an additional budget allocation during FY 1969 and continuing through program runout. A May 4 message from MSC confirmed the information telephoned to Headquarters May 1.

The following ground rules had been used in estimating the cost impact:

- All changes planned as of May 1 for the command and service modules and the lunar module were included.
- Vehicle delivery dates were as of April 29. Guidance and navigation schedules were adjusted to support revised CSM and LM need dates.

TWXs, NASA Hq. to MSC, "Cost Impact of 204 Accident," April 26, 1967; MSC to NASA Hq., "Cost Impact of the 204 Accident," May 4, 1967.

May 1

The Space and Information Systems Division of North American Aviation, Inc., was renamed Space Division, effective May 1.

TWX, North American Aviation Space Div., Downey, Calif., to NASA Hq., MSFC, MSC, and KSC, "Redesignation of S&ID as Space Division," May 9, 1967.

May 1

George C. White, Jr., NASA OMSF Director of Apollo Reliability and Quality, told Apollo Program Director Samuel C. Phillips that an MSC presentation on April 29 had restored confidence in Apollo's future, but three areas caused him concern as possible compromises with crew safety and mission success in the interest of near-term schedule and cost considerations. They were:

- Soldered joints in coolant system plumbing. Design of the joints was basically wrong; the insertion of the tubing into the sleeve was less than the tube diameter. Shear strength of the solder had to be depended upon for mechanical integrity against bending and vibration as well as for sealing. Insertion should be two to three times the diameter so that bending could be carried by the bearing of the tube in the sleeve, and the solder would only have to seal.
- Wiring harnesses. Wiring in the Block II spacecraft had a number of problems, the real significance of which was difficult to evaluate. Numerous instances of damaged insulation (bare conductor) had been found and the repairs had, in turn, resulted in more damage. At least once, split insulation (bare conductor) had been found inside a wire bundle; it could have been in the wire as received or could have resulted from cold flow.
- Modification procedure. MSC planned to make the changes in the Block II spacecraft by working directly from mockup to the spacecraft, using sketches and a minimum of paper work. While this kind of an operation could get a job done in a hurry, it required a strong leader, thoroughly experienced in working with engineering and factory people and procedures, and rigorous adherence to a minimal streamlined paper system. All "engineering" must be on drawings and all fabrication work must be inspected at least as rigorously as in a normal manufacturing process.

White urged close management attention to ensure quality. Memo, White to Phillips, "MSC plan presented on April 29, 1967," May 1, 1967.

May 2

The Air Force Manned Orbiting Laboratory Systems Program Office requested that MSC present a briefing to selected office and contractor personnel on NASA's progress in safety studies and tests associated with fire hazards aboard manned space vehicles. Information was requested for the MOL program to help formulate studies and activities that would not duplicate MSC efforts. The briefing was

given at MSC May 10.

TWXs, MOL Systems Program Office, Los Angeles, to MSC, "Request for Briefing on Safety Studies and Associated Tests," May 2, 1967; MSC to Space Systems Div., USAF, May 3, 1967.

May 2

ASPO Manager George M. Low asked the Chairman of the Apollo 204 Review Board to consider releasing CM 014 for use in the Apollo program. If the Review Board had a continuing need for the CM, Low requested that consideration be given to release of certain individual items needed for the Apollo Mission Simulator program. Board Chairman Floyd L. Thompson notified Low on June 22 that the CM mockup and CM 014 were no longer required by the Review Board and that their disposition might be determined by the ASPO Manager.

Memo, Low to Chairman, Apollo 204 Review Board, "Release of Command Module 014," May 2, 1967; TWX, Thompson to MSC, Attn: George M. Low, June 22, 1967.

May 2-4

NASA Block II Redefinition Task Team group leaders and CSM Program Manager Kenneth S. Kleinknecht arrived at North American Aviation Space Division at Downey May 2, followed by Task Team Manager Frank Borman the next day. Borman met with North American management May 4 to ensure understanding of the team plan and objectives. An afternoon meeting with NASA and North American Task Managers and group leaders reviewed the status of the Block II Redefinition task.

Following is a summation of the technical status at the time:

1. Ninety-five percent of the wires and break points had been defined, including additional wires for changes (approximately 200) plus the existing open items on spacecraft 101. Schematics for manufacturing and preparation of integrated schematics were to be available May 30.
2. AiResearch environmental control system components had been reviewed by North American and direction transmitted for materials changes.
3. North American was planning no compartment closeouts behind the front panels. This was unacceptable to NASA and closeouts would be required.
4. North American definition and review of all spacecraft materials applications were in progress, but Borman reported the progress was too slow to date and that a plan for expediting was under consideration.
5. Fire extinguisher interfaces had not yet been identified. A meeting was planned during the next week to resolve the problem.
6. NASA reaffirmed to North American the intention that DITMCO (an inspection process) of the completed installed harness be performed as late as possible and that harness protection be reinstalled immediately after DITMCO. Connectors which could not be DITMCOed must be

reviewed with NASA, connector by connector.

7. NASA reaffirmed that a crew compartment fit and function test was required on each spacecraft at Downey.
8. Two meetings had been held on the Downey spacecraft 101 test and checkout. Definition of requirements was progressing rapidly and was expected to be completed and signed off by May 5. A schedule would be prepared for distribution on May 9, for the preparation, review and final approval of the operational checkout procedures necessary for the approved test requirement. The launch site test plan for spacecraft 101 would be discussed in a meeting at Downey May 9, and this meeting would be followed by a discussion of spacecraft 2TV-1 Downey test requirements as related to the Houston tests for the spacecraft 101 mission.
9. The Test Group of the Task Team planned to work closely with the Checkout Working Group and would be represented in its next meeting in Downey on May 11.
10. Rework resulting from the wiring inspection of spacecraft 101 was not proceeding as rapidly as desired; however, Borman reported that more efficient procedures were being prepared and would be carried out as soon as possible.
11. The Apollo spacecraft quality requirements were being reviewed and the North American Quality Plan would be checked against these requirements in detail.

Borman reported on plans and schedules:

1. A documentation center was being established to provide configuration documentation to the North American and NASA teams. A master change status board would be maintained in the NASA Task Team Office, and Block II specifications would be updated to provide the predesign baseline.
2. North American had released Master Development Schedule-10 ahead of its May 12 schedule, and detailed engineering, manufacturing, and Apollo test operation schedules were being prepared.

Critical open items were:

1. TV monitor requirements and interfaces,
2. flashing beacon mechanization and requirements,
3. material for the lithium hydroxide canister,
4. emergency oxygen mask mechanization,
5. water chlorination mechanization,
6. rapid repressurization-mechanization or surge tank, and
7. cabin recirculation valve requirement.

TWX, RASPO at Downey, Calif., to distr., "Block II Redefinition Daily Report No. 1, dated May 4, 1967," May 5, 1967.

May 3

NASA's Space Science Steering Committee approved establishment of a facility on the moon consisting of arrays of solid corner reflectors. The first array was to be established by the earliest possible lunar landing mission, with other arrays to be carried on subsequent missions. Until the Committee and Manned Space Flight Experiment Board agreed on assignment of priorities among the various lunar science experiments, this experiment was to be considered a contingency experiment to be carried on a "space available" basis. The facility on the moon would be available to the principal investigator - C. O. Alley, University of Maryland - as well as to other scientists.

TWX, NASA Hq. to MSC, Attn: Robert Piland, May 3, 1967.

May 4

Directions had been prepared to designate mission AS-501 formally as Apollo 4, AS-204/LM-1 as Apollo 5, and AS-502 as Apollo 6, NASA Apollo Program Director Samuel C. Phillips informed Associate Administrator for Manned Space Flight George E. Mueller. Phillips said he thought it was the right time to start using the designations in official releases and appropriate internal documentation. Mueller concurred.

Note, Phillips to Mueller, May 4, 1967.

May 5

Circuit breakers being used in both CSM and LM were flammable, MSC ASPO Manager George Low told Engineering and Development Director Maxime A. Faget. Low said that although Structures and Mechanics Division was developing a coating to be applied to the circuit breakers, such a solution was not the best for the long run. He requested that the Instrumentation and Electronics Systems Division find replacement circuit breakers for Apollo - ideally, circuit breakers that would not bum and that would fit within the same volume as the existing ones, permitting replacement in panels already built. On July 12 Low wrote Faget again: "In light of the work that has gone on since my May 5, 1967, memo, are you now prepared to propose the use of metal-jacketed circuit breakers for Apollo spacecraft? If the answer is affirmative, then we should get specific direction to our contractors immediately. Also, have you surveyed the industry to see whether a replacement circuit breaker is available or will be available in the future?" Low requested an early reply.

Memos, Low to Faget, "Apollo circuit breakers," May 5, 1967; "Apollo circuit breakers, continued," July 12, 1967.

May 5

After review of operational considerations for a minimum restart capability in the Saturn launch vehicle's S IVB stage, MSC's Director of Flight Operations reported to NASA Hq. that an 80-minute

restart capability was believed the best compromise for the early lunar missions, "for the primary reason of providing sufficient time for ground support in verifying navigation, and flight crew checkout of CSM and S-IVB systems prior to TLI [translunar injection], while providing for two injection opportunities in both the Atlantic and Pacific Oceans (second and third revolutions). For later missions, consideration should be given to the hardware implications of providing a restart capability with minimum (zero) restrictions, so that advantage may be taken of confidence in onboard systems to gain additional payload."

Ltr., Christopher C. Kraft, Jr., MSC, to NASA Hq., "S-IVB Restart Capability," May 5, 1967.

May 9-10

NASA reported to Congress on actions taken on the Apollo 204 Review Board's findings and recommendations concerning the January 27 spacecraft fire. Administrator James E. Webb, Deputy Administrator Robert C. Seamans, Jr., and Associate Administrator for Manned Space Flight George E. Mueller testified before the Senate Committee on Aeronautical and Space Sciences May 9 and before the House Committee on Science and Astronautics' Subcommittee on NASA Oversight May 10. (See also September 21 and Appendix 8.)

Senate Committee on Aeronautical and Space Sciences, *Apollo Accident: Hearings*, 90th Cong., 1st sess., pts. 6-7, May 9, 1967; House Committee on Science and Astronautics, Subcommittee on NASA Oversight, , *90th Cong., 1st sess, vol. 3, May 10, 1967; Astronautics and Aeronautics, 1967 (NASA SP-4008, 1968), pp. 144-148.*)

May 10

MSC responded to a March 29 letter from NASA Hq. concerning two arrays of Apollo Lunar Surface Experiments Package (ALSEP) experiments. MSC said it had reviewed schedules, cost, and integration aspects of the requested configurations and that four areas of the project apparently should be modified to allow proper inclusion of the configurations:

1. extension of mission support efforts by Bendix Aerospace Systems Division (BxA) for the fourth ALSEP mission;
2. extension of KSC's support efforts by BxA for the fourth ALSEP mission;
3. extension of the ALSEP prototype test program to encompass three distinct system configurations rather than the two in the original plans; and
4. extension of the ALSEP qualification test program to encompass three distinct configurations rather than the original two.

The cost impact was estimated at \$670,000, and completion of the ALSEP contract was expected to be extended three months to allow for mission support for the fourth flight.

Ltr., Robert R. Gilruth, Director, MSC, to NASA Hq., Attn: Samuel C. Phillips, "Selection of Apollo Lunar Surface Experiments Package System Configurations," May 10, 1967.

May 11

NASA Administrator James E. Webb issued a statement on selection of the Apollo spacecraft contractor: "In the 1961 NASA decision to negotiate with North American Aviation for the Apollo command and service modules, there were no better qualified experts in or out of NASA on whom I could rely than Dr. Robert Gilruth, Dr. Robert C. Seamans, and Dr. Hugh L. Dryden. These three were unanimous in their judgment that of the five companies submitting proposals, and of the two companies that were rated highest by the Source Evaluation Board, North American Aviation offered the greatest experience in developing high-performance manned flight systems and the lowest cost.

"In the selection of North American Aviation, the work of the Source Evaluation Board was not rejected or discarded. It was used as the basis for a more extensive and detailed examination of all pertinent factors than the Board had performed at the time its report was presented to Dr. Gilruth, Dr. Seamans, Dr. Dryden and to me.

"At that point it became the responsibility of NASA's Associate Administrator, Dr. Seamans; its Deputy Administrator, Dr. Dryden; and its Administrator, myself, to take all steps necessary to determine whether the facts then available formed an adequate basis for our selection of a contractor. We decided in the affirmative and then proceeded to select the contractor the facts indicated offered the most to the government."

NASA News Release 67-122, May 11, 1967.

May 12

George M. Low, Manager of the Apollo Spacecraft Program, notified NASA Hq. that Grumman was committed to a June 28 delivery for lunar module 1 (LM-1). This date included provisions for replacement of the development flight instrumentation harness with a new one. Low's assessment was that the date would be difficult to meet.

TWX, Low, MSC, to NASA Hq., Attn: Lee James, "LM-1 delivery schedule," May 12, 1967.

May 12

Anthony W. Wardell of the MSC Flight Safety Analysis Office wrote Apollo Manager Low that "the May 10 inspection further substantiates my previous recommendation to replace, rather than rework, the [spacecraft 101 wiring] harness. In addition to the visual evidence of wire damage noted, a book containing about 100 outstanding wire damage MRB (Material Review Board) actions was noted on a work table near the spacecraft." He did, however, list seven recommended suggestions to be followed in

the event the harnesses were reworked rather than replaced. The suggestions were passed on to CSM Manager Kenneth S. Kleinknecht by Low in a memorandum on May 13. Low requested that the suggestions be passed to North American Aviation as soon as possible, with additional suggestions from MSC Quality Control Chief Jack A. Jones, who had also inspected the harness.

Memos, Jones to Low, "Inspection of SC-101 Wire Harness Assemblies," May 10, 1967; Wardell to Low, "Inspection of Spacecraft 101 Wiring Harnesses," May 12, 1967; Low to Kleinknecht, "Spacecraft 101 wiring," May 13, 1967

May 12

Apollo 204 Review Board Chairman Floyd L. Thompson appointed a subcommittee to examine the final report of Panel 18 and prepare recommendations regarding its acceptability for inclusion in the Board's Report. Thompson named Maxime A. Faget, MSC, to chair the subcommittee and Frank Borman, MSC, George C. White, NASA Hq., and E. Barton Geer, LaRC, as members. Thompson asked that the subcommittee forward its recommendations at the earliest possible date and that it also review the comments of North American Aviation on the validity of the findings of the Board and its Panels.

TWX, Thompson to addressees, May 12, 1967.

May 15

The NASA Block II CSM Redefinition Task Team was augmented by the assignment of Gordon J. Stoops as Group Leader-Program Control, with the following functions:

- Liaison with North American Aviation Program Control and Contracts to expedite updating of the contract change authorizations and the issuance of timely program technical direction.
- Liaison with the ASPO CSM project Engineering and Checkout Division and CSM Contract Engineering Branch at MSC to expedite contract change authorizations and ensure timely program technical direction.

Memo, Manager, CSM, ASPO, to distr., "Block II redefinition, command and service modules," May 15, 1967.

May 18

Prime and backup crews for Apollo 7 (spacecraft 101) were named, with the assignments effective immediately. The prime crew for the engineering-test-flight mission was to consist of Walter M. Schirra, Jr., commander; Donn F. Eisele, CM pilot; and R. Walter Cunningham, LM pilot. The backup crew was Thomas P. Stafford, commander; John W. Young, CM pilot; and Eugene A. Cernan, LM pilot. Names had been reported to the Senate Committee on Aeronautical and Space Sciences on 9 May.

Memo, Astronaut Office to distr., "Astronaut Technical Assignments," May 18, 1967; Senate committee on Aeronautical and Space Sciences, *Apollo Accident: Hearings*, 90th Cong., 1st sess., pt. 6, May 9, 1967.

May 19

A Block II spacecraft vibration program was begun to provide confidence in CSM integrity and qualify the hardware interconnecting the subsystems within the spacecraft. A test at MSC was to simulate the vibration environment of max-q flight conditions. The test article was to be a Block II CSM. A spacecraft-LM adapter, an instrumentation unit, and an S-IVB stage forward area simulation would also be used.

Memo, Chief, Systems Engineering Div. (MS), to Manager, ASPO, "Block II spacecraft vibration program," with encl., "Block II Spacecraft Vibration Program," May 19, 1967.

May 20

MSC notified NASA Hq. that - with the changes defined for the Block II spacecraft following the January 27 Apollo 204 fire and with CSM delivery schedules now reestablished - it was necessary to complete a contract for three additional CSMs requested in 1966. North American Aviation had responded September 15, 1966, to MSC's February 28 request for a proposal, but action on a contract had been suspended because of the AS-204 accident. NASA Hq. on June 27, 1967, authorized MSC to proceed.

TWXs, Manager, ASPO, to NASA Hq., Attn: Samuel C. Phillips, "Authorization for procurement of three additional Block II CSM's," May 20, 1967; NASA Hq., Associate Administrator for Manned Space Flight to MSC, Attn: George Low, June 27, 1967.

May 22

MSC ASPO Manager George Low informed Grumman Senior Vice President George Titterton that he had asked North American Aviation assistance in improving access to the LM when placed inside the spacecraft-lunar module adapter (SLA). He also ordered a change request, in response to Grumman's April 18 request that MSC consider an SLA design change. Low had visited the pad at KSC Launch Complex 37, agreed action was necessary, and on May 19 asked North American's Apollo Program Manager Dale D. Myers for recommendations. Low said improved access to the LM was needed "both for rapid emergency egress and for normal servicing."

An emergency method of cutting through the SLA structure in premarked locations with a "cookie cutter" portable handsaw device was adopted - primarily for exit in an emergency occurring after hypergolics were loaded into the LM.

Ltrs., Titterton to MSC, Apr. 18, 1967; Low to Myers, May 19, 1967; Low to Titterton, May 22, 1967; memo, ASPO Manager to R. W. Williams, "Preparation of change request," May 22, 1967; Myers to Low, Aug. 11, 1967.

May 25

MSC submitted requirements to KSC that TV signals from cameras inside the LM and CM be monitored and recorded during manned hazardous tests, with hatch open or closed, and tests in the Vehicle Assembly Building, launch pads, and altitude chambers. A facility camera was to monitor the propellant-utilization gauging system during propellant loading. MSC specified that the field of view of the TV camera should encompass the shoulder and torso and portions of the legs of personnel at the normal flight stations in both the CM and the LM.

Ltr., Owen G. Morris, MSC, to KSC, "Continuous Television Recording in Support of Manned Apollo Tests at KSC," May 25, 1967.

May 26

ASPO Manager George Low told Charles A. Berry, MSC Director of Medical Research and Operations, that it had been determined there was no suitable substitute for water glycol as a coolant and it would continue to be used in the Apollo spacecraft. Low recognized that it was "essential that the effects of any possible glycol spill be well defined and that procedures be established to avoid any hazardous conditions." He asked Berry's office to define the limits of exposure for glycol spills of varying quantities and for recommendations concerning cabin purge in the event of a spill. Low also wondered, assuming development of a smelling agent, if it would be possible to determine the concentration of water glycol by the strength of the smell in the spacecraft. Berry's office replied June 22 that it was working with Crew Systems Division to identify an odor additive for leak detection. They would begin a program to establish a safe upper limit for human exposure to ethylene glycol and had asked the National Academy of Sciences Committee on Toxicity for information. Animal exposure tests probably would be necessary; if they were needed, a test plan would be submitted before July 1.

Memos, Manager, ASPO, to Berry, "Water glycol toxicity," May 26, 1967; Berry to Low, June 22, 1967.

May 26

NASA Headquarters and MSC officials attended a review of the CSM at North American Aviation in Downey. Following the North American briefing, the group visited the wire-harness layout and assembly areas. NASA Associate Administrator for Manned Space Flight George E. Mueller, with Anthony W. Wardell and Jack A. Jones of MSC, inspected the wiring in spacecraft 101 and 2TV-1 in detail.

Mueller stressed the importance of improving spacecraft delivery schedules, with particular emphasis on

spacecraft 020 and the second and third manned spacecraft, working up to two-month delivery intervals. He was concerned about the five- to six-week spacecraft 020 hatch delay and stated that Apollo Program Director Samuel C. Phillips must approve the proposed change. North American pointed out that it was using the resources of the corporation toward the two-month delivery schedule, and that a modification task-team approach would be used as long as it was effective in improving schedules. Tiger teams of engineering, quality, manufacturing, and materials personnel were working on wiring and plumbing in spacecraft 101. CSM Manager Kenneth S. Kleinknecht reviewed the Block II Redefinition Task Team effort for Mueller and he indicated that Phillips had considered an industry tiger team to assist in the overall spacecraft effort.

Memo, Kleinknecht to ASPO Manager, "Review of command and service modules," May 26, 1967.

May 26

Apollo 204 Review Board Chairman Floyd L. Thompson wrote NASA Deputy Administrator Robert C. Seamans, Jr., "The Apollo 204 Review Board respectfully submits that it has fulfilled all of its duties and responsibilities as prescribed by the Deputy Administrator's memorandum of February 3, 1967. Accordingly, it is requested that the Apollo 204 Review Board be dissolved."

Ltr., Thompson to Seamans, "Report of Completion of Apollo 204 Review Board Activities," May 26, 1967.

May 29

W. R. Downs, Special Assistant for Advanced Systems, MSC Structures and Mechanics Division, discovered that bare or defectively insulated silver-covered copper wires exposed to glycol/water solutions would ignite spontaneously and burn in oxygen. Copper wire or nickel-covered copper wire under identical conditions did not ignite. The laboratory results were confirmed in work at the Illinois Institute of Technology. In a June 13 memorandum, the Chief of the Structures and Mechanics Division recommended that if additional testing verified that nickel-coated wires were free of the hazard, consideration should be given to an in-line substitution of nickel-coated wires for silver-coated wires in the LM. It was understood that the Block II CSM already had nickel-coated wires. In a June 20 memo to the ASPO Manager, the Director of Engineering and Development pointed out that silver-plated pins and sockets in connectors would offer the same hazards. He added that Downs had also identified a chelating agent that would capture the silver ion and apparently prevent the reaction chain. In a July 24 memorandum, ASPO Manager George Low said that, in view of recent spills of ethylene glycol and water mixtures, spacecraft contractors North American Aviation and Grumman Aircraft Engineering had been directed to begin actions immediately to ensure that a fire hazard did not exist for the next manned spacecraft. Actions were to include identification of the location of silver or silver-covered wires and pins and of glycol spills.

Memos, Special Assistant for Advanced Systems to Chief, Structures and Mechanics Div., "Chemical

reactivity of silver covered copper wires with glycol/water solutions compared to copper or nickel covered copper wires," May 29, 1967 (rev. June 12, 1967); Chief, Structures and Mechanics Div., to Director of Engineering and Development, "Silver-covered copper wires as a fire producing hazard in spacecraft," June 13, 1967; Director of Engineering and Development to Manager, ASPO, "Silver-covered copper wires as a fire producing hazard in spacecraft," June 20, 1967; Manager, ASPO, to distr., "Silver-covered copper wires as a fire producing hazard in spacecraft," July 24, 1967.

May 31

Grumman Aircraft Engineering Corp.'s method of building wiring harness for the lunar module was acceptable, George Low, MSC Apollo Spacecraft Program Office Manager, wrote Apollo Program Manager Samuel C. Phillips at NASA Hq. Low had noted on a visit to Grumman on May 9 that many of the harnesses were being built on two-dimensional boards. In view of recent discussions of the command module wiring, Low requested Grumman to reexamine their practice and to reaffirm their position on two-versus three-dimensional wiring harnesses.

In his May 31 letter to Phillips, Low enclosed Grumman's reply and said that, in his opinion, Grumman's practice was acceptable because

1. most wire bundles on the LM were much thinner than the CSM wiring bundles and were much more flexible;
2. portions of the LM harness were often fabricated on a three dimensional segment of the harness board; and
3. connectors were usually mounted on metal brackets with the proper direction and clocking.

Ltrs., Low to Phillips, May 31, 1967; J. G. Gavin to Low, "Use of Two and Three Dimensional Harness Boards in Fabrication of LM Wiring," May 24, 1967; Grumman LM Manufacturing Memo, W. B. Atchison to C. W. Rathke, "Harness Board Design - 2D vs. 3D," 17 May 1967.

May 31

George M. Low told Joseph N. Kotanchik, Chief of MSC's Structures and Mechanics Division, that actions were pending on Pratt & Whitney pressure vessel failures. The pressure vessels were used in the Apollo fuel cell system. Kotanchik had spelled out a list of problem areas in connection with both the vessels and management interface between MSC and principal contractor North American Aviation, and between North American and its subcontractor Pratt & Whitney.

Memos, Chief, Structures and Mechanics Div., to Manager, ASPO, "Conduct of Pratt and Whitney Aircraft (PWA) on pressure vessel failure analysis," May 18, 1967; Low to Kotanchik, "Pratt & Whitney pressure vessel failures," May 31, 1967.

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Part 2 (C)

Recovery, Spacecraft Redefinition, and First Manned Apollo Flight

June 1967

1967

June 1

MSC's Director of Flight Operations Christopher C. Kraft, Jr., told ASPO Manager George M. Low that his Directorate was willing to support the flight test program presented in late May and felt that the computer programs and operational support he had in development would support the flights as currently scheduled. He did offer some comments on the proposed flight test program and asked that the NASA Office of Manned Space Flight be given an indication that his suggested program was being considered as a future alternate approach. The comments included:

1. "The first manned LM flight appears to be most ambitious. We believe that when the time comes, a much more conservative approach to the flight plan will be taken because of the lack of experience with the LM spacecraft. . . .
2. We have the general feeling that there are insufficient flight tests scheduled in order to prove the worthiness of the LM and that a lunar landing flight could only follow a successfully completed schedule of LM flights. . . .
3. We believe that a lunar orbit flight with the CSM/LM should be included in the flight test program, as an alternate to the third CSM/LM flight you have proposed, or as an additional flight to the program. . . .
4. . . . we believe it feasible that one of the LM development flights could be conducted as safely in the vicinity of the moon as in earth orbit, assuming that the CSM has been proven at that time. . . .
5. Finally, we believe that the lunar type flight programs we propose would have great impact on the stature of the nation's space program. . . ."

Memos, Owen E. Maynard, MSC, to Kraft, "Apollo Flight Program Definition," May 31, 1967 ; Kraft to Low, "Requested comments on Apollo Flight Program Definition," June 1, 1967.

June 2

A meeting at MSC discussed CSM and LM changes, schedules, and related test and hardware programs. On June 26, NASA Apollo Program Manager Samuel C. Phillips summarized the discussion in a letter to George Low. He pointed out that certain problems could result in serious program impact if not solved expeditiously and specifically mentioned couch design, the weight problem in the CSM and LM, docking changes, and delivery schedules.

Minutes of Apollo Program Meeting, June 2, 1967; ltr., Phillips to Low, June 26, 1967.

June 6

Bendix Corp. demonstrated the operation of a sliding boom concept to prove that the Apollo Lunar Surface Experiments Package (ALSEP) could be removed from the LM at various attitudes. MSC representatives viewing the demonstration at Ann Arbor, Mich., were Aaron Cohen, Don Weissman, Paul Gerke, Don Lind, and Harrison Schmitt. Cohen reported that the mockup was crude but indicated that the concept was satisfactory to both Grumman and NASAL Design refinement, qualification, and effect on LM structure would have to be looked into. It was believed an additional seven kilograms of weight would be added to the LM descent stage. Two interface problems were defined at the meeting:

1. Bendix and Grumman required maximum and minimum attitude position for the LM to complete the design of ALSEP handling equipment.
2. Both Grumman and Bendix required temperature criteria for the outer shield of the cask, which would contain radioactive material.

Memo, Cohen to A. L. Liccardi, RASPO, Grumman, "Trip Report to Bendix, Ann Arbor, Michigan, on June 6, 1967," June 13, 1967.

June 7

NASA Office of Manned Space Flight had redefined the Apollo Block II manned mission flight plan, ASPO informed the MSC Director of Science and Applications. The first manned flight plan called for

1. an open-ended mission up to 10 days,
2. sufficient instrumentation,
3. no extravehicular activity,
4. a CSM rendezvous with the S-IVB stage, and
5. no experiments that required spacecraft integration.

The redefinition resulted in OMSF's indicating that no scientific experiments would be flown on the mainstream Apollo flights unless they would contribute to the accomplishment of the lunar mission. ASPO therefore had told North American Aviation that certain scientific experiments planned for

spacecraft 101 would now be deleted from the program. The experiments were Simple Navigation (D019), Urine Volume Measuring System (M005), UV Stellar Photography (S019), and UV/X-ray Solar Photography (S020).

Memo, Manager, MSC ASPO, to MSC Director of Science and Applications, "Apollo Earth Orbital Experiments," June 7, 1967.

June 8

At a NASA and North American Aviation management meeting, North American was directed to proceed with development of larger drogue parachutes and staged main chute disreefing, using 5- and 8-second reefing-line cutters. Later analysis of the system and the proposed modifications still indicated only a marginal capability to offer adequate factors of safety, and North American was directed to use 6- and 10-second reefing-line cutters. In a letter to Headquarters, MSC Director Robert R. Gilruth mentioned that a review of these modifications had been covered at the September Manned Space Flight Management Council and, since no objections were voiced at that time, MSC assumed concurrence with the changes and would implement modifications for spacecraft 101 and subsequent Block II spacecraft.

"Minutes of Apollo Program Meeting" (June 2, 1967); ltr., Gilruth to NASA Hq., "Command Module Earth Landing System modification," Sept. 29, 1967.

June 8

In a memorandum to the Chief, Systems Engineering Division, MSC, ASPO Manager George M. Low pointed out the weight problem in the CSM and LM was critical. Low called for a detailed review of weight effects along with any proposed design change. The weight estimate was to be submitted by the affected contractor as a part of his change proposal, and this would then be verified by the subsystems manager and Systems Engineering.

To provide timely weight status to the Configuration Control Board, Systems Engineering Division was given the responsibility of presenting CSM and LM weight status at each weekly Board meeting as follows:

1. control weight,
2. current weight, and
3. estimated weight at time of launch.

These figures would be shown for three spacecraft: first manned, second manned, and lunar configuration. Both launch weight and reentry weight were to be included.

Memo, Low to Chief, Systems Engineering Div., MSC, "Spacecraft Weight," June 8, 1967.

June 8

Apollo Program Director Samuel C. Phillips, in a message to ASPO Manager George M. Low, spoke of a June 2 agreement to include a CSM active rendezvous with the Saturn S-IVB stage of the launch vehicle in the mission profile of the first manned Apollo mission. Phillips said that it should be recognized that such a rendezvous would not be a primary objective for the first manned mission and that the decision should be reviewed if any related problem that would complicate mission preparations were identified.

TWX, Phillips to Low, "First Manned Apollo Rendezvous," June 8, 1967.

June 9

Robert C. Seamans, Jr., Deputy Administrator of NASA, prepared a memorandum to the file concerning the selection of North American Aviation as the CSM prime contractor. The memorandum, a seven-page document, chronologically reviewed the steps that led to the selection of North American and followed by about a month the statement of NASA Administrator James E. Webb in response to queries from members of the Congress.

Memo to the File from Deputy Administrator, NASA, "The Selection of North American Aviation, Inc., as the prime contractor for the command and service module," June 9, 1967.

June 9

Robert O. Aller, NASA OMSF, told Apollo Program Director Samuel C. Phillips that considerable analysis, planning, and discussion had taken place at MSC on the most effective sequence of Apollo missions following the first manned flight [Apollo 7]. The current official assignments included three CSM/LM missions for CSM/LM operations, lunar simulation, and lunar capability. MSC's Flight Operations Directorate (FOD) had offered an alternate approach of that sequence by proposing that the third mission be a lunar-orbit mission rather than a high earth-orbit mission. Aller preferred the FOD proposal, since it would offer considerable operational advantages by conducting a lunar-orbital flight before the lunar landing. He recommended Phillips consider that sequence of missions and that consideration be given to including it as a prime or alternate mission in the Mission Assignments Document. "Identifying it in that document," Aller said, "would initiate the necessary detailed planning."

Memo, Aller to Phillips, "Apollo Flight Program," June 9, 1967.

June 13

The purpose of spacecraft 105 testing was to establish transition relations between the primary and secondary structure that supported systems' interconnecting hardware (wiring, tubing and associated valves, filters, regulators, etc.) and demonstrate structural integrity of the Block II CSM when subjected

to qualification vibration environment, with special emphasis on interconnecting hardware. The test vehicle was being configured with complete basic Block II wiring harness and fluid systems. The vehicle would be checked out before and after each phase of testing to verify wiring harness impedance and continuity and fluid systems pressure integrity. The fluid systems would be at operating pressure during the testing.

Memo, ASPO Manager to Chief, Flight Safety Office, MSC, "Vibration testing," June 13, 1967.

June 14

Designations and abbreviations for flight crewmen on all manned Apollo missions were selected:

- Commander - CDR
- Command module pilot - CMP
- Lunar module pilot - LMP

This terminology was to be used throughout the Apollo spacecraft program and compliance was required to minimize confusion.

Memo, Manager, ASPO, to distr., "Apollo crewmen designations," June 14, 1967.

June 15

MSC Director Robert R. Gilruth told George E. Mueller, NASA OMSF, that MSC desired that the vernier engine be fired after the touchdown of *Surveyor IV* on the lunar surface. He reminded Mueller that this experiment was supposed to have been performed on *Surveyor III* and was of prime importance to Apollo. The fact that *Surveyor III* landed with the vernier engine firing and did not experience any significant erosion had also been of importance to the Apollo program. He requested that *Surveyor IV* be targeted for the Apollo landing site in the Sinus Medii area. As a lower priority experiment, Gilruth said MSC would like to get a limited amount of photography on the first lunar day, which would allow a limited assessment of viewing conditions in earthshine.

Ltr., Gilruth to Mueller, "Surveyor IV support of Apollo," June 15, 1967.

June 17



X-ray inspection seeks to ensure that weldments, wires, and spacecraft components are free of cracks and other damage that could jeopardize crew safety and mission success.

Plans were to armor-plate 102 out of 167 solder joints inside the CM of spacecraft 101, ASPO Manager George M. Low informed Maxime A. Faget, MSC's Director of Engineering and Development. Of the remaining 65 joints, 53 would be accessible for armor-plating and x-raying, while the other 12 would not. Low said: "As joints become less accessible, the excess solder removal process, the joint-cleaning process, and the application of the armor-plating become more difficult. Also, in many places, the standard armor-plating sleeve does not fit, and a shorter or cutaway sleeve is required. I have therefore reached the conclusion that, at some point, the armor-plating process may become detrimental. . . . You should know that Mr. [Joseph N.] Kotanchik disagrees with this position. Joe believes that any joint in the spacecraft could be under stress and therefore is subject to creep. The only solution . . . according to Joe, is to armor-plate all joints. . . ." Low added that joints that are accessible from outside the CSM would also be armor-plated and that future spacecraft would include additional armorplating. He said, "My expectation is that all solder joints will be armor-plated in the lunar configuration. . . ."

Memo, Low to Faget, "Armor-plating of solder joints," June 17, 1967.

June 19

H. G. Paul, Chief of Marshal Space Flight Center's Propulsion Division, said it had come to the attention of his office that spacecraft/S-IVB rendezvous to within approximately 100 meters was being considered for the AS-205 mission. The division's position was that, unless the S-IVB stage were made passive, the division could not guarantee the stage would be in a safe condition. After the lifetime of a nonpassivated stage, it was possible that indiscriminant propellant-tank or bottle venting could cause the stage to tumble, thus permitting liquid to enter the propellant-tank vent lines. Another area of concern was the high-pressure bottles on the stage. Should a relief valve fail to function normally, a bottle rupture could result. The Propulsion Division therefore recommended that no rendezvous mission be planned with S-IVB stages of either Saturn IB or Saturn V launch vehicles after the guaranteed lifetime of the stage, unless that stage had been passivated.

Memo, Paul to Cochairman, Guidance and Performance Subpanel, "AS-205 Spacecraft/S-IVB Rendezvous," June 19, 1967.

June 20

Apollo spacecraft 017 was mechanically mated to its Saturn V launch vehicle at KSC in preparation for the Apollo 4 (AS-501) unmanned mission, scheduled for the third quarter of 1967.

Astronautics and Aeronautics, 1967 (NASA SP-4008, 1968), p. 191.

June 20

Leonard Reiffel of the NASA Hq. Apollo Program Office suggested to Program Director Samuel C. Phillips that "we do not schedule the ALSEP [Apollo Lunar Surface Experiments Package] for the first lunar landing," because:

- The duration on the lunar surface for the first mission was likely to be short and the ALSEP deployment time was likely to take a seriously disproportionate share of available time. "It is my opinion we will learn more of immediate consequence to science and to planning of subsequent missions from careful observations and sample collection as contrasted to emplacement of an all-up ALSEP."
- With the exception of the lunar atmosphere, manned operations would not disturb the conditions ALSEP was intended to measure. These, therefore, could be measured on later flights.
- The magnetometer was in trouble. The interpretability of plasma experiments on an ALSEP that did not include a magnetometer would be markedly depreciated.
- The problem of LM weight control would be eased substantially if only the lunar geological tools and sample boxes, rather than the full ALSEP, were carried.

- Waiting for the second lunar mission would decrease the risk of wasting a full ALSEP payload, since the Apollo system already would have successfully reached the moon once.

He added, "An uncrowded time line on the lunar surface for the first mission would seem to me more contributory to the advance of science than trying to do so much on the first mission that we do nothing well. . . ."

Memo, Reiffel to Phillips, "Flight Schedule for ALSEP and Related Matters," June 20, 1967.

June 20

Officials at the Manned Space Flight Management Review decided that Apollo 4 and Apollo 5 missions would be flown with no less than a 21-day interval between flights. This period was determined necessary to provide an adequate turnaround of the ground support systems to ensure proper reconfiguration, validation, and updating. The Apollo 4 mission would be given priority over Apollo 5 in the checkout and readiness phase if conflicts in use of facilities and equipment should arise.

Memo, Director, Mission Operations, NASA OMSF, to distr., "Mission Priority and Turnaround between Apollo 4 and Apollo 5," July 10, 1967.

June 22

A committee was established to conduct an operational readiness inspection (ORI) of the MSC Space Environment Simulation Laboratory. The inspection would supplement the original ORI of the facility. Emphasis would be placed on reviewing modifications since the previous inspection and upon readiness to perform the test series on LTA-8 and 2TV-1. The committee was made up of Martin L. Raines, Chairman; Rexford H. Talbert, Executive Secretary; Edward L. Hays, Alan Harter, James E. Powell, John W. Conlon, Armistead Dennett, and Joseph P. Kerwin, all of MSC; Dugald O. Black, KSC; and E. Barton Geer, LaRC.

Memo, Director, MSC, to distr., "Operational Readiness Inspection of the MSC Space Environmental Simulation Laboratory," June 22, 1967.

June 23

Although the LM-1 wiring harness had been accepted by the Customer Acceptance Readiness Review Board it was not clear that the harness would also have been accepted for manned flight, ASPO Manager George M. Low told Apollo Systems Engineering Assistant Chief R. W. Williams. Low asked Williams to assign someone to prepare a plan of actions needed to ensure that the harnesses in LM-2 and subsequent vehicles would be acceptable.

Memo, Low to Williams, "LM spacecraft wiring and splices," June 23, 1967.

June 26

Apollo Program Director Samuel C. Phillips told ASPO Manager George Low he believed progress had been made toward Apollo objectives. At the same time, Phillips believed certain problems, if not solved expeditiously, could seriously delay the program. He was concerned particularly with the couch design, weight problem, docking changes, and delivery schedules. Phillips requested an early response on the problem areas.

Ltr., Phillips to Low, June 26, 1967.

June 26

Possible hazards to the crew in the lunar module thermal vacuum test program (using LTA-8) were pointed up in a memorandum to Manager, ASPO, and Director of Engineering and Development from the Director of Flight Crew Operations. Manning procedures required crewmen to make numerous hard vacuum transfers between the Space Environment Simulation Laboratory's environmental control system (ECS) umbilicals and the LM environmental control system hoses. Also, during the manning operations the crewmen would be on the LM-ECS with the cabin depressurized. In the configuration in use, if one of the crewmen lost his suit integrity, there would be no protection for the other man. Because of these hazardous conditions the following actions were requested:

1. provide equipment to make vacuum transfers of oxygen hoses acceptably safe; and
2. change the LTA-8 vehicle ECS so that one crewman was protected if the other lost suit integrity in a vacuum ambient.

Memo, Director of Flight Crew Operations to Manager, ASPO, and Director of Engineering and Development, "Possible hazards to the crew during the Lunar Module Thermal Vacuum Tests in Chamber B," June 26, 1967.

June 28

The Apollo Program Director requested MSC to assign the following experiments to AS-205, spacecraft 101: M006 - Bone Demineralization, M011 - Cytogenic Blood Studies, M023 - Lower Body Negative Pressure, S005 - Synoptic Terrain Photography, and S006 - Synoptic Weather Photography. Experiment D008, Radiation in Spacecraft, would be included in the above list at the option of ASPO. On July 21 ASPO Manager George M. Low informed CSM Manager Kenneth S. Kleinknecht that he was approving reinstatement of Experiments S005 and S006 on AS-205. On the same date Low informed the Apollo Program Director that S005 and S006 would be carried on AS-205. He proposed that experiments M006, M011, and M023, which required pre- and postflight operations with the crew, be classified not as experiments but as part of the normal pre- and postflight medical evaluation. Experiment D008 was deleted from AS-205 and all other inflight experiments previously assigned had been deleted from the

spacecraft. MSC's Director of Medical Research and Operations Charles A. Berry and Director of Space Science and Applications Wilmot N. Hess concurred with Low's decision.

Ltrs., Apollo Program Director to MSC, Attn: George M. Low, "Earth Orbital Experiment Assignments," June 28, 1967; Low to NASA Hq., Attn: Samuel C. Phillips, "Earth Orbital Experiment Assignments," July 21, 1967; memo, Manager, ASPO, to K. S. Kleinknecht, "Experiments S005 and S006," July 21, 1967.

June 28

Dale D. Myers, Apollo CSM Manager for North American Aviation, Inc., requested a meeting with ASPO Manager George M. Low and ASPO CSM Manager Kenneth S. Kleinknecht to resolve issues concerning materials replacement and objectives for boilerplate tests. In reply, on July 6, Low said that Kleinknecht had conducted a complete review of flammable materials since receipt of Myers' June 28 letter and that a number of telephone conversations had been held on the subject. MSC recommended that the insulation on the environmental control unit be covered with nickel foil and that silicone-rubber wire-harness clamps could possibly be covered with a combination of "Laddicote" and nitroso rubber. Plans were for the boilerplate mockup tests to use an overloaded wire in a wire bundle as an ignition source. At Myers' suggestion, MSC was also looking into the use of electric arcs, or sparks, as a possible ignition source. Low said: "As you know, our goal in the mockup tests will be to demonstrate that any fire in a 6 psi [4.1 newtons per square centimeter] oxygen atmosphere extinguishes itself. . . . If we can demonstrate that in the 6 psi oxygen atmosphere a fire would spread very slowly so that the crew could easily get out of the spacecraft while on the pad . . . , then I believe that we should also be satisfied."

Ltrs., Myers to Low, June 28, 1967; Low to Myers, July 6, 1967.

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Part 2 (D)

Recovery, Spacecraft Redefinition, and First Manned Apollo Flight

July through September 1967

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July 3

To prevent flight crew incapacitation from possible carbon dioxide buildup in their Block II spacesuits after emergency exit from a spacecraft, development of a small air bottle was proposed. Bottles, to be attached to the suit to provide proper atmosphere in an emergency, would be stowed on the spacecraft access arm until needed.

Ltr., Donald K. Slayton, MSC, to ASPO Manager, "Emergency air supply for a suited flight crew during a spacecraft emergency egress," July 3, 1967.

July 5

A board was appointed by MSC White Sands Test Facility Manager Martin L. Raines to determine the cause of a fire that had occurred at Test Stand 403 on July 3. The board was to submit its findings by July 17.

Ltr., Raines to distr., "Appointment to Investigation Board," July 5, 1967.

July 12

A CSM shipment schedule, to be used for planning throughout the Apollo program and as a basis for contract negotiations with North American Aviation, was issued by NASA Hq. The schedule covered CSM 101 through CSM 115, CSM 105R, and CSM 020 and the period September 29, 1967, through November 17, 1969.

Ltr., Robert R. Gilruth, MSC, to Samuel C. Phillips, NASA Hq., July 12, 1967; TWX, Phillips to Gilruth and George M. Low, MSC, July 24, 1967.

July 18

Kurt H. Debus, KSC Director, appointed John Bailey of MSC Chairman of an ad hoc Safety Group, following discussions with George E. Mueller of NASA OMSF, MSC Director Robert R. Gilruth, and MSFC Director Wernher von Braun. The Safety Group was to examine the overall operating plans, organizational responsibilities, flight hardware, and ground support equipment and to identify existing and potential personnel hazards associated with the preparation, checkout, and launch of Apollo 4 (AS-501). The group would submit an initial report by August 15.

Ltr., Debus to Bailey, "Establishment of Apollo 4 (AS-501) Ad Hoc Safety Group," July 18, 1967.

July 18

Visual display systems of complex optical devices were being used with the lunar module mission simulators. To help solve problems that some of these systems were creating, assistance was requested from J. E. Kupperian, E. S. Chin, and H. D. Vitagliano, all from Goddard Space Flight Center.

Ltr., Robert R. Gilruth, MSC, to John F. Clark, GSFC, July 18, 1967.

July 18

CSM flammability mockup testing was discussed at a program review. It was pointed out that boilerplate testing was being conducted at Downey and that an all-up test should not be performed until all individual tests were completed and the final configuration was completely established.

Memo, George M. Low, MSC, to Kenneth S. Kleinknecht, MSC, "Flammability mockup testing," July 21, 1967.

July 19

In a letter to Apollo Program Director Samuel C. Phillips, MSC Director Robert R. Gilruth requested that the Boeing Company personnel ceiling be increased to 373. This action was taken as a result of a reevaluation of the requirement of basic task statements and a better understanding of the tasks to be

performed. During the planning sessions on the new contract with Boeing, a manpower ceiling of 250 had been established.

Ltr., Gilruth to Phillips, July 19, 1967.

July 21

The RTG Review Team - established to investigate the relation of the radioisotope thermoelectric generator's fuel-cask subsystem to Apollo mission safety and success - submitted a preliminary report. Apollo Program Director Samuel C. Phillips had established the team after concern was expressed over the design and safety of the subsystem at a June 1 review at NASA Hq. of the Apollo Lunar Surface Experiments Package (ALSEP).

The team's preliminary report was based on data received and observations of the LM at Grumman that indicated the interface of the RTG, LM, and spacecraft-LM adapter (SLA) presented a potential problem to the Apollo mission. The most serious hazard was the presence of the 530-640 K (500-700 degrees F) RTG fuel cask in the space between the LM and the SLA, where leaks were possible during fuel unloading or in the mechanical joints of the LM fuel system.

Plans were to fuel the LM four days before launch and to pressurize the LM fuel system at T (time of launch) minus 16 hours. The RTG fuel element was to be loaded into the graphite cask, which was mounted on the LM at T minus 12 hours and the system secured. All work would be completed on the ALSEP by T minus 10 hours. If a condition occurred that required unloading fuel from the LM after installation of the fuel element in the cask, the hot cask would be a partial barrier to reaching one of the fuel unloading points and also would be a potential fire hazard. No mechanism was available to remove the entire cask system rapidly. Other potential problems were:

1. a review showed all propellants that could come into contact with the cask had spontaneous ignition temperatures below the temperature of the RTG cask, and thus fuel vapors could be a problem;
2. after launch no indicators would be available to show the crew the status of the RTG or the SLA area, and no jettisoning mechanism was available for the RTG fuel cask; and
3. during deployment of the ALSEP on the lunar surface the astronauts would be required to remove the RTG fuel element and load it into the RTG assembly. While handling tools were available for this operation, no means had been demonstrated to protect the spacesuit if accidentally brushed against the cask.

"Radioisotopic Thermoelectric Generator Review Team Preliminary Report," July 21, 1967

July 22

A series of oxygen purge system (OPS) transfer runs were conducted in the Water Immersion Facility at

MSC. Preliminary reports indicated the results of the tests were highly satisfactory, but an assessment of pad abort procedures following several runs in the Apollo Mission Simulator were not so promising. Further work and study in this area was in progress.

Memos, Donald K. Slayton, MSC, to George M. Low, MSC, "Preliminary evaluation of Pad Abort and Oxygen Purge System (OPS) Transfer Procedures," July 26, 1967; Low to Slayton, "Pad abort procedures and Oxygen Purge System transfers," July 29, 1967.

July 24

The ASPO Manager summarized the lunar module oxygen capacity and design requirements for the lunar mission and made an analysis of his decision to leave both portable life support systems (PLSS) on the lunar surface. He recommended that NASA OMSF accept the PLSS discard philosophy as well as the design capacity for lunar module oxygen.

Ltrs., George M. Low, MSC, to Samuel C. Phillips, NASA Hq., July 24, 1967; Phillips to Low, Aug. 10, 1967.

July 24

ASPO Manager George M. Low issued instructions that the changes and actions to be carried out by MSC as a result of the AS-204 accident investigation were the responsibility of CSM Manager Kenneth S. Kleinknecht. The changes and actions were summarized in Apollo Program Directive No. 29, dated July 6, 1967.

Memo, George M. Low to distr., July 24, 1967.

July 25

Following a series of discussions on the requirements for the lunar mapping and survey system (LMSS), the effort was terminated. An immediate stop work order was issued to the Air Force, the Centers, and the contractors in the LMSS effort. The original justification for the LMSS, a backup Apollo site certification capability in the event of Surveyor or Lunar Orbiter inadequacies, was no longer valid, since at least four Apollo sites had been certified and the last Lunar Orbiter would, if successful, increase that to eight.

Memos, Robert C. Seamans, Jr., NASA Hq., to George E. Mueller, NASA Hq., "Lunar Mapping and Survey System (LMSS)," July 13, 1967; Mueller to Seamans, same subject, July 18, 1967; Seamans to Mueller, "Termination of the Lunar Mapping and Survey System," July 25, 1967.

July 25

MSC Director of Flight Operations Christopher C. Kraft, Jr., raised questions about lunar module number 2: Would it be possible for LM-2 to be a combined manned and unmanned vehicle; that is, have the capability to make an unmanned burn first and then be manned for additional activities? Would additional batteries in the LM provide greater flexibility for earth-orbital missions? Mission flexibility would be worthwhile only if it allowed deletion of a subsequent mission, at least on paper.

Memo, G. M. Low, MSC, to O. E. Maynard, MSC, "LM mission flexibility and other points," July 25, 1967.

July 26

The Air Force Chief of Staff announced the reassignment of Carroll H. Bolender from Washington to Houston as Program Manager for the lunar module at MSC. He had been Apollo Mission Director at NASA Hq.

TWX, Air Force Chief of Staff to NASA Hq. and MSC, July 26, 1967.

July 26

MSC asked continued engineering and inspection support from KSC, although increased activity at KSC was making support and factory operations more difficult. KSC had provided support for LM-1 at Bethpage, Long Island, and had also provided support for previous CSM and some Gemini vehicles. The aid of the KSC inspection personnel was particularly beneficial in ensuring a smooth transition of the vehicle from the factory to the field.

Ltr., Robert R. Gilruth, MSC, to Kurt H. Debus, KSC, July 26, 1967.

July 27

MSC Director Robert R. Gilruth wrote MSFC Director Wernher von Braun that MSC had two lunar landing research vehicles (LLRVs) for crew training and three lunar landing training vehicles (LLTVs) were being procured from Bell Aerosystems Co. Gilruth explained that x-ray inspection of welds on the LLTVs at both Bell and MSC had disclosed apparent subsurface defects, such as cracks and lack of fusion. There was, however, question as to the interpretation of the x-rays and the amount of feasible repair. Gilruth mentioned that James Kingsbury of MSFC had previously assisted MSC in interpreting weldment x-rays, stated that further x-rays were being taken, and asked MSFC assistance in interpreting them and in determining the amount and methods of repair needed.

Ltr., Gilruth to von Braun, July 27, 1967.

July 28

ASPO announced that a detailed review of the Block II CSM would be held to gain a better understanding of the hardware. ASPO Manager George M. Low pointed out that it had been customary in the Gemini and Apollo Programs to conduct Design Certification Reviews (DCRs) before manned flight of the "first of a kind" vehicle. He added that the detailed review should address itself to design and analysis, test history and evaluation of test results, and the understanding of operational procedures for each element in the CSM. To ensure the most thorough review, MSC divisions would conduct preliminary reviews. The division chiefs would then present their findings to the directorates, the ASPO management, and the MSC Director.

Memo, George M. Low to distr., July 28, 1967.

August 1

Rocketdyne Division of North American Aviation was selected for negotiation of a contract for the design, development, qualification, and delivery of four production models of an injector for the lunar module ascent engine. The project would serve as a backup to the injector program already being conducted by Bell Aerospace Corp. under subcontract to Grumman. The ascent engine was considered to be the most critical engine in the Apollo-Saturn vehicle. No backup mode of operation remained if the ascent engine failed.

Ltrs., Samuel C. Phillips, NASA Hq., to George M. Low, MSC, Aug. 16, 1967; George E. Mueller, NASA Hq., to Robert R. Gilruth, MSC, Aug. 17, 1967; NASA News Release 67-207, Aug. 2, 1967.

August 1

Kenneth S. Kleinknecht, CSM Manager at MSC, requested that North American organize a team of engineers with broad design backgrounds to make an independent assessment of component design efficiency. The team would identify actions to reduce spacecraft weight and to establish control methods to prevent future weight increases. The team would be placed under the leadership of a North American employee with broad knowledge of Apollo hardware.

To deal with Apollo weight problems, North American replied in October, accurate and timely weight visibility was of paramount importance. To provide this visibility, North American used system design personnel directly in weight prediction and reporting. As part of this plan, all engineering-design-change documentation would contain a delta weight effect that would be reviewed and approved by engineering management; weight trends and status would be reported monthly to North American and NASA management. A list of weight reduction candidates was suggested to NASA.

Ltr., Kleinknecht to Dale D. Myers, North American Aviation, Aug. 1, 1967; ltr., Myers to George M. Low, MSC, Oct. 5, 1967.

August 1-11

Lunar Orbiter V was launched from the Eastern Test Range at 6:33 p.m. EDT August 1. The Deep Space Net Tracking Station at Woomera, Australia, acquired the spacecraft about 50 minutes after liftoff. Signals indicated that all systems were performing normally and that temperatures were within acceptable limits. At 12:48 p.m. EDT August 5, *Lunar Orbiter V* executed a deboost maneuver that placed it in orbit around the moon. The spacecraft took its first photograph of the moon at 7:22 a.m. EDT August 6. Before it landed on the lunar surface on January 31, 1968, *Lunar Orbiter V* had photographed 23 previously unphotographed areas of the moon's far side, the first photo of the full earth, 36 sites of scientific interest, and 5 Apollo sites for a total of 425 photos.

Lunar Orbiter V Post Launch Reports 1 through 7, Aug. 2, 3, 7, 9, 11, 1969; *Astronautics and Aeronautics*, 1967 (NASA SP-4008, 1968), pp. 229, 235, 417.

August 11

Apollo Program Director Samuel C. Phillips was appointed Chairman of a NASA task group, reporting to Administrator James E. Webb, Deputy Administrator Robert C. Seamans, Jr., and Associate Administrator for Manned Space Flight George E. Mueller. The group was chartered to review the content of the Apollo program in order to determine alternatives necessary for programming and budget planning decisions. It would inquire into and report on all aspects of the Apollo program necessary to provide a base of accurate data and information to support decisions on FY 1968 expenditure control and FY 1969 budget planning. Specifically, the group was requested to identify planned activities that could be eliminated if the Apollo program were to be terminated with the manned lunar landing. The group was also requested to determine the effect of placing a hold order on production of Saturn V vehicles 512 through 515 and to develop the cost estimates resulting from these actions as well as other tangible alternatives. Memo, Webb to Phillips, "Review of Apollo Program," Aug. 11, 1967.

August 15

ASPO wrote Lewis Research Center about studies of ignition sources inside the pressure suits worn by the astronauts. In recent tests, the communications and biomedical circuits inside the suit and connected to the spacecraft panel through the crewman electrical umbilical were evaluated to determine the ignition characteristics. Studies on the flammability of various materials used in the suit loop had been completed and the data compiled.

Memo, G. M. Low, MSC, to I. I. Pinkel, Lewis Research Center, "Ignition source inside the suit," Aug. 15, 1967.

August 18

The NASA task team for CSM Block II redefinition, established on April 27, was phased out. During its duration the task team provided timely response and direction in the areas of detail design, overall

quality and reliability, test and checkout, baseline specifications, and schedules. With the phaseout of the team, Apollo Spacecraft Program Office policies and procedures would be carried out by the ASPO resident manager. A single informal point of contact was also established between MSC and North American for engineering and design items.

Memo, Kenneth S. Kleinknecht, MSC, to distr., "Phaseout of the NASA Task Team for Block II Redefinition, Command and Service Modules," Aug. 18, 1967.

August 19

ASPO Manager George M. Low, in a letter to Dale D. Myers of North American Aviation, expressed disappointment that both spacecraft 2TV-1 and 101 had slipped approximately six weeks. He also expressed astonishment that managers, who were supposedly using a planning system, did not understand the meaning of the charts they were using. Low suggested more attention to detail by managers, a better tracking system for shortages, assignment of responsible individuals to areas where special efforts were needed; and a mechanized system for tracking such things as work needing to be done and shortages.

Ltr, Low to Myers, Aug. 19, 1967.

August 22

A senior design review group was established to review the command module stowed equipment and the stowage provisions, to ensure the timely resolution and implementation of changes necessary because of new materials criteria and guidelines. Robert R. Gilruth, MSC Director, would head the group.

Memo, George M. Low, MSC, to distr., "Design Review of Command Module storage provisions," Aug. 22, 1967.

August 24

An interagency agreement on protecting the earth's biosphere from lunar sources of contamination was signed by James E. Webb, NASA; John W. Gardiner, HEW; Orville L. Freeman, Department of Agriculture; Stewart L. Udall, Department of Interior; and Frederick Seitz, National Academy of Sciences. The agreement established a committee to advise the NASA Administrator on back contamination and the protection of the biological and chemical integrity of lunar samples, on when and how astronauts and lunar samples might be released from quarantine, and on policy matters.

Interagency Agreement between the National Aeronautics and Space Administration, the Department of Agriculture, the Department of Health, Education, and Welfare, the Department of Interior, and the National Academy of Sciences on the Protection of the Earth's Biosphere from Lunar Sources of Contamination, Aug. 24, 1967.

Week Ending August 25

Grumman proposed a procurement for a study of the mission effects projector, to assist Grumman with an item that had been designed and built by Farrand but did not meet the established specifications. Grumman solicited assistance of qualified firms in the optomechanical field. Of 15 firms approached 7 were interested: Itek Corp., Kollmorgen Corp., Bausch & Lomb, Inc., Kollsman Instrument Corp., Biorad, General Precision Link Group, and Conductron. Technical proposals were received from Itek, Biorad, Link, and Conductron. Grumman considered the Itek proposal most technically acceptable and proposed a letter contract in which NASA concurred.

MSC, BMR Bethpage, "Weekly Activities Report, Week Ending August 25, 1967," Aug. 30, 1967.

August 26

"Reuse of failed equipment" was the subject of a memorandum to W. M. Bland in the MSC Reliability and Quality Assurance Office from ASPO Manager George M. Low. He said: "I have recently heard of several instances of reuse of apparently failed equipment without any fixes applied to that equipment. I understand that, if a component or subsystem is removed from the spacecraft because it has apparently failed but a subsequent failure analysis does not show anything to be wrong with the equipment, the equipment is then put back into stock for reinstallation. It appears to me that, if a component is once suspected or known to have caused a failure or to have failed, it should not be allowed back in the program unless a fix has been made or unless it has been proved conclusively that the failure was not caused by that component. If we do not now have a program directive that states such a policy, I think we should impose one as quickly as possible and set up adequate procedures to control it."

Memo, Low to Bland, Aug. 26, 1967.

August 30

A review team's findings on the lunar surface magnetometer program were reported to the NASA Administrator. The magnetometer program still suffered from the schedule delays and high costs that had prompted the review, but recent management changes and technical progress were halting the trends. With the team recommendation and the endorsement of the Office of Space Science and Applications, Philco Corp. was directed to continue its effort to develop a lunar surface magnetometer.

Memos, Samuel C. Phillips, NASA Hq., to NASA Administrator, "Lunar Surface Magnetometer," Aug. 30, 1967; W. H. Close, NASA Hq., to Deputy Administrator, "ALSEP Lunar Surface Magnetometer," Oct. 13, 1967.

September 1

An Apollo test flow study group was formed to make a detailed evaluation of spacecraft, launch vehicle, and space vehicle testing at KSC. The group was composed of aerospace industry and NASA personnel.

Memo, R. O. Middleton, KSC, to G. M. Low, MSC, "Apollo Test Flow Study Group," Sept. 1, 1967.

September 6

Apollo Program Directive No. 31 established and implemented the Apollo System Safety program and defined program requirements in consonance with NASA Management Instruction 1138.12, August 29, 1967. The directive was applicable to all Apollo Headquarters and Center System Safety activities and it spelled out Headquarters and Center Apollo responsibilities. Among Center requirements were:

1. "An office responsible for Apollo System Safety shall be established in accordance with the requirements set forth in NASA Management Instruction #1138.12."
2. "Each Center office for Apollo System Safety shall prepare a plan that describes the safety tasks to be performed and the method to be used for the accomplishment of these tasks. . . ."

On September 20, ASPO Manager George Low asked Aleck Bond of the MSC Engineering and Development Office if he was taking action. Bond replied that the Flight Safety Office was preparing an overall safety plan for the Center that would meet the requirements of the directive. In an October 16 letter to Apollo Program Director Samuel C. Phillips, Low pointed out that "The . . . directive stipulates that an office responsible for Apollo System Safety shall be established. . . . In reviewing this Management Instruction we can find no mention of such a Center office. . . ." Low added that ASPO had appointed an Assistant Program Manager for Flight Safety who would work with the MSC Flight Safety Office and ensure that the Center's flight safety policies and procedures were carried out throughout the Apollo spacecraft program.

Apollo Program Directive No. 31, "Apollo System Safety Program Requirements," Sept. 6, 1967; informal note, Low to Bond, Sept. 20, 1967; memo, Bond to Low, "Apollo Program Directive No. 31 - Apollo System Safety Program Requirements," Sept. 25, 1967; ltr., Low to, Phillips, "APD No. 31 - Apollo System Safety Program Requirements," Oct. 16, 1967.

September 7



LM-1, fitted inside spacecraft - lunar module adapter 7, is raised to position at Kennedy Space Center in preparation for the Apollo 5 mission.

LM-1 (Apollo 5) continued to have serious schedule difficulties. However, all known problems were resolved with the exception of the propulsion system leaks. Leak checks of the ascent stage indicated excessive leaking in the incline oxidizer orifice flange. The spacecraft was approximately 39 days behind the July 18, LM-1 KSC Operations Flow Plan.

MSC, "ASPO Weekly Project Status Report," Sept. 7, 1967.

September 8

A revised spacecraft delivery schedule with a maximum delivery rate of six spacecraft per year as opposed to a delivery rate of one spacecraft every six weeks for the Apollo program was proposed by MSC and approved by NASA Hq.

Ltr., Robert R. Gilruth, MSC, to Samuel C. Phillips, NASA Hq., Sept. 8, 1967; TWX, Phillips to Gilruth, "CSM Delivery Schedules," Sept. 22, 1967.

September 6

ASPO Manager George Low in a letter to Dale Myers of North American Aviation, emphasized that the spacecraft weight situation was the single most serious problem in the entire Apollo program. An example of the weight estimating problem was the spacecraft hatch. When the decision was made in March 1967 to incorporate a new hatch, the net weight increase was estimated at 185 kilograms, but calculations indicated that this increase was actually 558 kilograms. Neither of these numbers included the additional ballast, which doubled the required weight. Clearly weight estimates were inadequate, making a workable weight control program impossible. North American was requested to take immediate action to bring the weight problem under control. A letter in a similar vein was sent by C. H. Bolender, ASPO LM Manager, to J. G. Gavin, Jr., Grumman Aircraft Engineering Corp.

Ltr., Low to Myers, Sept. 9, 1967; Bolender to Gavin, Sept. 22, 1967.

September 15

A short circuit occurred during checkout of CSM 020 at North American, Downey, Calif. External power batteries in parallel with the reentry batteries had indicated low power and were replaced. During preparations to continue the test, arcing was reported and emergency shutdown procedures were applied. Investigation was under way to determine the cause of the arcing. Initial indications were that at least 100 amps were imposed on a small portion of the spacecraft wiring, causing some damage to the spacecraft batteries.

TWX, ASPO Manager to Director, Apollo Spacecraft Program, Sept. 18, 1967.

September 16

During operational checkout procedures on CSM 017, which included running the erasable memory program before running the low-altitude aborts, the guidance and navigation computer accidentally received a liftoff signal and locked up. Investigation was initiated to determine the reason for the liftoff

signal and the computer lockup (switch to internal control). No damage was suspected.

TWX, ASPO Manager to Director, Apollo Program Office, Sept. 18, 1967.

September 18

The Systems Engineering Division of ASPO presented a briefing to the ASPO Manager and other MSC officials on the logic of the lunar surface activity for the first lunar landing mission. Several potential missions were presented in terms of interactions between timelines, consumables, weight, and performance characteristics. Purpose of the demonstration was to elicit policy decisions on the number of extravehicular excursions to be planned for the first mission as well as the activities for each excursion. The following ground rules were established:

1. Priority of scientific objectives would be, in order, minimum lunar sample, ALSEP, and lunar geologic survey including sample collection.
2. The first EVA on the lunar surface during the first lunar mission would consist of a set of simplified, mutually independent activities and the timeline would permit rest periods between each activity. The minimum lunar sample would be collected during the first EVA but the ALSEP would not be deployed.
3. A second EVA would be included for planning purposes and would include ALSEP deployment. The second EVA would not be considered a primary mission objective.
4. For mission planning purposes the 22 1/2-hour lunar surface staytime would be pursued as the prime candidate for the first lunar landing mission.

Memo, George M. Low, MSC, to distr., "Surface activity during first lunar landing mission," Sept. 18, 1967.

September 18

Garrett Corp. Vice President Mark E. Bradley sent recommendations of the Garrett-AiResearch Safety Audit Review Board to Dale D. Myers, Vice President and Project Manager, Apollo Program, North American Aviation. Bradley said the Board had been appointed in May 1967 to make "an independent review of ECS [environmental control system] systems and components from a crew safety standpoint" and that the recommendations were "based on the considered professional judgment of the Board members without bias or prejudice with regard to cost or schedule."

In a reply to Bradley on October 21, Myers said: "Your letter has been reviewed in detail and it has been determined in some cases the recommendations are of a design improvement nature. . . . Because of the seriousness of your conclusions and recommendations, I believe it necessary and pertinent the following comments be made. . . . The magnitude and complexity of the Apollo program precludes any single system subcontractor the capability of full and knowledgeable assessment of the effects his system has on the whole. . . . This is not a criticism of your Safety Board function, rather a criticism of the charter

and ground rules on which the Board's recommendations are based. . . . It is disturbing to me to find your letter is being used as a vehicle to attempt reconsideration of Engineering Design Change Proposals (EDCP's) already given careful consideration and a subsequent disposition made. . . . I must insist that future Board comments be channeled through your Apollo project group for processing by the established EDCP procedures. If the EDCP affects Crew Safety or Mission success, it should be so indicated in the EDCP and will be given proper consideration by the management of NAR and NASA. . . . Because of the seriousness of your conclusions and recommendations, I am asking the NASA ASPO to form a Board with me to review your recommendations with you for disposition. . . ."

Myers also wrote ASPO Manager George Low on October 21, enclosing the AiResearch recommendations. He said: "I found that AiResearch had used different criteria for evaluation than we use, but I felt we have a situation that requires immediate and joint top-level review by us. . . . The Board made significant recommendations that could constrain a manned flight with the current configuration of the ECS. I hope that this is not the case and that the recommendations were meant to be in the area of design improvement rather than constraints of Crew Safety or Mission Success nature. . . . If you agree with the need for this NASA NAR joint ECS Safety Review Board, I will arrange such a meeting with the AiResearch Review Board."

Low replied to Myers on October 30, saying, "I agree with you that we should give serious consideration to each of the AiResearch recommendations and that a joint NASA/NAR Safety Review Board would be the best means of accomplishing this. I would be pleased to serve on such a board with you. . . ." Low asked Myers to set up the meeting following the Apollo 4 mission.

In a November 7 meeting at MSC the AiResearch Safety Board recommendations were discussed and initial dispositions made, with AiResearch being asked to provide a written acceptance or rejection of each.

Ltrs., Bradley to Myers, "Recommendation of Garrett-AiResearch Safety Audit Review Board," Sept. 18, 1967; Myers to Bradley, Oct. 21, 1967; Myers to Low, Oct. 21, 1967; Low to Myers, Oct. 30, 1967; Myers to Low, Dec. 13, 1967; Low to Myers, Mar. 19, 1968.

September 20

MSC proposed to the NASA Office of Manned Space Flight a sequence of missions leading to a lunar landing mission. The sequence included the following basic missions:

- A - Saturn V/unmanned CSM development
- B - Saturn IB/unmanned LM development
- C - Saturn IB/manned CSM evaluation
- D - Saturn V/manned CSM and LM development (A dual Saturn IB mission would be an alternative to the Saturn V for mission D)
- E - CSM/LM operations in high earth orbit

- F - Lunar orbit mission
- G - Lunar landing mission (like Apollo 11)
- H - Lunar landing mission (Apollo 12, 13, and 14)
- I - Reserved for lunar survey missions (not used)
- J - Lunar landing missions, upgraded hardware (Apollo 15, 16, and 17)

Memos, George M. Low, ASPO Manager, to distr., "Mission development and planning," Sept. 25, 1967; Low to Director, MSC, "Meetings with General Phillips and Dr. Mueller," Sept. 9, 1967; ltr, Robert R. Gilruth, MSC, to George E. Mueller, NASA Hq., Sept. 19, 1967; telecon, Ivan D. Ertel to John Sevier, Feb. 26, 1975.

September 21

At the request of Congress NASA was preparing a formal document on all the action items resulting from the January 27 AS-204 accident. The document would be used as a report to the entire Congress by the responsible Senate and House subcommittees and was expected to include two volumes. The first would cover Apollo 204 Review Board findings; the second would cover panel findings, results of Congressional testimony, and Apollo program direction. The report was forwarded to Congress in December 1967 (House) and January 1968 (Senate).

Ltr., Samuel C. Phillips, NASA Hq., to George M. Low, MSC, "AS-204 Accident Closeout Report," Sept. 21, 1967. House Committee on Science and Astronautics, Subcommittee on NASA Oversight, *Status of Actions Taken on Recommendations of the Apollo 204 Accident Review Board*, 90th Cong, 2nd sess., Committee Print, Serial L, 1968; Senate Committee on Aeronautical and Space Sciences, *Apollo Accident: Hearings*, 90th Cong., 2nd sess., pt. 8, January 1968.

September 22

C. H. Bolender, ASPO Manager for the lunar module, wrote Joseph G. Gavin, Jr., Grumman LM Program Director, that recent LM weights and weight growth trends during the past several months established the need to identify actions that would reduce weight and preclude future weight growth. He pointed out that the Configuration Control Board (CCB) at MSC had emphasized such actions, while recognizing the specific weight increases associated with design change actions resulting from the AS-204 accident. Several other design corrections or improvements had been implemented, such as increased plume protection, ascent engine reflection protection, descent stage upper-deck structural repair, and landing gear shielding. Bolender told Gavin, "We cannot afford to exercise ultraconservatism as an expedient to problem solving. The modification of the descent stage skin panels may be a case in point. . . . We have already asked that in consideration of minimum weight design, you reassess your recommendation to change to a uniform panel thickness." He requested that the objectives of the recent Super Weight Improvement program (a weight saving "tool" employed by Grumman) be reiterated in design activity and that weight reduction suggestions be solicited and evaluated for implementation. Bolender requested a biweekly review of weight reduction candidate changes and told Gavin he was

asking Systems Engineering Division to maintain close coordination with Grumman and to report progress of the weight reduction and control activity at the regular CCB meetings.

Ltr., Bolender to Gavin, Sept. 22, 1967.

September 22

The merger of North American Aviation, Inc., and Rockwell-Standard Corp. became effective and was announced. The company was organized into two major groups, the Commercial Products Group and the Aerospace and Systems Group. The new company would be known as North American Rockwell and use the acronym NR.

North American Rockwell Corp., "A First Look," Sept. 22, 1967,

September 25

Associate Administrator for Advanced Research and Technology Mac C. Adams requested concurrence of MSC Director Robert R. Gilruth to naming the following as members of Research Advisory Committees for Fiscal Year 1968: Christopher C. Kraft, Jr., Committee on Space Vehicles; Joseph G. Thibodaux, Jr., Committee on Chemical Rocket Propulsion; Charles A. Berry and Richard S. Johnston, Committee on Biotechnology; and Robert E. Johnson, Subcommittee on Materials. Gilruth concurred on September 28.

Ltrs., Adams to Gilruth, Sept. 25, 1967; Gilruth to Adams, Sept. 28, 1967.

September 26

The Flammability Test Review Board met at MSC to determine if the M-6 vehicle (a full-scale mockup of the LM cabin interior) was ready for test and that the ignition points, configuration, instrumentation, and test facility were acceptable for verifying the fire safety of LTA-8 and LM-2 vehicles. The Board agreed that the M-6 did accurately and adequately simulate the LTA-8 and the LM-2 and established that the M-6 mockup was ready for testing. The Board was composed of Robert R. Gilruth, Chairman; Carroll H. Bolender; Aleck C. Bond; Maxime A. Faget; Christopher C. Kraft, Jr.; Donald K. Slayton; A. Duane Catterson, all of MSC; E. Z. Gray of Grumman; and G. H. Stoner of Boeing, a nonvoting observer.

Ltr., Gilruth to distr., "Minutes of the Flammability Test Review Board Meeting No. 1," Oct. 23, 1967; memo, Joseph N. Kotanchik, Chief, Structures and Mechanics Div. to distr., "Progress Report on Lunar Module M-6 flammability mockup," Sept. 28, 1967.

September 28

In spite of efforts to eliminate all flammable materials from the interior of the spacecraft cabin during flight, it was apparent that this could not be completely accomplished. For example, silicone rubber hoses, flight logs, food, tissues, and other materials would be exposed within the cabin during portions of the mission. However, flammable materials would be outside their containers only when actually needed. Special fire extinguishers would be carried during flight.

Memos, George M. Low, MSC, to Donald K. Slayton, MSC, "Procedures for use of flammable material in spacecraft," Sept. 28, 1967; Low to Slayton, "Training in use of fire extinguishers," Sept. 28, 1967.

September 28

ASPO Manager George M. Low informed the MSC Director of Flight Crew Operations that effective November 1 configuration management of the Apollo mission simulators and LM mission simulators would be transferred from ASPO to the Flight Crew Operations Directorate, with the understanding that Director Donald K. Slayton would personally chair the Configuration Control Panel.

Memo, Low to D. K. Slayton, "Configuration Control Panel for simulators," Sept. 10, 1967.

September 28

MSC's Engineering and Development (E&D) Directorate recommended that the Apollo CM be provided with a foam fire extinguisher. E&D also recommended that the LM be provided with a water nozzle for extinguishing open fires and that cabin decompression be used to combat fires behind panels. An aqueous gel (foam) composition fire extinguisher was considered most appropriate for use in the CM because hydrogen in the available water supply could intensify the fire, water spray could not reach fires behind panels, and a shirt-sleeve environment was preferred. E&D further recommended that development of a condensation nuclei indicator be pursued as a flight fire detection system, but that it not be made a constraint on the Apollo program. ASPO Manager George M. Low concurred with the recommendations September 28 and MSC Director Robert R. Gilruth concurred October 7.

On October 26, the Director of Flight Crew Operations stated that his Directorate was formulating and implementing a training program for flight crews to give them experience in coping with fire in and around the spacecraft. "In total, the crew training for cockpit fires will consist of: Review of BP 1224 and M-6 'burn test' film; demonstration briefings on the fire extinguishers and their most effective use; procedural practice simulating cockpit fire situations in conjunction with one 'g' spacecraft/mockup/ Apollo Mission Simulator walkthroughs and in the egress trainer placed in the altitude chamber; and as a part of the overall launch pad emergency and evacuation procedures training at the fire service training area at KSC."

Memos, Low to Donald K. Slayton, "Training in use of fire extinguishers," Sept. 28, 1967; Slayton to Low, "Crew training in use of fire extinguishers," Oct. 26, 1967; Maxime A. Faget to Gilruth, "Information Staff Paper No. 41 - Spacecraft fire extinguishing systems and onboard spacecraft fire

detection instrumentation for the Apollo program," Sept. 28, 1967.

September 29

ASPO Manager George M. Low, in a letter to Richard E. Horner, Senior Vice President of Northrop Corp., following a phone call to Horner on Sept. 28, reiterated NASA's "continuing and serious concern with the quality control at Northrop Ventura on the Apollo spacecraft parachute system. In recent weeks, I have had many reports of poor workmanship and poor quality, both in the plant at Northrop Ventura and in the field at El Centro."

On October 20 Horner told Low he had taken time to assure himself of the best possible information available before replying and offered background on the situation: "The design effort goes back to 1961 and testing began at the El Centro facility in 1962. There was continuous operation of the test group at El Centro until 1966 when the completion of the Block II testing program dictated the closeout of our operation there. In our total activity, we have had a peak of 350 personnel assigned to the Apollo, with 20 of that number located at El Centro during the most active portion of the test program. When it was finally determined that the increased weight capability redesign was necessary for mission success, the program nucleus had been reduced to 30 personnel and the established schedule for the system re-design, test and fabrication requires a build-up to 250. . . . The schedule has also dictated the adoption of such procedures as concurrent inspection by the inspectors of Northrop, North American and NASA, a procedure which, I am sure, is efficient from a program point of view but is inherently risky in terms of the wide dissemination of knowledge concerning every human mistake. This is significant only from the point of view of the natural human failing to be more willing to share the responsibility for error than for success. . . . We do not intend in any way to share responsibility for these errors and expect to eliminate the potential for their recurrence. We have established standards of quality for this program that are stringent and uncompromising. . . . Even though the technical and schedule challenge is substantial, we are confident that by the time qualification testing is scheduled to start during the first week of December 1967 we will have a flawless operation. . . ."

Ltrs., Low to Horner, Sept. 29, 1967; Horner to Low, Oct. 20, 1967; memos, Low to Kenneth S. Kleinknecht, "Parachute packing," Sept. 1, 1967; Low to Donald K. Slayton, "Apollo parachutes," Sept. 23, 1967.

September 29

An Apollo Entry Performance Review Board was established by the MSC Director to review and validate the analytical tools as well as the Apollo operational corridor. The Board was set up because the performance of the ablation heatshield in the Apollo spacecraft, as then analyzed, imposed a limitation on the entry corridor at lunar return velocity. The following were named to the Board: Maxime A. Faget, MSC, chairman; Kenneth S. Kleinknecht, MSC; Eugene C. Draley and Don D. Davis, Jr., Langley Research Center; Alvin Seiff and Glen Goodwin, Ames Research Center; and Leo T. Chauvin, MSC, secretary.

Ltrs., MSC Director Robert R. Gilruth to Directors of Ames Research Center and Langley Research Center, Sept. 29, 1967.

September 29

Key dates in the spacecraft 101 schedule were agreed to during a meeting of Samuel C. Phillips, Robert R. Gilruth, George M. Low, and Kenneth S. Kleinknecht with North American management: inspection of wiring, October 7, 1967; completion of manufacturing, December 15, 1967; delivery, March 15, 1968. In addition, several decisions were reached concerning certain systems of spacecraft 101. Among these, it was agreed that the entry monitor system would not be checked out on spacecraft 101 (see October 12).

Memo for the Record, George M. Low, Manager, ASPO, "North American activities," Oct. 2, 1967.

September 29

Because of many questions asked about spacecraft weight changes in the spacecraft redefinition, ASPO Manager George M. Low prepared a memo for the record, indicating weights as follows:

Lunar Module Significant Weight Changes

Lunar module injected weight status March 1, 1967 (ascent and descent less propellant) - 4039.6 kg

- Material substitution +23.1;
- decrease clamps and potting, -4.5;
- government furnished equipment changes (pressure garment assembly, portable life support system, oxygen purge system), +68;
- plume heating and "fire-in-the-hole" protection, +59.8;
- redesign umbilical hoses, +2.2;
- revised oxygen and water requirements, +19.5;
- provision for ALSEP removal, +11.3;
- increasing crack resistance of webs, +13.6;
- additional wiring to provide redundant circuits, +4.9;
- fuel cask and support increase, +14.9;
- guidance and navigation equipment, +3.1;
- instrumentation, +9.9;
- communications, +1.8;
- miscellaneous changes, +2.2.

Net change from March to September was +230.4 kg.

Lunar module injected weight status September 22, 1967 - 4270.0 kg

Command Module Significant Weight Changes

Command module injected weight status March 1, 1967 - 5246.7 kg

- New hatch, +114.7;
- environmental control system and weight management system changes, +103.4;
- instrumentation and electrical power, +48;
- wiring and tubing protection, +44.4;
- crew compartment materials and crew equipment, +101.6;
- forward heatshield separation, +13.6;
- earth landing system (larger drogues), +21.7;
- miscellaneous structural changes, +26.7;
- ballast for lift-over-drag ratio of 0.35, +175;
- other, +19.5.
- Reductions - transfer of portable life support system to LM,-31.2;
- reduced ballast for lift-over-drag ratio of 0.28, -142.8;
- other MSC weight reductions, -61.6.

Net change from March to September was +433.1 kg.

Command module injected weight status September 22, 1967 - 5679.8 kg

Memo for the Record, George M. Low, Manager, ASPO, "Apollo weight changes," Sept. 29, 1967.

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Part 2 (E)

Recovery, Spacecraft Redefinition, and First Manned Apollo Flight

October 1967

1967

October 2

Apollo Program Director Samuel C. Phillips, NASA Hq., reaffirmed that the following was the best course of action to follow with LM-2 and LM-3 : "Decide now to configure LM-2 for its unmanned contingency mission and reassign LM-3 to join with CSM 103 for a manned CSM-LM mission. In the event the LM-2 unmanned contingency mission is not required, LM-2 could be reworked to manned configuration and cycled back into the GAEC [Grumman] line for later delivery. On this basis, LM-2 could be delivered in unmanned configuration in late January 1968, or immediately after the Apollo 5 flight, and could be flown on AS-206 about 3½ months after delivery; i.e., in May 1968. The outlook for LM-3 indicates an April 1968 delivery which appears to be compatible with the expected delivery date of CSM 103."

Memos, Phillips to R. C. Seamans, Oct. 2, 1967; G. E. Mueller to Seamans, "LM-2 Configuration," Oct. 2, 1967.

October 5

An exchange of correspondence between MSC and North American Rockwell emphasized the seriousness of the spacecraft weight problem. Accurate and timely weight visibility was of paramount importance for weight control and resulted from proper implementation and control of weight prediction, weight control from design initiation, and weight status reporting. To ensure visibility, North American Rockwell was instituting a program that would use system design personnel in weight prediction and reporting. Preliminary design personnel in the Design Requirements Group were designated to integrate the effort.

Ltrs., George M. Low, MSC, to Dale D. Myers, North American Rockwell Corp., Aug. 1, 1967; Low to Myers, Aug. 17, 1967; Myers to Low, Oct. 5, 1967.

October 5-15

MSC established an Apollo Spacecraft Incident Investigation and Reporting Panel, with Scott H. Simpkinson as chairman. Panel members would be selected from ASPO, the Flight Safety Office, and the Engineering and Development Directorate. In addition, members would be assigned from the RASPO offices at Downey, Bethpage, and KSC when incidents occurred at their locations. All incidents suspected of directly affecting the safety of the spacecraft or its ground support equipment and all incidents that represented a hazard to personnel working in the area were to be investigated and reported. Incidents having a cost impact of over \$5,000 or a schedule impact of 24 hours would also be reported to the panel chairman and considered for investigation. Panel membership was announced October 16. The following day, a letter from Simpkinson to panel members established procedures for investigating and reporting incidents.

MSC Announcement No. 67-136, "Apollo Spacecraft Incident Investigation and Reporting Panel," Oct. 5, 1967; list of members and alternates of Apollo Spacecraft Incident Investigating and Reporting Panel, Oct. 16, 1967; ltr., Scott H. Simpkinson to Apollo Spacecraft Incident Investigation and Reporting Panel, "Implementation of an Apollo Spacecraft Incident Investigation and Reporting Panel," Oct. 16, 1967

October 8

Because of wind conditions, an abort of the Apollo spacecraft from a Saturn V in the near-pad region would result in land impact. To ensure the maximum potential safe recovery of the crew during a near-pad abort, certain forms of preparation within the abort area were being considered. Tests were being prepared at MSC and KSC to determine the most favorable soil condition for spacecraft landing. The capability of the spacecraft to sustain a land impact was also being investigated by MSC.

Memo, G. M. Low, MSC, to R. O. Middleton, KSC, "Improvement of landing areas for Apollo near pad aborts," Oct. 8, 1967.

October 10

A series of meetings discussed the oxygen purge system (OPS) program status and design configuration. The following conclusions were reached:

- The OPS theoretical reliability for completion of a 30-minute operation time was extremely high and would not be appreciably improved by the addition of redundant systems or components.
- Capability for preoperational checkout in the LM was desirable and was incorporated into the OPS design.
- Manual actuation was preferable to automatic actuation and was reflected in the design.

Memo, Maxime A. Faget, MSC, to ASPO Manager, "Oxygen purge system (OPS) review," Oct. 10, 1967.

October 12

Key MSC and NASA Headquarters management changes were announced at a press conference at MSC. George S. Trimble, Jr., was transferred from NASA OMSF to serve as Deputy Director of MSC. Eberhard F. M. Rees of MSFC would be temporarily assigned as a Special Assistant on Manufacturing Problems to George M. Low, ASPO Manager. Edgar M. Cortright was named as Deputy to George E. Mueller at OMSF. Participating in the press conference were NASA Administrator James E. Webb, Mueller, MSC Director Robert R. Gilruth, Trimble, and MSC Public Affairs Officer Paul P. Haney.

Press Conference Transcript, Tape A, Oct. 12, 1967, pp. 1, 2.

October 12

ASPO Manager George Low submitted a memorandum for the record on the September 29 decision not to check out the spacecraft 101 entry monitor system (EMS). He said: ". . . it has come to my attention that this decision had been based on incomplete information. Because the EMS incorporates both the Delta V counter and the .05 g indication on Block II spacecraft, this system is required for all missions, including 101. . . . "I verbally directed North American on October 10, 1967, that this system will be checked out on Spacecraft 101."

Memo for Record, Low, "Checkout of entry monitor system," Oct. 12, 1967.

October 13

In an effort to keep a tight rein on changes made in spacecraft, the Apollo Spacecraft Configuration Control Board (CCB) established the following ground rules:

- All changes on CSMs 101 and 103 and LM-3, no matter how small, would now be considered by the Senior Board only and not by any of the panels.
- Only mandatory changes would be considered for CSMs 101 and 103 and LM-3.
- Final implementation of all changes must be concluded within 30 days after a contract change authorization was written, and no change in implementation would be allowed without a new review by the MSC CCB.
- No changes would be made on LM-6 and subsequent LMs and CSM 107 and subsequent CSMs unless they were also on LM-5 and CSM 106 or unless the Senior CCB made a special exception to this rule. The purpose was to make certain that the configurations of the mission simulators and the Mission Control Center could be stabilized.
- Board members would generally be chairmen of subsidiary Configuration Control Panels and would not delegate this chairmanship. Thus Donald K. Slayton would chair the Simulator Panel,

Maxime A. Faget would chair the panel that passed on government furnished equipment items (see October 18), and probably Christopher C. Kraft, Jr., would chair the Software Control Panel (the last position had not yet been decided).

An additional step to gain a better understanding of the configuration baseline was taken by appointing Jesse F. Goree responsible for configuration management.

Ltr., George M. Low, MSC, to Samuel C. Phillips, NASA Hq., Oct. 14, 1967.

October 13

A proposal to use a Ballute system rather than drogue parachutes to deploy the main chutes on the Apollo spacecraft was rejected. It was conceded that the Ballute system would slightly reduce dynamic pressure and command module oscillations at main parachute deployment. However, these advantages would be offset by the development risks of incorporating a new and untried system into the Apollo spacecraft at such a late date.

Ltr., George M. Low, MSC, to Robert T. Madden, Goodyear Aerospace Corp., Oct. 13, 1967.

October 17

NASA Hq. informed MSC that NASA Deputy Administrator Robert C. Seamans, Jr., had approved the project approval document authorizing four additional CSMs beyond No. 115A. MSC was requested to proceed with all necessary procurement actions required to maintain production capability in support of projected schedules for these items.

TWX, George E. Mueller, NASA Hq., to Director Robert R. Gilruth, MSC, Oct. 17, 1967.

October 18

A conference at NASA Hq. discussed Headquarters and MSC operational problems in the lunar sample program, including the Lunar Receiving Laboratory (LRL). Associate Administrator for Space Science and Applications John E. Naugle chaired the meeting. Lunar Receiving Operations Director John E. Pickering of NASA OMSF discussed plans - approved by the Department of Agriculture; Department of Health, Education, and Welfare; and Department of Interior - for quarantine of the returned astronauts and lunar materials, and noted that the NASA Administrator or his designee would approve release of astronauts and lunar samples from quarantine on the advice and recommendations of the Interagency Committee on Back Contamination. Pickering also noted that "many of the problems concerning quarantine operations at the LRL were due to

1. lack of clearly defined responsibilities for the Medical Research and Operations and Science and Applications Directorates,

2. the lack of proven competence and maturity of the LRL staff, and
3. an integrated operational plan.

"MSC Director of Science and Applications Wilmot N. Hess indicated that item (1) was resolved by a memorandum of understanding between MSC Director of Medical Research and Operations Charles A. Berry and himself but that MSC Director Robert R. Gilruth had not approved it. Hess also pointed out that an operational plan was being developed, but that LRL was primarily a scientific laboratory, not just a quarantine facility. This statement was disputed in view of the fact that the LRL was justified to Congress on the basis of a need for a quarantine facility.

Memo, V. R. Wilmarth, NASA Hq., to distr., "Conference on Lunar Sample Program," Oct. 26, 1967.

October 18

MSC's Director of Engineering and Development Maxime A. Faget, at the request of the ASPO Manager, established a Configuration Control Panel (CCP) for government furnished equipment (GFE). The panel would integrate control of changes in the GFE items supplied for the Apollo spacecraft. "Authority to bring change recommendations to the GFE Panel will be invested in Division Chiefs. Changes rejected by the Division Chiefs need not be reviewed by the GFE CCP," the memorandum establishing the panel said. Membership on the panel was as follows: Chairman, Maxime A. Faget; Alternate Chairman, James A. Chamberlin; Members, Richard S. Johnston, Robert A. Gardiner, R. W. Sawyer (sic), and William C. Bradford. Secretary would be John B. See. (See also October 13.)

Memo, Faget to distr., "E&D/Apollo GFE Configuration Control Panel," Oct. 18, 1967.

October 20

In an effort to meet a mid-April 1968 delivery date for LM-3, Grumman made a number of organizational changes. Top level direction was strengthened by adding experienced managers in strategic positions and by reinforcing the Grumman LM organization with more management talent and additional test personnel. A spacecraft director for each vehicle was brought into the program for LM-2, -3, -4, and -5, with responsibility for overall Grumman support of individual vehicles from cradle to grave.

Ltr., L. J. Evans, Grumman Aircraft Engineering Corp., to G. M. Low, MSC, Oct. 20, 1967.

October 20

The SM reaction control system (RCS) for spacecraft 101 was criticized by C&SM RCS Subsystem Manager Ralph J. Taeuber. The results of the 101 RCS checkout, he said, "illustrate what we believe to be a lack of adequate workmanship and quality control during the manufacture and checkout of the RCS system. A total of 352 squawks have been written against the S/C 101 SM RCS and quad A has only

been partially tested. This high number of discrepancies, most of which cannot be directly related to design deficiencies, is mute testimony to our contention. Test units of the RCS have been built at MSC from scratch with no significant problems either during manufacturing, checkout, or test firing. Thus we have demonstrated that the system can be built successfully even without the specialized equipment and facilities at NAA. Furthermore, NAA has fabricated a number of units with a minimum of discrepancies. . . ."

CSM Manager Kenneth S. Kleinknecht enclosed Taeuber's memorandum and a summary engine failure report written by McDonnell Douglas Corp. after completion of the Gemini program in an October 26 letter to North American Rockwell's Apollo CSM Program Manager Dale D. Myers. Kleinknecht pointed out: "Their conclusion that system contamination was the most likely source of failure in flight, coupled with the fact that the Mercury Program was also plagued with a similar problem, and added to the facts presented in the report by Mr. Ralph Taeuber leads me to believe that positive action must be taken to tighten up the quality control, both at North American Rockwell Corporation and at all subcontractors and vendors that supply the parts for the Apollo RCS. . . . Something must be done to consistently bring the contamination of this system down to an acceptable level. The numerous problems with corrosion and foreign matter are occurring so frequently that it is possible we have other quality or procedural failure modes that are hidden by the constant and over-riding failure modes associated with contamination."

Kleinknecht added that he expected to receive within two weeks a written notice from North American that it was implementing a plan for corrective action and that the plan must include corrective action at the subcontractor and vendor levels.

Myers advised Kleinknecht December 4 that, to determine the cause of the recent valve failures from internal contamination, North American Quality & Reliability Assurance had begun an accelerated investigation October 22. All RCS valve suppliers were investigated, and one supplier was found to have introduced an improper cleaning sequence on an assembled helium-isolation valve, resulting in trapped deionized water in the valve. Valves suspected of moisture contamination were removed from the RCS and, after the supplier corrected the irregularities in his cleaning operation, the valves were returned for rework under North American source inspection surveillance. At the plant of the sub-tier supplier responsible for cleaning the valves that failed on spacecraft 101, a North American source inspector was now required to review the supplier's shop planning and indicate product acceptance by witnessing and verifying newly inserted inspection points on the supplier's in-process paper work.

Myers said that, as pointed out in Kleinknecht's letter, "systems and component contamination were a serious quality and technical problem faced by all major space programs. To rationalize these problems as workmanship and inspection errors introduced the risk of creating misdirected effort that attacks the result instead of the cause.

"The investigation and remedial action taken on the helium valves was a logical and aggressive response to apparent quality problems and is directed toward correcting both the unsatisfactory condition and

eliminating the factors that cause the condition to develop. Suspected hardware was immediately removed from the production cycle, inspection surveillance was increased at critical points in the process to insure against continuation of the problem, and a longer range program was implemented to provide extra assurance that similar problems do not exist or develop at other suppliers.

"The process control investigation that revealed the cause of trouble with the helium valve was being expanded to include a re-evaluation of all suppliers involved with cleaning valves, regulators, etc., used in the Apollo CSM. In addition to a fresh look at the suppliers fabrication and cleaning activities, the process evaluation is a comprehensive review of North American and supplier specifications for compatibility between the requirements for one assembly and the next, and a re-survey of the suppliers facilities to assure he has the technical capability and equipment to meet the stringent Apollo CSM quality requirements. The plan of action for this process study is being developed, and action to the plan will commence within a week."

Memo, Taeuber to S. H. Simpkinson, MSC, "S/C 101 SM RCS Checkout," Oct. 20, 1967; ltrs., Kleinknecht to Myers, Oct. 26, 1967; Myers to Kleinknecht, Dec. 4, 1967.

October 28

The following ground rules were established for extravehicular activity planning. The EVA transfer would be demonstrated and thermal-degradation samples retrieved during the AS-503/103/LM-3 (Apollo 8) mission. No other pre-lunar-landing mission would include planned EVA exercises. The first lunar landing mission would be planned with two EVA excursions.

Memo, George M. Low to distr., "Mainline Apollo EVA Policy," Oct. 28, 1967.

October 28

Plans were to use 100-percent oxygen in the CSM cabin during prelaunch operations for manned flights but, since flammability tests of the CSM were not finished, the possibility existed that air might be used instead of pure oxygen. Therefore, contingency plans would be developed to use air in the cabin during the prelaunch operations so that a change would not delay the program.

Memo, G. M. Low, MSC, to R. O. Middleton, KSC, "Possible use of air in the CSM cabin during prelaunch operations," Oct. 28, 1967.

October 30

Confirming an October 27 telephone conversation, ASPO Manager George M. Low recommended to Apollo Program Director Samuel C. Phillips that the following LM delivery schedule be incorporated into official documentation: LM-2, February 5, 1968; LM-3, April 6, 1968; LM-4, June 6, 1968. Subsequent vehicles would be delivered on two-month centers. The dates had been provided by

Grumman during the last Program Management Review. Ltr., Low to Phillips, Oct. 30, 1967.

October 30

Actions on television cameras were reported by ASPO Manager George M. Low to Apollo Program Director Samuel C. Phillips:

- During the Apollo spacecraft redefinition effort; a decision was made to fly the Block I TV camera in the CSM and the Block II TV camera in the LM. It was also decided that the CSM onboard TV camera could not be used for monitoring hazardous tests.
- In recent weight-saving exercises, those decisions were reexamined and a conclusion was reached that no TV camera would be carried in the CSM. This would not only save four kilograms directly but would also reduce the required stowage space and reduce the overall weight by minimizing the number of required containers.
- A decision was made to stow the Block II TV camera in the descent stage during the lunar mission. There would still be a requirement for checking out the lunar TV camera in earth orbit to ensure that it would work on the lunar surface. For that reason, it was planned to carry the camera in the ascent stage on the LM-3 mission, and in the descent stage on subsequent vehicles.

Low said, "Our present plans for TV in Apollo spacecraft call for the use of facility cameras to monitor hazardous testing on the ground. There will not be any television equipment in the Command Module on any flight."

Ltr., Low to Phillips, Oct. 30, 1967.

October30

A parachute test (Apollo Drop Test 84-1) failed at El Centro, Calif. The parachute test vehicle (PTV) was dropped from a C-133A aircraft at an altitude of 9,144 meters to test a new 5-meter drogue chute and to investigate late deployment of one of the three main chutes. Launch and drogue chute deployment occurred as planned, but about 1.5 seconds later both drogue chutes prematurely disconnected from the PTV. A backup emergency drogue chute installed in the test vehicle and designed to be deployed by ground command in the event of drogue chute failure also failed to operate. The PTV fell for about 43 seconds before the main chutes were deployed. Dynamic pressure at the time of chute deployment was estimated at about 1.2 newtons per square centimeter (1.7 pounds per square inch). All parachutes failed at or shortly after main parachute line stretch. The PTV struck the ground in the drop zone and was buried about 1.5 meters. An accident investigation board was formed at El Centro to survey mechanical components and structures, fabric components, and electrical and sequential systems. R. B. West, Earth Landing System Subsystem Manager, represented NASA in the investigation. It was determined that two primary failures had occurred:

1. failure of both drogue parachute-reefing systems immediately after deployment; and

2. failure of the ground-radio-commanded emergency-programmer parachute system to function.

On November 3, a preliminary analysis of the drop test failure was made at Downey Calif., with representatives of NASA, North American Rockwell, and Northrop participating. The failure of the drogue, being tested for the first time, was determined to be a result of the failure of the reefing ring attachment to the canopy skirt. The reason the ring attachment failed seemed to be lack of a good preflight load analysis and an error in the assumption used to determine the load capacity of the attachment. The failure of the deployment of the emergency system was still being investigated.

TWX, George M. Low to Director, Apollo Program Office, NASA Hq., Oct. 31, 1967; memos, Milton A Silveira to Kenneth S. Kleinknecht, "Failure which occurred on Apollo Drop Test 84-1," Oct. 31, 1967; "Further information on Apollo Drop Test 84-1 failure," Nov. 1, 1967; and "Results of Preliminary Analysis of Apollo Drop Test 84-1 Failure," Nov. 6, 1967.

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Part 2 (F)

Recovery, Spacecraft Redefinition, and First Manned Apollo Flight

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November 2

Maxime A. Faget, MSC Director of Engineering and Development, told the ASPO Manager that he had reviewed the LM insulation status and concluded that "the present design is susceptible to degradation from cabin leakage during pressurized conditions. The present insulation design is unacceptable for the lunar landing mission." He agreed with the contractor that design changes were required and specified that the insulation design change should be effective on LM-4 and the changes should be installed for the LTA-8 tests in support of LM-5.

Memo, Faget to Manager, ASPO, "LM Insulation," Nov. 2, 1967.

November 3

A cooling design to keep heating effects of the radioisotope thermoelectric generator (RTG) below 450 kelvins (350 degrees F) was being sought for the Apollo Lunar Surface Experiments Package. Studies had shown that the RTG could be a fire hazard when the ALSEP was carried in the lunar module, heating temperatures up to 590 kelvins (600 degrees F) unless cooling was provided. Temperatures from 460 to 465 kelvins (370 degrees F to 380 degrees F) were hazardous with the fuels in the LM. (See also July 21, 1967, entry.)

Memo, George C. White, Jr., NASA Hq., to William M. Bland, Jr., MSC, "Failure Effects Analysis-LM/ALSEP Interface," Nov. 3, 1967.

November 3

A series of lunar surface operations planning meetings was scheduled to establish and coordinate operational requirements and constraints, review analysis and simulation data for lunar surface

operations, review hardware status and requirements, review test and simulation planning, identify and resolve operational problems, obtain agreement on mission guidelines and recommended flight activities, and collect comments on the surface operations plans.

Memo, Donald K. Slayton, MSC, to distr., "Lunar Surface Operations Planning Meetings," Nov. 3, 1967.

November 3-December 19

In an exchange of correspondence, KSC Director Kurt H. Debus and MSC Director Robert R. Gilruth agreed that close coordination was required between the two Centers regarding launch site recovery and rescue in the event of malfunction leading to an unsuccessful abort before or just after ignition during a launch phase. Coordinated recovery and rescue plans were being formulated for such an emergency. Plans would also include the Department of Defense Eastern Test Range and required coordination with DOD. On December 19 Debus was informed by NASA Hq. that his proposal for a slide wire emergency system had been reviewed and approved.

Ltrs., Debus to Gilruth, Nov. 3, 1967; Gilruth to Debus, Nov. 20, 1967; Gilruth to Samuel C. Phillips, NASA Hq., Nov. 16, 1967; Phillips to Debus, Dec. 19, 1967.

November 4

NASA announced an Apollo mission schedule calling for six flights in 1968 and five in 1969. NASA Associate Administrator for Manned Space Flight George E. Mueller said the schedule and alternative plans provided a schedule under which a limited number of Apollo command and service modules and lunar landing modules, configured for lunar landing might be launched on test flights toward the moon by the end of the decade. Apollo/uprated Saturn I flights were identified with a 200 series number; Saturn V flights were identified with a 500 series number. The 1968 schedule was:

- Apollo/Saturn 204 - first unmanned test of the LM in earth orbit
- Apollo/Saturn 502 - second unmanned flight test of the Saturn V and Apollo CSM
- Apollo/Saturn 503 - third unmanned test of the Saturn V and Apollo CSM
- Apollo/Saturn 206 - second unmanned flight test of LM in earth orbit
- Apollo/Saturn 205 - first Apollo manned flight, a 10-day mission to qualify the CSM for further manned missions
- Apollo/Saturn 504 - first manned Apollo flight on Saturn V. This mission would provide first manned operation in space with both the CSM and LM, including crew transfer from CSM to LM and rendezvous and docking.

These flights would be flown in the above order and as rapidly as all necessary preparations could be completed.

The 1969 flight schedule called for five manned Apollo/Saturn V flights, AS-505 through AS-509. Four

of these-505, 506, 507, and 508-were programmed as lunar mission development flights or lunar mission simulations. It was considered possible that the lunar landing could be made on Apollo/Saturn 509, but it was also possible this might be delayed until one of the remaining six Saturn V flights.

TWX, Ralph E. Gibson, Deputy News Chief, NASA Hq., to all NASA Centers and Stations, NASA News Release 67-282, "Apollo/Saturn Schedule," Nov. 4, 1967.

November 7

MSC Director Robert R. Gilruth, wrote Warren B. Hayes, President of Fansteel Metallurgical Corp., that planned schedules for the lunar landing training vehicle (LLTV) could not be maintained because of the need for refabrication of the hydrogen peroxide tanks. The tanks had been manufactured by Airtek Division of Fansteel under contract to Bell Aerosystems Co. Airtek's estimates were that the first of the new tanks would not be available until January 1 968, two months later than required to meet the LLTV program schedule. Gilruth said: "The LLTV is a major and very necessary part of the crew training program for the lunar landing maneuver. It is my hope that Airtek will take every action to assure that the manufacturing cycle time for these tanks is held to an absolute minimum." In preparing background information for Gilruth, Flight Crew Operations Director Donald K. Slayton had pointed out that the first set of tanks (total of eight) had been scrapped because of below-minimum wall thickness. Qualification testing of a tank from the second set revealed out-of-tolerance mismatch of welded tank fittings, and this set was also scrapped.

Ltr, Gilruth to Hayes, Nov. 7, 1967; memo, Slayton to MSC Director, "Proposed letter to President, Fansteel Metallurgical Corporation," Nov. 3, 1967.

November 8

The MSC Director of Engineering and Development pointed out that a fullscale CSM would soon be tested to evaluate the hazard of fire propagation both in orbit (cabin atmosphere of oxygen at pressure of 3.8 newtons per square centimeter - 5.5 pounds per square inch absolute) and on the pad (oxygen at 11.4 newtons per sq cm-16.5 psia). There was a reasonable probability that the CSM might qualify in the first but not the second case. In such event, it was proposed that the prelaunch cabin atmosphere be changed from 100-percent oxygen to a mixture of 60-percent oxygen and 40percent helium or to a mixture of 60-percent oxygen and 40-percent nitrogen. This proposal was made on the assumption that those mixtures at 11.4 newtons per sq cm would not offer more of a fire hazard than 100percent oxygen at 3.8 newtons. It was also assumed that these mixtures would be physiologically suitable after being bled down to orbital pressure without subsequent purging or being enriched with additional oxygen. Structures and Mechanics Division (SMD) was requested to make flammability tests to determine the relative merit of the two mixtures and to outline a minimum test program to provide confidence that the mixed gas atmosphere might be considered equivalent to oxygen at 3.8 newtons.

Memo, Maxime A. Faget to Chief, Structures and Mechanics Div., MSC, "Prelaunch atmosphere for

Command Module," Nov. 8, 1967.

November 9

Apollo 4 (AS-501) was launched in the first all-up test of the Saturn V launch vehicle and also in a test of the CM heatshield. The Saturn V, used for the first time, carried a lunar module test article (LTA-10R) and a Block I command and service module (CSM 017) into orbit from KSC Launch Complex 39, Pad A, lifting off at 7:00:01 a.m. EST - one second later than planned. The launch was also the first use of Complex 39. The spacecraft landed 8 hours 37 minutes later in the primary recovery area in the Pacific Ocean, near Hawaii, about 14 kilometers from the planned point. CM, apex heatshield, and one main parachute were recovered by the carrier U.S.S. *Bennington*.

Main objectives of the mission were to demonstrate the structural and thermal integrity of the space vehicle and to verify adequacy of the Block II heatshield design for entry at lunar return conditions. These objectives were accomplished.

The S-IC stage cutoff occurred 2 minutes 30 seconds into the flight at an altitude of about 63 kilometers. The S-II stage ignition occurred at 2 minutes 32 seconds and the burn lasted 6 minutes 7 seconds, followed by the S-IVB stage ignition and burn of 2 minutes 25 seconds. This series of launch vehicle operations placed the S-IVB and spacecraft combination in an earth parking orbit with an apogee of about 187 kilometers and a perigee of 182 kilometers. After two orbits, which required about three hours, the S-IVB stage was reignited to place the spacecraft in a simulated lunar trajectory. This burn lasted five minutes. Some 10 minutes after completion of the S-IVB burn, the spacecraft and S-IVB stage were separated, and less than 2 minutes later the service propulsion subsystem was fired to raise the apogee. The spacecraft was placed in an attitude with the thickest side of the CM heatshield away from the solar vector. During this four-and-one-half-hour cold-soak period, the spacecraft coasted to its highest apogee - 18,256.3 kilometers. A 70 mm still camera photographed the earth's surface every 10.6 seconds, taking 715 good-quality, high-resolution pictures.

About 8 hours 11 minutes after liftoff the service propulsion system was again ignited to increase the spacecraft inertial velocity and to simulate entry from a translunar mission. This burn lasted four and one half minutes. The planned entry velocity was 10.61 kilometers per second, while the actual velocity achieved was 10.70.

Recovery time of 2 hours 28 minutes was longer than anticipated, with the cause listed as sea conditions - 2.4-meter swells.

MSC, "Apollo 4 Mission Report," Jan. 7, 1968; TWXs, W. C. Schneider, NASA Hq., to addressees, "Apollo 4 24-Hour Report," Nov. 10, 1967; R. O. Middleton, KSC, to addressees, "Apollo 4 Quick-Look Assessment Report," Nov. 13, 1967; Arthur Rudolph, MSFC, to addressees, "AS-501 Flight Results (10 day report)," Nov. 21, 1967; Saturn AS-501 Evaluation Bulletins No. 1 and No. 2, Nov. 14 and Nov. 22, 1967; NASA, "Apollo Program Weekly Status Report," Nov. 10, 1967.

November 11

Tests of sample constant-wear garments (underwear) fabricated from Beta fabric were reported as showing the garments were a source of excessive lint and irritated the skin. Efforts were being made to fabricate a knitted garment that would overcome these problems. Other flame resistant materials and flame retardant treatments were also being investigated. However, since delivery schedules of training and initial flight items required an immediate decision concerning material selection, it was decided to use the original cotton undergarment configuration.

Memo, George M. Low, MSC, to Samuel C. Phillips, NASA Hq., "Constant wear garment," Nov. 11, 1967.

November 13

ASPO Manager George Low, in a memorandum to CSM Manager Kenneth Kleinknecht, remarked that he had "just read Dale Myers' letter to you . . . on the subject of Northrop Ventura performance. In addition I have . . . read a letter from Dick Horner to me in response to my letter . . . of September 29, 1967. Both of these letters have the same general tone: they indicate that problems did exist in the past, but that all problems have now been resolved. . . . I am still . . . uneasy about the Northrop Ventura situation. I would, therefore, recommend that you might personally want to visit the Northrop Ventura facilities so that you can, at first hand, inspect their plant, review their program and talk to their people. You might want to ask Eberhard Rees, Scott Simpkinson and Sam Beddingfield to join you on such a visit. I would hope . . . you would see fit to make this visit in the very near future so that any corrective actions that you might identify can be taken before the Spacecraft 101 parachutes are packed."

Memo, Low to Kleinknecht, "Parachutes," Nov. 13, 1967.

November 14

A full-time lunar landing training vehicle (LLTV) operating capability was essential to lunar landing training. Optimum proficiency for the critical lunar landing maneuver would be required at launch. Crew participation in the three months or more of concentrated checkout and training at KSC before each lunar mission, coupled with routine launch delays, would make KSC the preferred location for LLTV operating capability.

Ltrs., George E. Mueller, NASA Hq., to Robert R. Gilruth, MSC, Nov. 14, 1967 and Dec. 16, 1967; TWX, Maynard E. White, NASA Hq., to MSC and KSC, "Lunar Landing Training Vehicle," Nov. 20, 1967.

November 14

In a letter to North American Rockwell and Grumman management, ASPO Manager George Low pointed out that he had taken a number of steps to strengthen the Configuration Control Board (CCB) activities and said he felt it was "very desirable to have senior management from NAR and GAEC present for our Board meetings." The meetings were held each Friday North American Apollo CSM Manager Dale D. Myers replied on November 17 that he, Charles Feltz, or George Jeffs would attend the meetings on an alternate schedule. Myers informed Low that North American was implementing new requirements designed to strengthen its own CCB. MSC's Kenneth S. Kleinknecht had been invited to attend North American's weekly Tuesday meetings when possible and RASPO Manager Wilbur Gray was invited to attend routinely.

Ltrs, Low to Myers, Nov. 14, 1967; Myers to Low, Nov. 17, 1967.

November 15

MSC informed MSFC that it would provide the following payload flight hardware for the AS-503/BP-30 flight test: boilerplate 30 (BP-30, already at MSFC); spacecraft-LM adapter 101 and launch escape system (SLA-101/LES) jettisonable mass simulation; and lunar module test article B (LTA-B, already at MSFC). MSC had no mission requirements but recommended that any restart test requirements for the Saturn S-IVB stage be carried out on this mission to simplify requirements for the first manned Saturn V mission.

Ltr., George M. Low to Arthur Rudolph, MSFC, "AS-503/BP-30 flight test," Nov. 15, 1967.

November 15

Spacecraft 017 (recovered after flight on the Apollo 4 mission) arrived in Downey, Calif., and was inspected by Robert R. Gilruth, George M. Low and others from MSC. Its condition was much better than anticipated, considering the severe heating it had been subjected to. Maximum erosion was between 2.5 and 7.6 millimeters.

"MSC Weekly Activity Report for Mr. Webb," week ending Nov. 17, 1967.

November 16

MSC Flight Operations Directorate issued mission rules concerning beach impact for the Apollo 7 mission. The Directorate referred to minutes of the Near-Pad Abort Meeting, dated September 26, which said the possibility of injury to the crew should it impact on land near Complex 34 necessitated mission rules prohibiting spacecraft launch in wind conditions that would cause a land impact after an abort. A satisfactory means of escape "must be provided to the crew while in the spacecraft during pad tests when wind conditions prohibit pad aborts due to possible beach impact." Mission rules developed were:

1. An integrated launch abort trajectory would be conducted at MSC before the launch, using the

actual measured launch-day wind profile for computing impact points.

2. Spacecraft launch would not be attempted if beach impacts were predicted before 15 seconds ground elapsed time (GET).
3. Launch would be permitted for predicted beach impacts occurring after 15 seconds GET provided the total time that the impact point was on land was no greater than 5 seconds.
4. If the wind conditions became marginal during countdown before the flight crew entered the spacecraft and if weather predictions indicated that the beach impact constraints would be violated at planned liftoff time, crew entry would be delayed until wind measurements indicated a trend that would allow a safe launch. And
5. if at any time after flight crew entry the measured wind conditions indicated a beach impact for a pad abort, the access arm would not be retracted until after the winds were determined to be safe as confirmed by a balloon release.

Memo, Christopher C. Kraft, Jr., to Manager, ASPO, "Mission Rules concerning predicted beach impact for the Spacecraft 101 launch," Nov. 16, 1967; telecon with Charles Harlan, MSC Flight Control Div., by Ivan Ertel, Aug. 31, 1970.

November 16

Robert R. Gilruth, George M. Low, and Maxime A. Faget, with other MSC personnel and North American Rockwell management officials visited AiResearch to review the status of the Apollo environmental control unit electronic components. There had been serious concern about AiResearch capabilities in this area. The review indicated that AiResearch circuit designs were satisfactory; that the electronic parts used were not satisfactory, but that substitutions of high-reliability parts could be made; and that AiResearch's capability in the manufacture of electronic components was substandard insofar as the aerospace industry was concerned. AiResearch was directed to obtain a subcontractor to build the most critical electronic controller in accordance with AiResearch designs and parts lists. All other electronic components were still under review and additional ones might be added to the backup contractor at a later date.

"MSC Weekly Activity Report for Mr. Webb," week ending Nov. 17, 1967.

November 17

An MSC meeting discussed environmental acceptance testing of Apollo spacecraft at the vehicle level. The meeting was attended by representatives of OMSF, MSC, and General Electric. Lad Warzecha presented results of a GE analysis of ground- and flight-test failures in a number of spacecraft programs. GE had concluded that a significant number of failures could be eliminated through complete vehicle environmental (vibration and thermal vacuum) acceptance testing and recommended such testing be included in the CSM and LM programs. James A. Chamberlin, MSC, presented a critique of the GE recommendations and found fault with the statistical approach to the GE analysis, indicating that each flight failure would have to be considered individually to reach valid conclusions. After considerable

discussion ASPO Manager George M. Low said that he had reached the following conclusions:

1. Adequate environmental screening at the piece part and component level was essential. Significant steps in this direction had been taken by requiring a wider use of high-reliability parts and by imposing higher vibration levels in black box acceptance testing.
2. Vehicle-level environmental acceptance testing was not applicable to the CSM or LM spacecraft. This conclusion was reached because it was not possible to vibrate, or otherwise excite, any of the Apollo spacecraft in a way to give meaningful vibration levels at most internal spacecraft locations.

Memo for the Record, Low, Manager, ASPO, "Apollo complete vehicle environmental acceptance testing," Nov. 18, 1967.

November 17

Eberhard F. M. Rees of MSFC sent MSC ASPO Manager George M. Low the results of a brief survey he had made at North American Rockwell. This was a preliminary step to plans agreed on by NASA Administrator James E. Webb, Associate Administrator for Manned Space Flight George E. Mueller, MSFC Director Wernher von Braun, MSC Director Robert R. Gilruth, and Low. Rees was to head a special task group, to be stationed at Downey and concerned largely with planning control and feedback; engineering, development, and design; manufacturing and assembly, manufacturing methods, and process control; quality assurance and reliability; and procedures, configuration control, etc.

Rees recalled that his assignment, as spelled out by Webb, was mainly to support MSC on manufacturing problems. Accompanying Rees on the survey trip from October 24 to November 3 were Jerald R. Kubat of the Apollo Program Office, NASA Hq., and two MSFC associates of Rees, Jack Trott and E. D. Mohlere. Rees met with RASPO Manager Wilbur H. Gray and ASPO CSM Manager Kenneth S. Kleinknecht and with top North American officials. Discussions were held with RASPO personnel on configuration control, quality assurance, manufacturing problems, and the environmental control system in preparation for a trip to AiResearch. "Finally we reviewed the so-called Problem Assessment Room of NAR."

Before offering some recommendations for consideration, Rees pointed up a need for a considerably intensified program of subcontractor penetration and quality review, to include in-process inspections in critical processes or in assembly of critical components. He recommended that

1. he lead the task team, reporting to Kleinknecht since he felt the team should support and not only advise and consult;
2. all actions be executed with the contractor by RASPO;
3. the size of the group be 20 to 25 persons and the task length about six months; and
4. the team not involve itself in any design activities or new "inventions," but see to it that all problems be made visible and resolved according to the time schedule with follow-up actions and

feedback.

Rees also listed a number of areas of possible improvement, among which were:

"Intensified exploration looking toward modularization in order to reduce impact of restricted work conditions in the capsule, although, according to my opinion, NAR has already taken steps in the proper direction and made improvement."

"Development of highly responsive communications system that will permit immediate revelation to management of manufacturing anomalies discovered on the shop floor."

"NAR quality control was, in my opinion, somewhat erratic. In some cases, jobs were over-covered, in others, coverage was missing."

"Returning to the matter of the communication link between shop and responsive levels of management, two examples will serve to illustrate the point. The S/C 101-RCS [reaction control system] quarter panel fastener hole mismatch was initially reported on January 9 within a shop loop. It did not get management attention until late October. Impact on other S/C requires attention. Again, the S/C 020 heat shield required grinding to remove interference with the umbilical. This, too apparently applied to other spacecraft. . . ."

Speaking of the field of controls and prompt display of problems, Rees said: "I feel that the so-called 'Problem Assessment Room' is a good beginning but that it requires much refinement. For example, it currently does not inform management of repetitive non-conformances or developing trends. Also, I learned that the previously mentioned improperly fitting RCS panel did not show on the board. The reason given was that it was not displayed because no solution to the problem had yet been developed. It would appear to me that such a condition would eminently qualify a problem for display."

Memo, Rees to Low, "Brief Survey of CSM at NAR, Downey," Nov. 17, 1967.

November 20

Bell Aerosystems Co. informed MSC and NASA Hq. that the company had reached a point in the LM ascent engine program where it was confident that it would meet all commitments and requirements for the Apollo missions.

Ltrs., William G. Gisel, Bell Aerosystems Co., to Robert R. Gilruth and George M. Low, MSC. and Samuel C. Phillips, NASA Hq., Nov. 20, 1967.

November 20

MSC asked MSFC assistance in identifying and understanding any propellant sloshing effects that might

create problems in the flight test program. The greatest uncertainty was associated with the techniques for passive thermal control in nonpowered flight.

Ltr., Robert R. Gilruth, MSC, to Wernher von Braun, MSFC, Nov. 20, 1967.

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Part 2 (G)

Recovery, Spacecraft Redefinition, and First Manned Apollo Flight

December 1967

1967

Week Ending December 1

A meeting on LM testing was held at Grumman Aircraft Engineering Corp., with Robert R. Gilruth and George M. Low, MSC; George Hage, OMSF; Hilliard Paige, General Electric Co.; and George Stoner, Boeing Co., in addition to Grumman personnel. After NASA reviewed the LM vibration environment and previous acceptance test decisions, Grumman recommended that complete vehicle vibration testing with externally mounted acoustic horns should be continued beyond LM-2; that wider use of thermovacuum testing at the component level be considered; and that the LM designated for the lunar landing mission be subjected to complete thermovacuum tests either at MSC or KSC.

MSC concluded that

1. for schedule purposes it would plan to continue complete vehicle acoustic testing after LM-2; however, implementation of this decision would depend on the results of the LM-2 testing;
2. MSC would reexamine the application of more widespread thermal testing at the component level; and
3. the Grumman proposal to subject the LM designated for the lunar mission to more testing than earlier manned flights was unacceptable. Past experience had shown that earlier vehicles should always have more testing than later ones.

MSC, "Weekly Activity Report for Mr. Webb," week ending Dec. 1, 1967.

December 1

NASA Hq. requested MSC to forward by December 5 the Center's plan for providing qualified LM ascent engines with dynamically stable injectors for manned LM flights. The plan was expected to be based on ground rules established in July when a NASA team went to Bell Aerosystems Co. that the

current BAC engine would be the prime effort with the Rocketdyne Division (North American Rockwell) injector development as backup. Headquarters asked that the plan contain the following elements:

1. effectivity of Bell-improved design in LM;
2. earliest phaseout of Rocketdyne program, assuming satisfactory completion of BAC program; and
3. effectivity of backup Rocketdyne design in LM if the BAC effort was not successful.

TWX, Samuel C. Phillips, OMSF, to MSC, Dec. 1, 1967.

December 1

NASA Hq. announced that, as concurred in by the Center Apollo Program Managers, the following decisions, based on the results of the Apollo 4 mission, were firmly established:

- CSM 020 would be flown on the Apollo 6 mission.
- Boilerplate 30 was assigned to the AS-503 unmanned mission.
- If Apollo 6 was successful, AS-503 would be flown as the first Saturn V manned mission.

TWX, NASA Hq. to MSC, MSFC, and KSC, "Apollo 6 and AS-503 Unmanned CSM Assignments," Dec. 1, 1967.

December 2

NASA Administrator James E. Webb approved the designation "Saturn IB" as the standard way of referring to that launch vehicle in public statements, congressional testimony, and similar materials, rather than "Up-rated Saturn I."

Memo, Associate Deputy Administrator Willis H. Shapley to distr., "Saturn IB Nomenclature," Dec. 2, 1967.

December 5

Walter J. Kapryan of the MSC Resident ASPO at KSC told the KSC Apollo Program Manager that one of the primary test objectives of the SM-102 static-fire test was to determine system deterioration caused by the static-fire sequence and exposure to residual hypergolics trapped in the system during subsequent prelaunch operations. He said it was imperative that the objective be met before the planned static-firing test of the SM-101. MSC requested that every effort be made to make the SM-102 test as soon as possible to ensure a representative time for subsequent storage and that a contractor tear-down inspection could be made to assess the advisability of static-firing the flight spacecraft. A firing date of January 15, 1968, would accomplish those objectives.

Memo, Kapryan to Apollo Program Manager, KSC, "SM-102 Static Fire Schedule," Dec. 5, 1967.

December 7

Astronaut Charles (Pete) Conrad's concern about an anticipated attitude control problem in the LM was reported. Conrad had said, "The LM is too sporty when in a light weight configuration." Minimum impulse was expected to produce about 0.3 degree per second rate, which was estimated to be about four times too fast. A memo on the problem possibility was written by Howard W. Tindall, Jr., Deputy Chief of MSC's Mission Planning and Analysis Division, to stimulate thinking. On December 9, ASPO Manager George M. Low asked Donald K. Slayton and Warren J. North if there was any chance of setting up a simulation to see whether this was a real concern.

Memo, Tindall to distr., "Light weight LM attitude control is too sporty," Dec. 7, 1967.

December 8

An Apollo drop test failed at El Centro, Calif. The two-drogue verification test had been planned to provide confidence in the drogue chute design (using a weighted bomb) before repeating the parachute test vehicle (PTV) test. Preliminary information indicated that in the test one drogue entangled with the other during deployment and that only one drogue inflated. The failure appeared to be related to a test deployment method rather than to drogue design. The test vehicle was successfully recovered by a USAF recovery parachute-intact and reusable.

TWX, George M. Low, MSC, to Director, Apollo Program Office, NASA Hq., Dec. 8, 1967.

December 9

MSC ASPO Manager George M. Low reminded NASA Apollo Program Director Samuel C. Phillips that at a meeting three weeks previous MSC had presented a Bell Aerospace Corp. qualification completion date for the LM ascent engine of March 28, and a Rocketdyne Division, North American Rockwell, completion by May 1, 1968. MSC at that time had expressed confidence that the Rocketdyne program could be accelerated to be completed in mid-March and be competitive to the BAC date, permitting a selection to install the best engine on LM-3.

During the interim, program reviews had been conducted at both Bell and Rocketdyne. The Bell program had been accelerated to complete qualification by February 9, 1968, by conducting qualification and design verification testing in parallel. While a greater risk would be incurred, both Grumman and NASA agreed to the procedure to expedite the Bell program. The Rocketdyne program could not be accelerated to complete qualification by February because of an uncertainty as to the performance of its engine, but qualification testing was expected to be completed by March. Anticipating that the only change would be a pattern modification, Rocketdyne was already

manufacturing injectors to support an accelerated program.

Ltr., Low to Phillips, "Ascent engine program plan," Dec. 9, 1967.

December 11

NASA Hq. asked further MSFC studies of one of the most critical phases during an Apollo mission, the period between holddown arm release and launch umbilical tower clearance. Failures or incompatibilities that could cause a vehicle collision with ground equipment or a pad fallback were major elements of potential danger. Problems during that phase would be difficult to cope with from a crew safety or an abort point of view and also posed the double jeopardy possibility of losing both the space vehicle and mobile launcher.

A number of studies had been made at MSFC of certain aspects of the problem, particularly postliftoff flight dynamics, the effects of winds, etc. Those studies had brought out the catastrophic potential of near- pad engine-out and actuator-hardover failures. NASA Hq. now asked MSFC to investigate further, with assistance of other Centers as required, the inadvertent system operation and component failures that could affect

1. a first-stage cutoff between holddown arm release and time of separation of the last physical connection between the vehicle and ground complex;
2. inadvertent critical operation or inhibition of such space vehicle systems as the emergency detection subsystem, guidance and control, electrical, and range safety during the same critical period; and
3. a premature or out-of-sequence liftoff.

The MSFC task leaders were asked to report findings to a panel made up of the MSFC, MSC, and KSC Apollo Program Managers and NASA Apollo Program Director Samuel C. Phillips before the flight readiness reviews for Apollo 5 and 6, scheduled for January 3 and mid-January 1968.

Ltr., Phillips to MSFC, "Apollo Lift-off Hazards," Dec. 11, 1967.

December 12

The phase I customer acceptance readiness review (CARR) of CM 101 was held at North American Rockwell in Downey, Calif. MSC's CSM Manager Kenneth S. Kleinknecht chaired the meeting, and SC 101 Manager John Healey represented North American. The review was the first of a three-phase CARR system initiated by North American. A total of 44 customer acceptance review item dispositions (CARIDs) were presented to the board and 13 were closed. The spacecraft was accepted for turnover to Apollo Test Operations pending submission of data to close the remainder. The majority of open CARIDs were for completing documentation for engineering orders, operation checkout procedures, and photography, with both North American and MSC having action item for closing out CARIDs. Five

CARIDs made reference to flammability of material. The most significant item was the installation of 27.4 meters of coaxial cable in the spacecraft that did not meet flammability guidelines.

Memo, W. C. Brubaker, Bellcomm, Inc., to distr., "Trip Report - Phase I Customer Acceptance Readiness Review of SCM 101 - Case 320," Dec. 29, 1967.

December 12

Apollo Program Director Samuel C. Phillips wrote to the three manned space flight Centers:

"I am sure that you are keenly aware of the importance of the forthcoming series of Apollo manned flights and the requirement that all responsible actions are taken to assure the success of each mission. To this end the Design Certification Review, established for manned flights, serves an important role. Shortly our program of progressive Design Certification Reviews leading to certification for the manned lunar landing will commence. A significant part of the effort requires a comprehensive supporting analysis of critical hardware to assure that all single failure points have been identified and accepted by all levels of Apollo Program management.

"I believe it necessary, therefore, that the Design Certification Review program formally record a listing of single failure points existing in flight and launch critical ground equipment which would cause crew or mission loss, together with a statement of rationale for accepting the risk of each of these single failure points. Establishing such a listing requires particular attention to commonality of ground rules and categorization such that the overall mission single failure point listing is an effective Design Certification Review input. While recognizing the present efforts existing at contractors and Centers in identifying single failure points, some additional work is required to obtain a consistent mission single failure point listing.

"It is requested that you initiate action to prepare for each Design Certification Review a single failure point listing which includes all considerations supporting the acceptance of each single failure point. This listing shall be prepared in accordance with ground rules established and coordinated by the Apollo Program Reliability and Quality Assurance Office, be approved by the Center, and shall be required 60 days in advance of the final Design Certification Review Board signoff."

Ltrs., Phillips to MSC, MSFC, and KSC, "Apollo Program Single Failure Points," Dec. 12, 1967.

December 14

Apollo Program Director Samuel C. Phillips wrote the manned space flight Centers of Apollo schedule decisions. In a September 20 meeting at MSC to review the Apollo test flight program, MSC had proposed a primary test flight plan including

1. the addition of a second unmanned LM flight,

2. addition of a third unmanned Saturn V flight, and
3. addition of a new' primary mission, a lunar orbital mission.

Phillips now wrote that decisions had been made to accommodate MSC's first two proposals into the mainline Apollo flight mission assignment. In addition, the proposal for the lunar orbital mission would be included in the Apollo flight mission assignments as an alternate to a landing mission.

Ltr., Phillips to Directors, MSC, MSFC, and KSC, "Apollo Spacecraft Flight Test Program Review/ Apollo Mission Assignments," Dec. 14, 1967.

December 15

The Apollo Site Selection Board met at MSC and discussed landing ellipse topography, landing approach path topography, and operational considerations, among other topics. The board heard recommendations on landing sites for the first and second missions, and approved them subsequent to the meeting, and Apollo Program Director Samuel C. Phillips emphasized that three launch opportunities should be provided for all months of the year. Board members, in addition to Phillips, were James H. Turnock, John D. Stevenson, Charles W. Mathews, and Oran W. Nicks, all of NASA Hq.; Owen E. Maynard and Wilmot N. Hess of MSC; Ernst Stuhlinger, MSFC; and R. O. Middleton, KSC.

Memo, Apollo Program Director to distr., "Minutes of the Apollo Site Selection Board Meeting of December 15, 1967," Jan. 29, 1968.

December 15

Robert O. Piland, Technical Assistant to the MSC Director, reminded ASPO Manager George M. Low that some time previously Wilmot Hess, MSC, had requested incorporation of a camera on AS-502 to take photos of the earth from orbital altitudes. The camera would be the same kind as used on AS-501 but pictures would be taken from a height of 80 to 160 kilometers rather than from 16,000. Piland said he understood the mission would allow a strip of photography 160 kilometers wide across the southern part of the United States and Africa and would make a significant contribution to the initiation of an earth resources survey program. Low replied on December 20, "Our plans are to do this, assuming we can without schedule impact."

Memo, Piland to Low, "Photography on Mission 502," Dec. 15, 1967; note, Low to Piland, Dec. 20, 1967.

December 16

Top NASA and North American Rockwell management personnel discussed flammability problems associated with coax cables installed in CMs. It was determined that approximately 23 meters of flammable coax cable was in CM 101 and, when ignited with a nichrome wire, the cable would burn in

oxygen at both 4.3 and 11.4 newtons per square centimeter (6.2 and 16.5 pounds per square inch). Burning rates varied from 30 to 305 centimeters per minute, depending upon the oxygen pressure and the direction of the flame front propagation. The cable was behind master display panels, along the top of the right-hand side of the cabin, vertically in the rear right-hand corner of the cabin, in the cabin feed-through area, and in the lower equipment bay. The group reviewed the detailed location of the cable, viewed movies of flammability tests, examined movies of the results of testing with fire breaks, discussed possible alternatives, and inspected cable installations in CMs 101 and 104.

The following alternatives were considered:

1. Replace all coax cable.
2. Wrap all coax cable with aluminum tape.
3. Partially wrap the cable to provide fire breaks. Tests at North American indicated that a 102-millimeter segment of wrapped cable with four layers of aluminum foil would provide a fire break. MSC tests indicated such a fire break was not adequate for multiple cables.
4. Leave the installation as it was.

The following factors were considered in reaching a decision for spacecraft 101:

1. The wiring in that spacecraft had been completed for several months. All subsystems had been installed and protective covers had been installed. Complete replacement or complete wrapping of all coax cables would be time consuming; it might take as long as three months, when taking retest into consideration. Additionally, in spite of extreme care, complete replacement or wrapping might do considerable damage to the installed wiring, and even partial wrapping might cause damage in many areas.
2. The coax cable could not self-ignite under any conditions.
3. In most installations, the coax cable was a separate bundle and not part of other wire bundles. An exception was the feed-through area in the lower right-hand corner of the cabin, where the coax cable was intertwined with other wires. Although power cables existed in this area, these were not high-current-carrying cables.
4. A minimum number of possible ignition sources existed in the vicinity of the coax cables, and a complex series of events would be required to ignite the cable.

In view of these factors, decisions for spacecraft 101 were:

1. The cable would be flown essentially as installed. The only exception was that the vertical cable bundle in the right-hand corner of the spacecraft would be wrapped with layers of aluminum tape. Each cable in this bundle would be individually wrapped.
2. An analysis by North American would document all other wiring near the coax cable, including the wire size, functions, maximum currents carried, and degree of circuit-breaker protection.
3. All possible ignition sources near the coax cable would be documented.
4. Tests would be made in boilerplate (BP) 1250 to determine the effects of fire breaks inherent in

the installation.

In making these decisions, NASA and North American recognized that they were contrary to existing criteria and guidelines. Those present agreed that the decisions were an exception and in no way should be construed as a change or relaxation of the criteria and guidelines. The basic reason for the exception was summarized as follows: "As a result of the clean installation of the coax cables, the lack of external ignition sources, and the complete job done in cleaning up the spacecraft from the flammability viewpoint, the risk of igniting the coax cables is exceedingly small. This risk is believed to be less than would likely be incurred through possible damage to existing installations had a decision been made to replace or wrap the cables."

The installation in spacecraft 2TV-1 would not be changed. This decision was made fully recognizing that more flammable material remained in 2TV-1 than in 101. However, the burning rate of coax cable had been demonstrated as very slow, and it was reasoned that the crew would have sufficient time to make an emergency exit in the vacuum chamber from 2TV-1 long before any dangerous situations would be encountered.

Officials also agreed that coax cable in boilerplate 1224 would not be ignited until after the results of the BP 1250 tests had been reviewed.

Memo for the Record, Manager, ASPO, "Command Module coax cable flammability considerations," Dec. 19, 1967.

December 17

A LM test failed in the Grumman ascent stage manufacturing plant December 17. A window in LM-5 shattered during its initial cabin pressurization test, designed to pressurize the cabin to 3.9 newtons per square centimeter (5.65 pounds per square inch). Both inner and outer windows and the plexiglass cover of the right-hand window shattered when the pressure reached 3.5 newtons per sq cm (5.1 psi). An MSC LM engineer and Corning Glass Co. engineers were investigating the damage and cause of failure.

TWX, ASPO Manager, MSC, to NASA Hq., Attn: Apollo Program Director, Dec. 19, 1967; "Activity Report - Quality Assurance," Bethpage, N.Y., Dec. 13-19, 1967.

December 18

NASA Associate Administrator for Manned Space Flight George E. Mueller informed MSC Director Robert R. Gilruth that he intended to establish a Guidance Software Task Force to determine whether any additional actions could be taken to improve the software development and verification process. He requested that MSC make a thorough presentation to the task force at its first meeting, to include flight software problem areas and also such matters as crew training, crew procedures development, mission planning activities, and the abort guidance system software. Mueller himself would chair the task force

and other members would be: Richard H. Battin, Massachusetts Institute of Technology Instrumentation Laboratory; Leon R. Bush, Aerospace Corp.; Donald R. Hagner, Bellcomm, Inc.; Dick Hanrahan, IBM; James S. Martin, Jr., LaRC; John P. Mayer, MSC; Clarence Pitman, TRW; and Ludie G. Richard, MSFC.

Ltr., Mueller to Gilruth, Dec. 18, 1967.

December 18

NASA Administrator James E. Webb approved a reorganization of NASA Headquarters, making changes in OMSF. On January 26, 1968, Associate Administrator for Manned Space Flight George E. Mueller spelled out OMSF changes:

1. The Deputy Associate Administrator for Manned Space Flight would continue with "across the board" responsibility and act for Mueller when he was absent or not available;
2. the Deputy Associate Administrator for Manned Space Flight (Management) would be responsible for the supervision of all administrative aspects of management within the manned space flight organization; and
3. the Deputy Associate Administrator for Manned Space Flight (Technical) would be responsible as the technical director and chief engineer of the manned space flight programs.

Memo, Mueller to OMSF Employees, Jan. 26, 1968.

December 19

NASA Hq. announced establishment of the Lunar Exploration Office within the Office of Manned Space Flight's Apollo Program Office. The new office, headed by Lee R. Scherer, merged program units directing Apollo lunar exploration and planning exploration beyond the first manned lunar landing. OMSF would staff the Systems Development element; the Lunar Science group would be staffed by the Office of Space Science and Applications, which would approve operating plans and scientific objectives, payloads, and principal investigators for specific missions.

NASA Special Announcement, "Establishment of an Apollo Lunar Exploration Organization within OMSF," Dec. 19, 1967; NASA News Release 68-5, Jan. 4, 1968.

December 20

As a part of the managers' technical status review, Dale Myers of North American Rockwell presented his analysis of fixes for the coax cable in spacecraft 103 and subsequent spacecraft. The North American recommendation was:

1. For spacecraft 103, 104, and 106 - remove all coax and wrap with aluminum tape using a 75- to 90-percent overlap. Re-install wrapped coax with additional teflon overwrap in areas where

chafing might occur. This wrapping would increase spacecraft weight by 0.9 kilograms. Schedule impact was estimated at five days for spacecraft 103 and 104 and one day for spacecraft 106.

2. For spacecraft 107 and subsequent spacecraft - install new coax cable that would meet nonmetallic-materials guidelines. There would be no schedule impact.

According to MSC's CSM Manager Kenneth S. Kleinknecht, the North American recommendation was justified for the following reasons:

1. All coax would be installed before the inspection process.
2. Spacecraft 106 was ready for electrical harness closeout; fabrication of new cables, with guideline material, would delay closeout by about three weeks.
3. The new cable to be used in spacecraft 107 was already used on the spacecraft upper deck, but had not been subjected to corrosive contaminants, oxygen, and humidity qualification. This qualification would be completed in line and before cable installation.
4. Although connectors used with coax on the upper deck were compatible with black boxes in the spacecraft and were supposedly available, there were not enough in stock to support the fabrication of new cables for spacecraft 103, 104, and 106.
5. Testing at North American and MSC supported the conclusion that wrapping with aluminum tape would preclude propagation of burning if ignition of the coax should occur.

Kleinknecht decided, with concurrence of Maxime A. Faget and Jerry W. Craig, to accept the proposal and Myers was authorized to proceed, subject to concurrence by Program Director Samuel C. Phillips and Program Manager George M. Low. Kleinknecht received oral concurrence from Low and Phillips on December 20; then, in confirming the decision with Myers, he requested that North American develop a schedule recovery plan to negate the impact of the coax fix on spacecraft 103, 104, and 106.

Memo, Kleinknecht to Low, "Command module coax cable decisions relative to spacecraft 103 and subsequent," Jan. 9, 1968.

December 20

ASPO Manager George M. Low pointed out to E. Z. Gray of Grumman that in October 1964 NASA had sent a letter to Grumman voicing concern over possible stress corrosion problems. The Grumman reply on October 30 of that year was unsatisfactory when considered in the light of stress corrosion cracks recently found in the LM aluminum structural members. Low asked what Grumman planned to do to make sure that no other potential stress corrosion problems existed in the LM and asked for a reply by January 1968 on how the problem would be attacked.

On December 21, Low wrote a similar letter to Dale D. Myers of North American Rockwell, reminding him of a letter sent by MSC in September 1964. He said that recent stress corrosion problems had been encountered in the LM and asked that North American make a detailed analysis to ensure that not a single stress corrosion problem existed in the CSM or associated equipment. Again, Low asked for a

reply by January 15, 1968.

Ltrs., MSC to Grumman, "Contract NAS 9-1100, Stress Corrosion," Oct. 12, 1964; Grumman to MSC, "Stress Corrosion," Oct. 30, 1964; Low to Gray, Dec. 20, 1967; MSC to North American Aviation, "Contract NAS 9-150, Stress Corrosion," Sept. 17, 1964; Low to Myers, Dec. 21, 1967; TWX, North American Rockwell to MSC, "NAS 9-150, Stress Corrosion," Oct. 13, 1967.

December 21

A Lunar Mission Planning Board meeting was held at MSC with Julian M. West as acting chairman. Also present were Wilmot N. Hess, Christopher C. Kraft, Jr., Paul E. Purser, and Andre J. Meyer, Jr. (secretary); and invited participants Gus R. Babb, John M. Eggleston, and James J. Taylor. The meeting agenda involved two main subjects:

1. review of major meetings recently held involving lunar exploration and planning; and
2. review of the remote sensors for use in lunar orbit and payload available on the CSM during a manned landing mission for carrying remote sensing instrumentation.

Hess, MSC Director of Science and Applications, reviewed the Group for Lunar Exploration Planning (GLEP) meeting in Washington December 8 and 9, which had examined potential sites for lunar exploration beyond Apollo based on scientific objectives and not operational considerations. He pointed out that during the GLEP group study at Santa Cruz, Calif., in the summer, scientists had strongly recommended a manned orbital mission be flown before manned landings, to gain additional photographic information for more effective mission planning and to make remote-sensing measurements to detect anomalies on the lunar surface. Hess said this position had changed to some extent.

Hess pointed out that lunar exploration was the responsibility of the new Lunar Exploration Office at NASA Hq. (see December 19). The office had further been subdivided into the Lunar Science Office, responsible for science and experiment planning, and the Flight Systems Office, responsible for modifications in the Apollo spacecraft to increase capability for developing advanced support systems such as mobility units and for developing the advanced ALSEP packages. Hess felt that dual launches, if conducted at all, would be carried out in the far distant future and therefore directed his group to select sites for nine single-launch missions, three of which should be planned without the aid of mobility and be limited to one-and-a-half kilometers; and the other six sites limited to five-kilometer maximum mobility radius.

Ground rules used in reduction of the proposed 39 lunar exploration sites were:

1. landing accuracy would be improved so the LM would land within a one-kilometer radius circle around the target point;
2. Lunar Orbiter high-resolution photography must cover any site considered;

3. science payload including mobility devices would be limited to 340 kilograms and
4. the lunar staytime would be limited to three days to include four extravehicular (EVA) periods totaling 24 hours.

Hess mentioned new criteria which would affect mobility on the lunar surface. He said that MSC's Director for Flight Crew Operations Donald K. Slayton stated he would permit a single roving vehicle to go beyond walk-back distance if the vehicle had two seats so that both astronauts could simultaneously and if the unit carried two spare back-packs. Hess said, "This new criteria, however, would result in a roving vehicle weight of well over 227 kg when the backpacks were induced and thus could not be carried on a single launch mission."

MSC, "Minutes of the Lunar Mission Planning Board," Dec. 21, 1967.

December 21

Apollo Program Director Samuel C. Phillips told ASPO Manager George M. Low that a review had begun on the "Apollo Spacecraft Weight and Mission Performance Definition" report dated December 12 and that his letter indicated approval of certain changes either requested or implied by the report. Phillips added that his letter identified a second group of pending changes for which insufficient information was available. He stressed his serious concern over the problem of spacecraft weight growth and said weight must be limited to the basic 45,359-kilogram launch vehicle capability. "According to the progression established in your report, CM's 116 through 119 could exceed the parachute hand-weight capability. I would like to establish a single set of controlled basic weights for the production vehicles. For product improvement changes a good rule is a pound deleted for every pound added. For approved changes to the basic configuration, it is the responsibility of NASA to understand the weight and performance implication of the change and to establish appropriate new control values. . . ."

Ltr., Phillips to Low, Dec. 21, 1967.

December 22

The first fire-in-the-hole test was successfully completed at the White Sands Test Facility (WSTF). The vehicle test configuration was that of LM-2 and the test cell pressure immediately before the test was equivalent to a 68,850-meter altitude. All test objectives were satisfied and video tapes of TV monitors were acquired. Test firing duration was 650 milliseconds with zero stage separation.

TWX, WSTF to MSC, Dec. 22, 1967.

Week Ending December 22

Bethpage RASPO Business Manager Frank X. Battersby met with Grumman Treasurer Pat Cherry on missing items of government property. The Government Accounting Office (GAO) had complained of

inefficiency in Grumman property accountability records and had submitted a list of some 550 items of government property to Grumman. After nine weeks of searching, the company had found about 200 items. The auditors contended the missing items amounted to \$8 million-\$9 million. Cherry said he believed that all the material could be located within one week. Battersby agreed to the one-week period but emphasized that the real problem was not in locating the material but rather in establishing accurate records, since GAO felt that too often the contractor would be tempted to go out and buy replacement parts rather than look for the missing ones.

"Weekly Activity Report, Business Manager, RASPO Bethpage," week ending Dec. 22, 1967, to Chief, Apollo Procurement Br., Procurement and Contracts Div., MSC, Dec. 27, 1967.

December 27

CSM Manager Kenneth S. Kleinknecht asked the Manager of the Resident Apollo Spacecraft Program Office (RASPO) at Downey to inform North American Rockwell that MSC had found the suggestion that aluminum replace teflon for solder joint inserts and outer armor sleeves in Apollo spacecraft plumbing unacceptable because

1. the teflon insert was designed to give an interference fit to prevent the passage of solder balls into the plumbing;
2. an aluminum insert could not be designed with an interference fit for obvious reasons;
3. the aluminum insert was tested at the beginning of the program and found to be inferior to the teflon insert; and
4. the aluminum armor seal could not be used as a replacement for the outer armor sleeves because it did not eliminate the creep problem of solder.

Memo, Kleinknecht to Manager, RASPO, Downey, Calif., "NR solder joint suggestion," Dec. 27, 1967.

December 28

The LM ascent engine program plan submitted to NASA Hq. on December 9 had been approved, Apollo Program Director Samuel C. Phillips told ASPO Manager George M. Low. Phillips was concerned, however, about the impact of recent unstable injector tests at Bell Aerosystems Co. on this plan. He said, "Resolution of these failures must be expedited in order to maintain present schedules. Also of concern, is the possible underestimation of the contractual and integration problems that will exist if the Rocketdyne [Division] injector should be chosen." Phillips asked that those areas receive special attention and that he be kept informed on the progress of both injector programs.

TWX, Phillips to Low, Dec. 28, 1967.

December 28

Confirming a discussion between George Low and Samuel Phillips on October 27, a decision was made to replace the glass windows in LM-1 with aluminum windows, as a precaution against a failure in flight similar to the one that occurred on LM-5 in testing.

TWX, J. Vincze, LM-1 Vehicle Management Office, MSC, to NASA Hq., Attn: S. C. Phillips,
"Replacement of windows on LM-1," Dec. 28, 1967.

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Part 2 (H)

Recovery, Spacecraft Redefinition, and First Manned Apollo Flight

January 1968

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January 2

MSC called to the attention of North American Rockwell the number of discrepancies found at KSC that could have been found at Downey before hardware shipment. In an effort to reduce the discrepancies North American was requested to obtain and use the KSC receiving inspection criteria as a guide for shipping inspections. It was also suggested that the possibility of sending a few key inspectors to KSC for periods of three to six months to gain additional experience might be investigated.

Ltr., Kenneth S. Kleinknecht, MSC, to Dale D. Myers, North American Rockwell, Jan. 2, 1968.

January 5

ASPO Manager George M. Low discussed with Rocco Petrone of KSC the problem of high humidity levels within the spacecraft-lunar module adapter. Petrone advised that several changes had been made to alleviate the problem: air conditioning in the SLA and the instrument unit would remain on during propellant loading; and the rate of air flow into the SLA was increased. Also, technicians at the Cape had designed a tygon tube to be installed to bring dry air into the LM descent engine bell, should this added precaution prove necessary. With these changes, Low felt confident that the humidity problem had been resolved.

Memo for the Record, Low, "SLA humidity," Jan. 8, 1968.

January 5

Bellcomm engineers presented to NASA a proposed plan for lunar exploration during the period from the first lunar landing through the mid-1970s. The proposed program - based upon what the company termed "reasonable" assumptions concerning hardware capabilities, scientific objectives, launch rates,

and relationships to other programs - was divided into four distinct phases:

1. an Apollo phase using existing vehicles,
2. a lunar exploration phase employing an extended LM with increased payload and longer staytime,
3. a lunar orbital survey and exploration phase using remote sensors and photographic equipment on a polar orbit flight, and
4. a lunar surface rendezvous and exploration phase using an unmanned LM to deposit the increased scientific equipment and expendables necessary to extend Apollo's manned lunar capability to two-week duration.

N. W. Hinners et al., Bellcomm Technical Memo 68-1012-1, "A Lunar Exploration Program," Jan. 5, 1968.

January 5

Apollo Special Task Team (ASTT) Director Eberhard F. M. Rees, Martin L. Raines, and Ralph Taeuber of MSC, and J. McNamara, North American Rockwell, visited Rocketdyne Division to review the status of the LM ascent engine backup program. The presentation was made by Steve Domokos.

The group was favorably impressed and felt that there was every indication that the Rocketdyne injectors would meet the LM requirements. ASTT recommended that MSC establish a board, chaired by the Chief of the Propulsion and Power Division and including one MSFC propulsion engineer, one MSFC manufacturing specialist, and other MSC personnel as required to provide a recommendation to ASPO of the ascent engine for LM-3.

Memo, Raines to Manager, ASPO, "Trip Report - Rocketdyne - January 5, 1968," Jan 8, 1968.

January 8

NASA Associate Administrator for Manned Space Flight George E. Mueller directed MSC Director Robert R. Gilruth to establish a task team to investigate why, in light of extreme precautions taken early in the program, the problem of stress corrosion in the LM was being encountered at such a late stage in Apollo. The problem, Mueller stressed, had been discovered at a most critical point in the program - the launch of the first LM was imminent and two subsequent vehicles were already well along in factory checkout. Any resultant slips in the LM program would seriously impact overall Apollo schedules. Gilruth replied he believed that such a team was not required. He affirmed that the reviews undertaken with the contractors in 1964 to guard against just these problems had proved inadequate when judged against present program demands. "The answer simply is that the job was not handled properly on the last go-round."

Ltrs., Mueller to Gilruth, Jan. 8, 1968; Gilruth to Mueller, Jan. 18, 1968.

January 9

George E. Mueller, NASA OMSF, in a letter to MSC Director Robert R. Gilruth, summarized a number of key Apollo program decisions required in order to emphasize the urgency of priority action in preparations necessary to certify the Apollo system design for manned flight. Mueller listed five items:

1. Assuming a successful flight of Apollo 5, the LM design must be certified ready for manned flight on AS-503.
2. A successful test firing of SM 102 at Cape Kennedy in January, in addition to the success of Apollo 4, would permit certification of the SM propulsion system for manned flight on AS-205.
3. A successful launch vehicle test of AS-502 (Apollo 6) would require that the Saturn V design be certified ready for manned flight by early April 1968.
4. A decision to certify the Block II CM design for manned flight should be essentially complete by early May 1968.
5. Launch Complex 34 design should be certified for manned flight no later than early June 1968.

Ltr., Mueller to Gilruth, Jan. 9, 1968.

January 11

Apollo Data Coordination Chief Howard W. Tindall, Jr., summarized mission planning for the first two hours on the lunar surface. That period, he said, would be devoted to checking out spacecraft systems and preparing for launch (in effect simulating the final two hours before liftoff). This procedure embodied several important benefits. As a pre-ascent simulation, it would afford an early indication of any problems in the checkout routine. More importantly, the initial checkout procedure would prepare the LM for takeoff at the end of the CSM's first revolution should some emergency situation require such an immediate flight abort.

Memo, Tindall to distr., "First 2 hours on the moon is a countdown to launch - simulated or real thing," Jan. 11, 1968.

January 11

A Parachute Test Vehicle (PTV) test failed at El Centro, Calif. The PTV was released from a B-52 aircraft at 15,240 meters and the drogue chute programmer was actuated by a static line connected to the aircraft. One drogue chute appeared to fail upon deployment, followed by failure of the second drogue seven seconds later. Disreefing of these drogues normally occurred at 8 seconds after deployment with disconnect at deployment at plus 18 seconds. The main chute programmer deployed and was effective for only 14 out of the expected 40 seconds' duration. This action was followed by normal deployment of one main parachute, which failed, followed by the second main parachute as programmed after four-tenths of a second, which also failed. The main chute failure was observed from the ground and the

emergency parachute system deployment was commanded but also failed because of high dynamic pressure, allowing the PTV to impact and be destroyed. Investigation was under way and MSC personnel were en route to El Centro and Northrop-Ventura to determine the cause and to effect a solution.

TWX, George M. Low, MSC, to NASA Hq., Attn: Apollo Program Director, Jan. 11, 1968.

January 11

CSM Manager Kenneth S. Kleinknecht wrote his counterpart at North American Rockwell, Dale D. Myers, to express concern about NR's seeming inability to implement configuration control of flight hardware and ground support equipment. Some progress had been made recently, Kleinknecht observed, but many steps still had to be taken to achieve effective configuration management on the CSM. The MSC chief pointed especially to North American's inability to ensure that final hardware matched that set forth in engineering documents, a weakness inherent in the separate functions of manufacturing: planning, fabrication, assembly and rework. MSC recommended a check procedure of comparing part numbers of installed equipment to the "as designed" parts list. "In short," Kleinknecht concluded, "I think that we should tolerate no further delay in establishing a simple 'as built' versus 'as designed' checking function, beginning with and including the first manned spacecraft."

North American began a more nearly complete engineering order accountability system, which provided an acceptable method of verifying the "as designed" to the "as built" configuration of each spacecraft. This system was planned to be applicable by the Flight Readiness Review on spacecraft 104 and on subsequent spacecraft at earlier points.

Ltrs., Kleinknecht to Myers, Jan. 11, 1968; Myers to Kleinknecht, Feb. 13, 1968.

January 13

The Senior Flammability Review Board met at MSC with Chairman Robert R. Gilruth, George M. Low, Maxime A. Faget, Aleck C. Bond, Charles A. Berry, Donald K. Slayton, Christopher C. Kraft, Jr., Kenneth S. Kleinknecht, all of MSC, and George Jeffs of North American Rockwell participating. The meeting summary reported that a 60-percent-oxygen and 40-percent-nitrogen atmosphere was acceptable from a crew physiological standpoint. The requirement for crew prebreathing before launch was not dependent upon launching with the atmosphere. Operationally, the crew could remove their helmets and gloves following orbital insertion and verification of the integrity of the cabin and its environmental control system; oxygen leakage would be allowed to enrich the crew compartment atmosphere.

On January 25, Berry, MSC Director of Medical Research and Operations, mote Gilruth: "We do not concur in the stated finding of the Board that a 60 per cent oxygen, 40 per cent nitrogen atmosphere is acceptable from a crew physiological standpoint. While it is true that a 60% oxygen, 40% nitrogen

atmosphere at 5.6 psi [3.9 newtons per sq cm] should result in a cabin atmosphere physiologically equivalent to sea level conditions, this will not be the case in a spacecraft launched with a 60% oxygen, 40% nitrogen atmosphere to which no oxygen is added except by normal operation of the cabin regulator. Oxygen will be metabolized by the crew at a much greater rate than nitrogen will be leaking from the spacecraft. Assuming a case in which cabin relief valve seats at 6 psi [4.1 newtons per sq cm] and the cabin regulator does not begin adding oxygen until 4.8 psi [3.3 newtons per sq cm], the cabin atmosphere would then consist of approximately 49% oxygen. This is physiologically equivalent to a 12,000-foot [3,700-meter] altitude in air. It would then take approximately 50 hours at the nominal cabin leak rate for the cabin regulator to enrich the mixture to a sea level equivalent."

"Senior Flammability Review Board Meeting," MSC, Jan. 13, 1968; memo, Berry to Gilruth, "Senior Flammability Review Board Meeting, January 13, 1968," Jan. 25, 1968.

January 13

ASPO Manager George M. Low outlined for the NASA Apollo Program Director MSC plans to static-fire the service propulsion system (SPS) as a complete unit. Houston officials maintained that at least one firing of such a complete system was necessary to prove the adequacy of all SPS manufacturing, assembly, and testing. However, because of several potential adverse effects that might accrue to testing the first such available system (that for the 101 SM), MSC proposed to test-fire the 102 unit and interpret those results - including any possible damage to the SM structure itself - before making a final decision on whether to proceed with a ground firing of the actual flight hardware before flight.

Memo, Low to NASA Hq., Attn: Samuel C. Phillips, "Requirements for static firing of Apollo service propulsion subsystem," Jan. 13, 1968.

January 15

George E. Mueller, NASA Associate Administrator for Manned Space Flight, summarized for Administrator James E. Webb recent program progress in Apollo. Preparations were under way toward the revised January 22 launch date for Apollo 5. Delays had resulted primarily from difficulties with hypergolic loading and contamination problems, but propellant loading had been completed several days earlier. Target for the countdown demonstration test was January 19. At Buffalo, N.Y., the NASA stability team assisted Bell Aerospace Co. in tackling the LM ascent engine instability problem. Post-test analysis of the qualification engine had revealed gouging of the chamber wall near the injector face. Bell engineers were assessing the amount of requalification testing that would be required and continued their testing on reworked engines, seeking to find the cause of previous engine instabilities. Meanwhile, the backup injector program at Rocketdyne Division was proceeding extremely well. Tests employing fuel film cooling had produced increased engine performance within acceptable chamber erosion limits. Altitude tests were scheduled to follow within a few weeks.

Memo, Mueller to Administrator and Deputy Administrator, "Manned Space Flight Report - January 15,

1968."

January 17

Eberhard Rees, Director of the Apollo Special Task Team at North American Rockwell's Downey plant, wrote ASPO Manager George Low outlining what he termed "serious quality and reliability resources deficiencies" and proposed several steps to bolster NASA's manpower in these areas. Specifically, Rees cited the immediate need for additional manpower (primarily through General Electric) to make vendor surveys, test failure assessments, and specification review and analysis and establish minimum inspection points. In addition, Rees said, many areas were almost totally lacking in coverage by the government, such as monitoring qualification tests, receiving inspections, pre-installation test, and many manufacturing operations. He urged Low to reassess his requirements in Houston to determine how many persons MSC might contribute (along with those from MSFC and GE) to plug these vital areas.

Ltr., Rees to Low, Jan. 17, 1968.

January 17

Eberhard Rees, Apollo Special Task Team chief at North American Rockwell, participated in a failure review at Northrop-Ventura of the recent parachute test failure (see January 11) and in development of a revised test plan. Others at the review included Dale Myers and Norman Ryker from North American and W. Gasich and W. Steyer, General Manager and Apollo Program Manager at Northrop-Ventura. Those at the review put together a revised drop test program that resulted in only a two-week schedule delay because of the failure. Repair of the parachute test vehicle was under way. Meantime, tests would continue, employing bomb and boilerplate devices. Also, Rees decided to establish a Flight Readiness Review Board (headed by Joseph Kotanchik of MSC) to approve each drop test, and Northrop officials had established an internal review board to review test engineering and planning and were tightening their inspection and quality control areas.

Memo, Rees to Manager, ASPO, "Trip Report to Northrop-Ventura on January 17, 1968," Jan. 19, 1968; ltr., Kenneth S. Kleinknecht, MSC, to Myers, Jan. 19, 1968.

January 18

A meeting was held at MSC to determine necessary action concerning recent contamination of CM 103's potable water, oxygen, and water-glycol lines. North American Rockwell proposed that all 103 aluminum lines in the potable water and oxygen systems (approximately 72 segments) be replaced; and proposed to follow a chemical flushing procedure for the water-glycol lines to remove the aluminum oxide and copper contamination. North American estimated that these actions would cause a 15-17 day serial impact. Removal and replacement of all lines would result in an estimated impact of 45 days. A decision was made to concur with the North American recommendation and on January 19 Kenneth S. Kleinknecht, MSC, informed Dale D. Myers, North American, of the concurrence and authorized him to

proceed immediately. In addition, Kleinknecht appointed a Special Task Team for Spacecraft 103 Contamination Control to ensure timely review of all contractor activities associated with removal of the contamination from the spacecraft environmental control system coolant system. Members of the team were: Wilbur H. Gray, Chairman; A. M. Worden, W. R. Downs, Jack Cohen, A. W. Joslyn, R. E. Smylie, R. P. Burt, and W. H. Taylor.

On February 20 Myers notified Kleinknecht of initiation of the potable water line changes and setting up of a monitor water-glycol system that would duplicate CSM 103 operations during the balance of checkout and would be examined for corrosion damage just before Flight Readiness Review.

Memo, Manager, CSM, ASPO, to Manager, ASPO, "Meeting held to determine course of action regarding contamination of CM 103 plumbing," Jan. 19, 1968; ltr., Kleinknecht to Myers, Jan. 19, 1968; memo, Manager, CSM, ASPO, to distr., "Spacecraft Plumbing Contamination Control Board," Jan. 19, 1968; ltr., Myers to Kleinknecht, Feb. 20, 1968.

January 18-19

Rolf Lanzkron and Owen Morris, Chiefs of MSC's CSM and LM Project Engineering Divisions, led a review of the 2TV-1 and LTA-8 (thermal vacuum test article and lunar module test article) thermal vacuum test programs at MSC. Chief concerns expressed during the review centered on the heavy concentration of testing during the summer of 1968, the need for simultaneous operation of test chambers A and B, and the lack of adequately trained chamber operations support personnel for dual testing. The review disclosed that maintenance of testing schedules for LTA-8 was most unlikely, even with a seven-day-a-week work schedule. (The central problem was the large number of open items that had to be cleared before start of the tests.)

Note, C. C. Gay, Jr., to LeRoy Day, Jan. 19, 1968.

January 19

Apollo Program Director Samuel C. Phillips wrote ASPO Manager George M. Low requesting that he establish and maintain a detailed comparison of configuration differences between the CSM and LM. This comparison, Phillips said, should include major interface differences, subsystems and components, weight, performance, and crew safety. Phillips ordered this comparison chiefly because the Apollo spacecraft was entering an extremely important phase to certify the vehicles for manned flight.

Ltr., Phillips to Low, Jan. 19, 1968.

January 22

NASA launched *Apollo 5* - the first, unmanned LM flight - on a Saturn IB from KSC Launch Complex 37B at 5:48:08 p.m. EST. Mission objectives included verifying operation of the LM structure itself and

its two primary propulsion systems, to evaluate LM staging, and to evaluate orbital performances of the S-IVB stage and instrument unit. Flight of the AS-204 launch vehicle went as planned, with nosecone (replacing the CSM) jettisoned and LM separating. Flight of LM-1 also went as planned up to the first descent propulsion engine firing. Because velocity increase did not build up as quickly as predicted, the LM guidance system shut the engine down after only four seconds of operation. Mission control personnel in Houston and supporting groups quickly analyzed the problem. They determined that the difficulty was one of guidance software only (and not a fault in hardware design) and pursued an alternate mission plan that ensured meeting the minimum requirements necessary to achieve the primary objectives of the mission. After mission completion at 2:45 a.m. EST January 23, LM stages were left in orbit to reenter the atmosphere later and disintegrate. Apollo program directors attributed success of the mission to careful preplanning of alternate ways to accomplish flight objectives in the face of unforeseen events.

Memo, Samuel C. Phillips to NASA Administrator, "Apollo 5 Mission (SA-204 LM-1) Post Launch Report #1," Feb. 12, 1968 (MOR M-932-68-05).

January 22

Joseph G. Gavin, Jr., LM Program Director at Grumman, advised ASPO Manager George M. Low of steps under way to attack the problem of stress corrosion in the LM. (Low had expressed MSC's concern over this potential danger on December 20, 1967.) While stating that he shared Low's concern, Gavin believed that stress corrosion would not prove to be of significance to the LM mission. However, his organization was prepared to reevaluate the LM's design and fabrication to determine to what extent the problem could be ameliorated. (Gavin denied that such metal corrosion could be absolutely eliminated using present materials as dictated by weight constraints on the LM design.) Gavin stated that he had created a special team of experienced designers and stress analysts to review engineering design of every LM part sensitive to stress corrosion, to review processes employed in fabrication of the LM structure, and to review the adequacy of the company's quality control procedures to ensure corrosion-free parts and assemblies.

Ltr., Gavin to Low, Jan. 22, 1968.

January 24

Eberhard F. M. Rees, head of the Apollo Special Task Team at North American Rockwell, met with Kenneth S. Kleinknecht, MSC, and Martin L. Raines, Manager of the White Sands Test Facility, to review the team's recent operations and the responses of North American and its numerous subcontractors to the team's recommendations. Kleinknecht listed what he thought were the chief problems facing the CSM program: the S-band highgain antenna (which he said should be turned over entirely to the task team for resolution); the parachute program; the environmental control system; and contamination inside the spacecraft. He urged that the team take the lead in developing solutions to these problems.

Memo for Record, Raines, "Review of Apollo Special Task Team Operations," Jan. 26, 1968.

January 25

In a letter to officials of the three manned space flight Centers, NASA Apollo Program Director Samuel C. Phillips called attention to the fact that as the time for the first manned Apollo flight was approaching constant concern for crew safety was becoming more pronounced. Phillips pointed out that the Crew Safety Panel, Flight Mechanics Panel, Launch Operations Panel, Hazardous Emergency Egress Working Group, and other Intercenter Coordination Panels had each dealt with specific aspects of Apollo crew safety. Individual Centers and contractors had exercised their crew safety responsibilities through system design, quality control, and test channels. Single-point failure analyses, dealing with specific hardware areas, had been made.

He said that these efforts had resulted in current provisions for rapid crew egress on the pad, for spacecraft abort during early phases of the launch, and for contingency flight modes. Phillips added, ". . . to insure that all of the many parts of the problem are properly integrated we should at this time step back and take another look at the overall crew safety picture from ingress to mission completion. The questions to be addressed are:

1. Have we systematically analyzed all likely failure modes or anomalies which could jeopardize the crew from ingress to mission completion?
2. In each of these cases do we have proper and timely cues coupled with a safe egress, abort, or contingency capability?
3. Do we have a plan for the timely solution of the known crew safety related problems?

. . . I would like to have this essential area worked under leadership of MSC-focused at a high management level - with assistance as required from MSFC and KSC. . . ." In a reply to Phillips, on February 28, MSC's George Low indicated that John Hodge had agreed to undertake the task and had already held discussions on the subject with George Hage of Phillips' office.

Ltrs., Phillips to MSC, MSFC, and KSC, "Apollo Crew Safety Review," Jan. 25, 1968; Low to Phillips, Feb. 28, 1968.

January 26

The Special Task Team for CSM 103, appointed January 18, submitted a progress report of activities during daily sessions held January 22 through 25. North American Rockwell and NASA had reached agreements on:

1. Cleaning and flushing of water management and oxygen systems. Since all aluminum lines except for three were replaced on CM 103 with new lines the resolution for cleaning and flushing

these systems was quickly accomplished.

2. Cleaning and flushing of water glycol system.

1. Pressure integrity of the water glycol system would be confirmed by a hydrostatic check to 248 newtons per square centimeter (360 pounds per square inch). Leak integrity would be confirmed by subsequent checks with helium at 41 newtons per sq cm (60 psi).
2. A resolution was obtained on the chemistry of the various cleaning and flushing fluids to be used on CM 103.
3. Agreement was reached on verification of cleaning and flushing all flow paths.

The events leading to the situation on CSM 103 were reviewed in sufficient detail to make visible the errors in the discipline governing the flushing carts. RASPO Manager Wilbur H. Gray stated that it was the RASPO responsibility to ensure the upgrading and control of all such equipment which interfaced with the spacecraft. The team would convene again January 30 to review reports and continue with other activities required to ensure adequacy of the CSM 103 plumbing system.

Memo, Gray to distr., "Summary of progress on the Special Task Team for CSM 103 Contamination Control," Jan. 26, 1968.

January 26

A LM-2 flight and requirement meeting was held at MSC, attended by key MSC and NASA Hq. officials. The group reached three conclusions:

1. The LM-1 performance on the January 22 Apollo 5 mission had been excellent for all conditions of the flight, as executed, with the exception of minor anomalies.
2. The LM-2 flight objectives that were partially accomplished could be better accomplished by further ground testing or on subsequent manned missions. Further unmanned flight testing was not required for man-rating purposes.
3. A LM-2 flight was not required to man-rate the ascent engine injector.

It was also agreed that a decision should be made not to fly the LM-2 mission, with this decision reversible if further evaluation of data from the LM-1 flight indicated any problems. This decision would be reviewed at the February 6 Manned Space Flight Management Council Meeting and on March 6 at the LM-3 Design Certification Review. The final decision would not be made until March 6.

Minutes of the LM-2 Flight Requirements Meeting, Jan. 26, 1968.

January 26

In response to a letter from ASPO Manager George M. Low in late December 1967, seeking assurances that no potential stress corrosion problems existed in the CSM, Dale D. Myers, CSM Program Manager at North American Rockwell, reviewed the three instances where problems had been encountered during

the CSM project and iterated the extensive efforts to ensure against such potential problems. Echoing much the same words as his counterpart at Grumman, Myers stated that "it is not possible to guarantee that no single instance of stress corrosion will ever occur" and that circumstances "could create a problem not anticipated." He concluded that his company's efforts in this direction had been "entirely adequate and beyond the requirements of the contract and good practice in this industry," and he seated his belief that additional efforts in this area would not produce measurable results.

Ltr., Myers to Low, Jan. 26, 1968.

January 30

MSC CSM Manager Kenneth S. Kleinknecht, in a letter to North American Rockwell's Dale D. Myers, protested lack of North American reponse to written MSC direction concerning parachute test vehicles. Kleinknecht pointed out that MSC had "considerably modified our usual requirements in supporting the boilerplate 19 task being performed for you by Western Ways, Inc. These efforts seem to be completely negated by delayed go-ahead to Northrop Ventura for their portion of the task. I understand that neither Western Ways nor Northrop Ventura was given a go-ahead until January 19, 1968. The original written direction to NR [North American] was on November 9, 1967, to provide another parachute test vehicle (PTV) and give us an estimate of cost and schedule for another boilerplate PTV." If the effort on the PTV had started at that time, "we would now be able to use that vehicle rather than the bomb-type vehicles after losing PTV No. 2. The cost and schedule for boilerplate 19 was not submitted to MSC until later, on December 22, asking for a reply by January 2, 1968. Because of the holiday period, this written reply was furnished on January 5, after an investigation of the cost and schedule. The Engineering Change Proposal [ECP] stated a completion date of May 5; however, after a request by my people to see what could be done to improve this date, the improvement moved the Northrop Ventura schedule from June 14 to May 24 [a Friday]. This date is three weeks later than the date cited in the ECP and is completely unacceptable. . . ."

On February 29, Myers assured Kleinknecht that North American had proceeded with the BP-19A task in advance of NASA full coverage. Initial partial coverage was issued to North American on January 5, 1968. On March 14, in a letter of commendation, Kleinknecht thanked Myers for the attention given the BP-19A effort that made a March 15 completion by Western Ways possible. On May 27, W. H. Gray, RASPO Manager, wrote another letter of commendation thanking North American for completing BP-19A in time for a drop test in May 1968.

Ltrs., Kleinknecht to Myers, Jan. 30, 1968; Myers to Kleinknecht, Feb. 29, 1968; Kleinknecht to Myers, Mar. 14, 1968; Gray to Drucker, May 27, 1968.

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Part 2 (I)

Recovery, Spacecraft Redefinition, and First Manned Apollo Flight

February 1968

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February 2

Eberhard F. M. Rees, Apollo Special Task Team Director at North American Rockwell, reported to ASPO Manager George M. Low on the need for audits of equipment supplied from vendors to the spacecraft contractor. Significant hardware failures and nonconformances had been discovered after delivery of equipment from the vendors to Downey, Rees stated, and NASA must take strong steps to upgrade the quality of workmanship at the vendors' locations.

Ltr., Rees to Low, Feb. 2, 1968.

February 3

ASPO Manager George M. Low advised Apollo Program Director Samuel C. Phillips that, in accordance with an action item resulting from the spacecraft environmental testing review at MSFC on January 10, he was reexamining the design, fabrication, and inspection of all interconnecting systems of the spacecraft to determine what further steps might be taken to ensure the integrity of those systems. Low had requested William Mrazek of MSFC to direct this effort, using a small task team to review the design of all spacecraft wiring and plumbing systems, their fabrication, and quality assurance and inspection techniques.

Ltr., Low to Phillips, Feb. 3, 1968.

February 5

A Senior Flammability Review Board meeting at MSC reached a number of decisions on the CSM. Attending were Robert R. Gilruth, chairman; George M. Low, Kenneth S. Kleinknecht, Aleck C. Bond, Maxime A. Faget, Donald K. Slayton, Charles A. Berry, and Rodney G. Rose, all of MSC; Samuel C.

Phillips, NASA Hq.; William B. Bergen and Dale D. Myers, North American Rockwell; and George Stoner, Boeing (nonvoting observer).

Several previous action assignments were reviewed:

1. Component level Flammability Test Program - North American reviewed the results of its material identification and test program, the component test program, and the boilerplate 1,250 tests. These tests had provided the basis for design decisions on selection and application of CM nonmetallic materials.
2. Boilerplate 1224 configuration comparison to CSMs 2TV-1 and 101 - North American presented the comparison and the Board decided that the boilerplate configuration was representative of the "worst case" configuration, considering both 2TV-1 and 101.
3. Internal ignition rationale - ignition rationale for the boilerplate 1224 tests was presented to the Board. Nichrome wire ignitors were used with the ignitor wire embedded in potting. In some locations a Ladicote cover was applied over the potting and ignitor. The Board pointed out that the ignition techniques were not really representative of actual operating conditions and were indeed overly severe.
4. Crew communications umbilical - North American was evaluating a fluorel crew communications umbilical as well as fluorel oxygen umbilicals. A Beta sleeve over the oxygen and crew communications umbilicals would also be evaluated for its operational acceptability by the Crew.

The Board presented a review of test results. In the tests at pressure of 4.3 newtons per square centimeter (6.2 pounds per square inch) in a 95-percent oxygen atmosphere, there were 38 ignitions in boilerplate 1224. Of these, 5 produced fires large enough to require further consideration. In tests at 11.2 newtons per sq cm (16.2 psia) in a 60-percent-oxygen and 40-percent nitrogen atmosphere, there were 31 ignitions. Of these, 4 produced fires large enough to require further consideration.

The Board concluded that the material changes made in the CM had resulted in a safe configuration in both the tested atmospheres. The Board agreed "that there will always be a degree of risk associated with manned space flight," but the risk of fire "was now substantially less than the basic risks inherent in manned space flight."

Among decisions reached were:

1. the CSM 2TV-1 and 101 coaxial cable configuration would be tested in the 60-percent-oxygen and 40-percent nitrogen atmosphere;
2. material improvements and testing would be continued and changes would be phased in, pending the availability of proved materials; and
3. action would be taken to be prepared to use a 60-percent-oxygen and 40-percent-nitrogen prelaunch atmosphere in CSM 101.

A final decision would be made at the Design Certification Review on March 7.

Minutes of the "Senior Flammability Review Board Meeting, Building 2 - Room 966, February 5, 1968," sgd. Robert R. Gilruth, Feb. 23, 1968.

February 5

Homer E. Newell, NASA Associate Administrator, told MSC Director Robert R. Gilruth that at the last meeting of the Lunar and Planetary Missions Board the subject of astronaut activity on the lunar surface had been taken into consideration. The following motion had been generally endorsed by all members of the Board but tabled for formal action with the request that comments of the Flight Crew Operations Directorate be made on the motion and returned to the Board for further consideration: "It is proposed that during lunar EVA it be regarded as general practice and a requirement on the astronauts to utilize fully the voice channel from them to each other and to earth. What is intended is almost incessant talking, describing all actions and thoughts as they occur, but without devoting much additional concentration or interrupting any actions for that purpose. Such talk will have the advantage of increasing the information available should any hazardous situation arise, and therefore increase crew safety; secondly, it will be a major source of information of scientific importance, and the record of such talk will be most helpful to the astronauts themselves as well as others to re-enact the activities later and so better understand the record and the observations obtained."

The MSC Director of Flight Operations prepared an information staff paper for Gilruth that said the proposal had been evaluated by the Directorate, and the "marginal utility to be gained by such a practice is questionable" because "constant talking would involve a real time process of separating significant data from trivia." The Flight Operations Directorate "does not believe that crew safety will be enhanced by constant talking. . . . In summary . . . our present astronaut talking requirements are sufficient to satisfy the scientific world and provide sound operational support. . . ."

Ltr., Newell to Gilruth, Feb. 5, 1968; Information Staff Paper No. 99 to Director, MSC, from Director of Flight Operations, "Lunar EVA Procedures," Apr. 16, 1968.

February 8

Grumman President L. J. Evans wrote ASPO Manager George M. Low stating his agreement with NASA's decision to forego a second unmanned LM flight using LM-2. (Grumman's new position - the company had earlier strongly urged such a second flight - was reached after discussions with Low and LM Manager G. H. Bolender at the end of January and after flight data was presented at the February 6 meeting of the OMSF Management Council.) Although the decision was not irreversible, being subject to further investigations by both contractor and customer, both sides now were geared for a manned flight on the next LM mission. However, Evans cited several spacecraft functions not covered during the LM-1 flight that would have to be demonstrated before attempting a lunar mission, notably control by the primary navigation and guidance system of the descent propulsion system burn as well as control of

stage separation and firing of the ascent propulsion system. To demonstrate these functions fully, he said, some modifications in mission plans for the next two manned flights might be necessary.

Ltr., Evans to Low, Feb. 8, 1968.

February 14

James P. Nolan, Jr., Chief of Plans, NASA OMSF, wrote Mission Operations Director John D. Stevenson describing a potential post-reentry fire hazard in the command module. A hazard might result from incomplete mixing of pure oxygen in the cockpit with normal air after landing, which could produce pockets of almost pure oxygen in closed cabinets, equipment bays, wire bundles, and interstices of the spacecraft. (Two test chamber explosions and fires had occurred at Douglas Aircraft Co. under similar conditions during the early 1950s, he advised.) Nolan suggested that the potential fire hazard be critically reviewed, including possible additional chamber flammability testing. Several weeks later, Stevenson informed Apollo Program Director Samuel C. Phillips that he had discussed Nolan's ideas with MSC Director Robert R. Gilruth, ensuring attention by the Flammability Review Board. He reported that MSC was planning an additional series of chamber tests to determine whether such a fire hazard actually existed.

Memos, Nolan to Director, Mission Operations, NASA, "Post Reentry Fire Hazard in the Command Module," Feb. 14, 1968; Stevenson to Apollo Program Director, same subject, Feb. 26, 1968.

February 14

In discussing the results of a manned test with MSC Director Robert R. Gilruth, George M. Low mentioned that a single 45-degree motion of the abort handle was required to initiate a launch abort in Apollo. Gilruth voiced concern that an abort could be caused by a single motion. Low asked Donald K. Slayton for comments on the subject. Slayton replied March 1 that "this item had also been a concern of the flight crews during the early design of the system." But he said: "The handle forces to actuate the abort sequence have been subjectively evaluated and are considered high enough to prevent inadvertent actuation. Additionally, the outboard rotation (counter clockwise) was chosen over an inboard rotation (clockwise) as being the more unnatural of the two motions. . . . Crew training for launch aborts in the Dynamic Crew Procedures Simulator has not shown this design to be a problem."

Memos, Low to Slayton, "Apollo Command Module abort handle," Feb. 14, 1968; Slayton to Manager, ASPO, "Apollo Command Module abort handle," Mar. 1, 1968.

February 14

NASA Hq. asked MSC's support for the effort under way by the Software Review Board (created at Apollo Program Director Samuel C. Phillips' request several weeks earlier) to reexamine software requirements for the lunar mission. A specific concern of the Board (which included representatives

from the major support contractors, IBM, TRW, and Bellcomm) was the level of sophistication and complexity inherent in the present MIT computer programs. To understand better the possibilities of carrying out the lunar mission using the present computer system but with much simpler programming, Mueller asked the Board to examine the feasibility, cost, and schedule implications of carrying out the mission using about half the fixed and erasable memory of the computer and otherwise trading off program simplicity for minor increases in propellant requirements.

Ltr., George E. Mueller, NASA OMSF, to Robert R. Gilruth, MSC, Feb. 14, 1968.

February 15

Apollo Program Director Samuel C. Phillips wrote ASPO Manager George M. Low setting forth a strategy for announcing selection of a prelaunch atmosphere for the spacecraft. Because the decision undoubtedly would draw much public attention, Phillips said, it was important that the decision be based on comprehensive study and be fully documented to explain the rationale for the decision both to NASA's management and to the general public. Foremost, he said, that rationale must include a clear statement of physiological requirements for the mission and for aborts. Secondly, it must also cover flammability factors in cabin atmosphere selection. Finally, the decision rationale must explain engineering factors related to hardware capability and crew procedures, as well as operational factors and how they affected the choice of atmosphere during prelaunch and launch phases of the mission.

Ltr., Phillips to Low, "Pre-launch Atmosphere," Feb. 15, 1968.

February 19

Meetings of the Software Task Force had brought out the lack of a formal requirement that the Change Control Board (CCB) consider how hardware and software changes might affect each other, NASA Associate Administrator for Manned Flight Mueller told Apollo Director Phillips. Mueller asked Phillips if he would consider a program directive requiring such assessments before changes could be approved. On March 2, ASPO Manager George Low wrote a note to Flight Operations Director Chris Kraft concerning the same problem. Low believed "our CCB Manual required that any changes requiring or affecting more than one panel (e.g., your software panel and Kleinknecht's CSM panel) should come to the Apollo spacecraft CCB." Kraft replied April 12 that he concurred. Kraft said that "various MSC organizations are represented on my Software Control Board [SCB]. These representatives identify related impacts on other functional elements of the program during the discussion of change actions in the . . . meeting. Also, we have taken action to assure integrated assessment of software and spacecraft changes prior to presentation to the SCB. . . . T. F. Gibson, Jr., Flight Operations Directorate, and J. F. Goree, Jr., ASPO, have resolved working arrangements to assure . . . the disciplines called for by the Configuration Management Manual are carried out. I understand that the Change Integration Group in ASPO will critique proposed change actions to either software or spacecraft hardware and identify associated impacts. . . . Changes involving interfaces between the software and spacecraft hardware, or other functional elements of the program, would then be brought to your CCB for disposition of the . . .

change as prescribed by the Configuration Control Manual. . . . I feel . . . this formal change integration function is appropriate as a check and balance. . . ."

Memo, George E. Mueller to Samuel C. Phillips, "Software Task Force Meetings," Feb. 19, 1968; informal note, Low to Kraft, Mar. 2, 1968; memo, Kraft to Low, "Software and spacecraft change integration," Apr. 12, 1968.

February 19

MSC Deputy Director George S. Trimble, Jr., recommended to Apollo Program Director Phillips that OMSF issue a definition for the end of the Apollo program. Trimble pointed out that parts of MSC planning would be clearer if there were a specified set of conditions which, when satisfied, would mark the termination of the Apollo program and the start of the lunar exploration program. He said: "It is recommended that the accomplishment of the first lunar landing and safe return of the crew be defined as the end of the Apollo Program. This will give a crisp ending that everyone can understand and will be the minimum cost program. The Lunar Exploration Program, or whatever name is selected, will have a definable whole and can be planned and defended as a unit. . . . The successful termination of the Apollo Program should not be dependent on the successful deployment of ALSEP, EVA on the lunar surface, photos, soil samples or other experiments. Such objectives should not be mandatory for the first landing mission." Trimble added that he had discussed these points with NASA's Associate Administrator for Manned Space Flight George E. Mueller and it was his understanding that Mueller not only agreed but also planned to include similar material in his congressional testimony in defense of the budget.

Ltr., Trimble to Phillips, Feb. 19, 1968.

February 19

ASPO Manager George Low appointed Douglas R. Broome to head a special task team to resolve the problem of water requirements aboard the Apollo spacecraft. For some six months, Low noted, numerous discussions had surrounded the question of water purity requirements and loading procedures. Several meetings and reviews, including one at MSC on January 16 and another at KSC on February 13, had failed to resolve the problem, and Low thus instructed Broome's team to reach a "final and definite agreement" on acceptable water specifications and loading procedures. Much unnecessary time and effort had been expended on this problem, Low said, and he expected the team "to put this problem to rest once and for all."

Memo, Low to distr., "Apollo water requirements," Feb. 19, 1968.

February 20

Reflecting the climate of scientific thinking at his Center, MSC Director Robert R. Gilruth responded to inquiries from Homer E. Newell, NASA Associate Administrator, concerning vocal communications

during exploration of the lunar surface. While he termed continuous talking undesirable, Gilruth stated an astronaut's running comment would in effect form a set of field notes that a geologist might ordinarily keep during a field exercise. This normal vocal narrative, he told Newell, would keep ground control informed of mission progress and would ensure a maximum scientific return from the flight.

Ltr., Gilruth to Newell, Feb. 20, 1968; memo, Wilmot N. Hess, MSC Director of Science and Applications, to Special Assistant to the Director, "Astronaut activity on lunar surface," Feb. 19, 1968.

February 20

MSC informed NASA Hq. that a reaction control system (RCS) engine ruptured at Marquardt Corp. the previous night during a heater integration test within a normal duty cycle run. This was a development test; the cause of the rupture was unknown at the time of the report. A second RCS failure occurred at Marquardt March 6 during a rerun of the LM heater integration tests. The rerun series started March 2. No facility damage or personnel injuries were reported from either incident. Investigation was under way at Marquardt by both NASA and Marquardt engineers to determine the cause of the failures and the effect on the program.

TWXs, George M. Low, MSC, to NASA Hq., Attn: Director, Apollo Program Office, Feb. 20, 1968, and Mar. 6, 1968.

February 26

The LM Descent Engine Program Review was held at TRW Systems, Redondo Beach, Calif., reviewing the overall program status, technical and manufacturing problems, and program costs. Program status reports showed that 28 engines had been delivered in the LM descent engine program to date, including all White Sands Test Facility engines and engine rebuilds and all qualification test and flight engines; 9 WSTF engines and 12 flight engines remained to be delivered. Grumman indicated all engine delivery dates coincided with the vehicle need dates.

Ltr., C. H. Bolender, MSC, to NASA Hq., Attn: Edgar M. Cortright, "LM Descent Engine Program Review at TRW Systems on February 26, 1968," Mar. 11, 1968.

February 26

Stress corrosion and window problems in the LM had been resolved, NASA Associate Administrator for Manned Space Flight George E. Mueller advised the Administrator in his weekly progress report. By a thorough analysis of the entire structure of the spacecraft, a team of engineers at Grumman had determined that widespread stress corrosion on the vehicle was highly unlikely. Also, inspection of more than 1,400 individual parts on exposed surfaces of lunar module test article LTA-3 and LMs 3 through 8 had failed to discover a single instance of stress corrosion cracking, and thus no major changes would be made to the structure of the spacecraft.

Regarding the window problem (a window had blown out during a routine pressure test of LM-5 on December 17, 1967), Mueller stated that the windows on the LM were made from the strongest glass ever used on manned spacecraft. The most important factor, he said, was to avoid scratches on the window surface. Accordingly, Grumman and MSC had instituted a new acceptance test procedure to be conducted at Bethpage immediately before installation, after which the windows would remain fully protected. The LM-5 window failure had been caused by a defect in the body of the glass. Grumman subsequently planned to pressure-test all LM windows at 17.2 newtons per square centimeter (25 pounds per square inch). Normal operating pressure was 4.0 newtons per sq cm (5.8 psia).

Memo, Mueller to NASA Administrator and Deputy Administrator, "Manned Space Flight Report - February 26, 1968."

February 27

The Flight Readiness Review Board for CSM 020, lunar module test article 2R (LTA-2R), and spacecraft-LM adapter 9 (SLA-9) met at KSC. Concern was expressed over the loss of parts and materials in the CSM. North American Rockwell reported that a search had been made for 38 man-hours and was terminated when it was felt that damage might result. A data-storage equipment item had failed at the vendor and was later installed on spacecraft 020. The "belt was off its associated pulley" and because of this and other open failures the equipment was replaced. The chairman noted that there was no reason why a device with belts could not be made without belt failure.

"Minutes of Meeting, The Flight Readiness Review Board, CSM 020/LTA-2R/SLA-9, February 27, 1968," submitted by H. L. Brendle, Secretary, approved by Robert R. Gilruth, MSC Director.

February 28

MSC Director of Flight Crew Operations Donald K. Slayton wrote Wilmot N. Hess, Director of Science and Applications, regarding priorities between scientific objectives and mission operations in Apollo mission planning, specifically for activities on the lunar surface. Slayton acknowledged that scientific priorities had to be included within an overall mission plan. However, those priorities must inevitably be adjusted by operational factors such as difficulty and duration of activities to maximize success of the mission. Flight planning for surface operations on the first Apollo landing mission, Slayton said, had followed guidelines laid down by ASPO Manager George M. Low on September 18, 1967 (reflecting an MSC Directors' consensus as voiced at a September 15 briefing on lunar surface activities):

- The first extravehicular activity excursion was to consist of a number of simple, mutually independent activities.
- A small lunar sample would be collected on the first excursion.
- The Apollo Lunar Surface Experiments package (ALSEP) would not be deployed on the first excursion.

- For planning purposes, a second excursion was also included, with ALSEP deployment as the primary scientific objective.

Deployment of the ALSEP during the first EVA operation, he continued, appeared precluded by safety considerations (no objective ranked higher than the astronauts initial familiarization with 1/6 gravity). Should 1/6 gravity operations turn out to be simpler and less time-consuming than anticipated, ALSEP unloading might be possible; but Slayton stated that EVA experience during the Gemini program dictated a much more conservative plan.

Memo, Slayton to Hess, "Apollo lunar surface operations planning," Feb. 28, 1968.

February 29

In response to action required by the CSM 2TV-2 and CSM 101 Wire Board in October 1967, Dale D. Myers, CSM Program Manager at North American Rockwell, submitted to MSC results of a wire improvement study for the umbilical feedthrough area for the lower equipment bay. Myers stated that substantial improvements in wiring appearance in the lower equipment bay had been made even before the Wire Board's ordered study and that further improvements of any significant nature could not be made without major structural changes (which would be intolerable from the standpoint of mission schedules). Thus, Myers recommended against further changes in wiring in the lower equipment bay. Further, as installation procedures and wire protective measures had improved, the occurrence of wiring damage had been progressively reduced. This same rationale, Myers affirmed, applied to other harness areas inside the spacecraft. (This study by North American completed action items generated at the Wire Board meeting.)

Ltr., Myers to MSC CSM Manager Kenneth S. Kleinknecht, Feb. 29, 1968, with encl., "Summary Report on Block II Command Module Wiring Improvement Study."

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Part 2 (J)

Recovery, Spacecraft Redefinition, and First Manned Apollo Flight

March 1968

1968

March 1

MSC had decided not to static-fire the service modules of Block II spacecraft before flight (specifically, spacecraft 101), ASPO advised NASA Hq. The decision was based on successful completion of the spacecraft 102 static firing, evaluation of the test history on the service propulsion system, and a review by a joint MSC-MSFC team that came out flatly against any such static firings at KSC and acceded to such tests at White Sands only under Houston's strict authority. During subsequent discussions in Houston (notably a February 19 meeting with the MSFC contingent), program planners rejected such firings at White Sands because the additional transportation and handling might degrade reliability of the hardware - exactly the opposite of what was being sought.

Ltr., ASPO Manager George M. Low to Apollo Program Director Samuel C. Phillips, March 1, 1968.

March 1

John D. Stevenson, Director of Mission Operations, NASA OMSF, requested that MSC Flight Operations Director Christopher C. Kraft, Jr., prepare an analysis of the potential terrestrial threat posed by an uncontrolled reentry of the Apollo 6 spacecraft. (Surviving debris presented a possible danger should a service propulsion system failure or other malfunction preclude a controlled reentry.) Stevenson asked Kraft to include the debris hazard in MSC's Abort and Alternate Mission Study for Apollo 6 then under preparation.

Ltr., Stevenson to MSC, Attn: Kraft, "Terrestrial Threat from Apollo 6 CSM Control Failure," March 1, 1968.

March 4

The MSC Flammability Review Board met to assess results of the CSM flammability tests conducted on boilerplate 1224. The Board unanimously recommended using a 60-percent-oxygen and 40-percent-nitrogen atmosphere in the spacecraft cabin during launch, but continued use of a pure oxygen atmosphere at pressure of 4.1 newtons per square centimeter (6 pounds per square inch) during flight. Members concluded that this mixed-gas environment offered the best protection for the crew on the pad and during launch operations, while still meeting physiological and operational requirements. During the final stages of the flammability test program, tests had indicated that combustion characteristics for the 11-newtons-per-sq-cm (16-psi), 60-40 atmosphere and for the 4.1-newton pure oxygen atmosphere were remarkably similar. Also, full-scale trials had demonstrated that in an emergency the crew could get out of the spacecraft quickly and safely.

Memo, George E. Mueller to Administrator, "Manned Space Flight Weekly Report - March 11, 1968."

March 6-7

Design Certification Reviews of CSM 101 and LM-3 were held at MSC. Significant program-level agreements reached included validation of a 60-percent-oxygen and 40-percent-nitrogen cabin atmosphere during launch (see March 4); reaffirmation of the February 6 Management Council decision that a second unmanned LM flight was not required; and the conclusion that, in light of successful static firing of the 102 service propulsion system and subsequent analysis, a static-firing of the 101 system was not required.

Ibid.

March 8

Apollo Special Task Team Director Eberhard F. M. Rees wrote Dale D. Myers, Apollo CSM Program Manager at North American Rockwell, to convey the concern of ASPO Manager George M. Low and others over the status of the S-band high-gain-antenna system. (Of all the subsystems in the spacecraft, that antenna seemed to face perhaps the toughest technical and schedule problems.) On December 14, 1967, Rees had visited the subcontractor's plant (Dalmo Victor) at Belmont, Calif., and had heard optimistic status reports on the entire system, including quality control and delivery schedules. Shortly thereafter, when Dalmo Victor began quality testing, the company encountered serious technical difficulties and the delivery schedule, as Rees put it, "collapsed completely." He then recounted several efforts by analytical teams to pinpoint the technical problems and to put the program back into shape (including reviews in mid-February and again on March 1, when very little progress could be seen). This record of inability to remedy technical problems, said Rees, indicated a serious weakness among Apollo contractors regarding visibility of their programs as well as their analytical engineering capability.

Ltr., Rees to Myers, March 8, 1968.

March 8

NASA technicians at KSC completed the flight readiness test for Apollo 6. The two-day event was delayed several days because of difficulties in modifying the service propulsion system tank skirt. With that significant launch-preparation event completed, program officials were reassessing the launch date in light of work remaining on the vehicle.

Memo, George E. Mueller to Administrator, "Manned Space Flight Weekly Report - March 11, 1968."

March 11

North American Rockwell technicians at Downey completed integrated system testing on 2TV-1, the CSM thermal vacuum test vehicle. Shipment of the test article to MSC was scheduled for the end of March.

Memo, George E. Mueller to Administrator, "Manned Space Flight Weekly Report- March 15, 1968," March 18, 1968.

March 12

Edgar M. Cortright, NASA Deputy Associate Administrator for Manned Space Flight, reported on the results of a thorough review of Apollo subcontractors made during January and February at the request of George E. Mueller. Cortright's review, coordinated with Apollo Program Directors in Washington and Houston, included detailed analysis of subsystem programs and on-site assessment of technical problems, schedule patterns, and testing programs. While favorably impressed with what he had found in general, he cited a number of what he termed "disturbing" conditions: most subsystems were facing hardware delivery schedule problems; many open failures existed; most qualification tests obviously would run beyond flight hardware delivery dates, requiring change-outs at KSC; several of the major subcontractors' difficulties had been compounded by lack of visibility of the overall spacecraft program (those "subs," he said, could have benefited from more attention by the "primes" and from allowing them a role in decision-making affecting their subsystems). Also, Cortright concluded that NASA itself could make more efficient use of subsystem managers and get them more deeply involved in the life of their respective programs. As a remedy to improve the total subsystem picture, Cortright recommended additional subsystem testing (and closer scrutiny by NASA of those tests); a reexamination of the entire Apollo system to determine any procedural errors in operating the subsystems that could result in failure of a subsystem; more contractor involvement in decision-making by both NASA and the primes; and greater emphasis on the manned space flight awareness program.

Memo for record, Cortright, "Apollo subcontractor review," March 12, 1968.

March 14

NASA announced to the public that program officials had decided to use a 60-percent-oxygen and 40-

percent-nitrogen atmosphere in the Apollo spacecraft cabin while on the launch pad (and to retain the pure-oxygen environment in space). This technical decision - because of the earlier tragedy with Apollo 204 over a year earlier - was subjected to closer public scrutiny than perhaps any comparable decision in the history of the U.S. space program. The change affected only ground operations and support equipment and did not necessitate any major changes in the spacecraft itself. Exhaustive testing of the redesigned interior of the vehicle since October 1967 had demonstrated that the risk of fire inside the spacecraft had been drastically reduced. Hardware changes inside the cabin, spokesmen said, had minimized possible sources of ignition and materials changes had vastly reduced the danger of fire propagation.

NASA News Release 68-47, "Apollo Spacecraft Cabin Atmosphere," March 14, 1968.

March 18

The MSC Structures and Mechanics Division reported to ASPO Manager George M. Low that additional verification of the spacecraft 020 reaction control system (RCS) pressure vessels would not be required. Using pressure vessel histories received March 14 and the previous propellant temperature restriction of 297 kelvins (75 degrees F) maximum, fracture mechanics analyses showed:

1. all RCS helium tanks were satisfactory to maximum design operating pressure (MDOP);
2. all CM RCS propellant tanks were satisfactory to MDOP;
3. all SM RCS tanks were satisfactory to MDOP; and
4. the differences between measured MDOPs on RCS SM oxidizer tanks and the pressures assured safe by fracture mechanics were considered to be insignificant differences.

Memo, Joseph N. Kotanchik to ASPO Manager, "Fracture Mechanics Review of Spacecraft 020 Reaction Control System (RCS) Pressure Vessels," March 18, 1968.

March 18

Samuel C. Phillips, NASA Apollo Program Director, expressed concern to ASPO Manager George Low that relaxed review procedures on LM-4 and LM-5 might tend to delay identification and resolution of problems. Phillips had understood that the LM-4 Phase II Customer Acceptance Readiness Review (CARR) had been rescheduled and that the LM-5 Phase I and Phase II CARRs might be combined. He requested that every possible effort be made to get a good Phase II review on LM-4 and separate Phase I and Phase II reviews on LM-5.

Ltr., Phillips to Low, March 18, 1968.

March 19

ASPO Manager George Low emphatically rejected North American Rockwell's suggestion of added

spacecraft delivery delays. Responding to a February letter from North American CSM Program Manager Dale D. Myers - suggesting further slips in delivery of 2TV-1 and spacecraft 101, 103, and 104 - Low reminded Myers that at the close of the Configuration Control Board meeting on February 23 he had cited a mid-April target for delivery of CSM 101. Since that time, Low said, KSC had been actively preparing for an early summer launch based on that mid-April delivery, and circumstances therefore made that date most important. Moreover, North American must deliver CSM 103 by the end of June 1968 in order to ensure meeting Apollo's end-of-the-decade goal. He reminded Myers that he had pursued this point on several occasions with him and with William Bergen. They both had told Low that they had found ways to deliver 103 within that time frame, and Low now suggested that this target date be made a firm commitment in the official Apollo schedules. At the earliest possible date, Low concluded, MSC and North American must establish firm contractual baselines for delivery schedules. Until then present delivery dates remained valid. He admitted that some schedule slips had resulted from NASA-dictated changes and that the schedules should be adjusted accordingly. The remaining delays, however, Low attributed directly to the company's inability to meet projected commitments. The contract was changed to call for an April 1968 delivery for CSM 101 and a June 1968 delivery for CSM 103.

Ltr., Low to Myers, March 19, 1968; Part IV Contract NAS9-150.

March 21

The lunar landing research vehicle was operating and training was being conducted, MSC Director Robert R. Gilruth wrote Langley Research Center's Acting Director Charles J. Donlan. MSC intended to conduct a second class for LLRV pilots and one of the first requirements for checkout was a familiarization program on Langley's Lunar Landing Research Facility. He requested that a program be conducted for not less than four nor more than six MSC pilots between April 15 and May 15.

Ltr., Gilruth to Donlan, March 21, 1968.

March 21

MSC asked Grumman to make a thorough review of the amount of nominal, off-nominal, and extended-life subsystem testing of LM production hardware and recommend any additional testing that should be done. The review of performance data was needed, Neal said, to ensure that program officials had sufficient test data to support flight planners and flight controllers during the manned missions.

Ltr., James L. Neal, LM Contracting Officer, MSC, to Joseph G. Gavin, LM Program Manager. Grumman Aircraft Engineering Corp., "Contract NAS 9-1100, Proposal for additional subsystem testing," March 21, 1968.

March 21

In an effort to resolve the continuing technical and schedule problems with the high-gain antenna system at Dalmo Victor, Apollo CSM Program Manager Dale D. Myers named a Resident Subsystem Project Manager at the vendor's plant. This change provided a single management interface with Dalmo Victor. The representative had been given authority to call on whatever North American Rockwell resources he might need to accomplish program objectives.

Ltr., Myers to Kenneth S. Kleinknecht, MSC, March 21, 1968.

March 22

Eberhard F. M. Rees, Director of the Apollo Special Task Team at North American Rockwell, wrote to the company's CSM Program Manager Dale D. Myers to express his concern over persistent problems with leaks in the ball valves for the service propulsion system. Rees doubted that any real progress was being made, stating that the problem persisted despite relaxations in leakage criteria and that qualification failures continued to occur. Rees described a review of the program on March 18 at Aerojet-General Corp. as lacking in factual depth. Also, the company did not appear to be pursuing developmental testing of configurational changes with any degree of vigor. Rees suggested to Myers that his people were on the right track and with management attention the vendor's efforts could be channeled to get some genuine results.

Ltr., Rees to Myers, March 22, 1968, with encl., "Minutes of AGC Ball Valve Presentation," March 18, 1968.

March 23

Apollo drogue chute test 99-5 failed at the El Centro, Calif., parachute facility. The drop was conducted to demonstrate the slight change made in the reefed area and the 10-second reefing cutter at ultimate load conditions. The 5,897-kilogram vehicle was launched from a B-52 aircraft at 10,668 meters and programmer chute operation and timing appeared normal. At drogue deployment following mortar activation, one drogue appeared to separate from the vehicle. This chute was not recovered but ground observers indicated the failure seemed to occur in the riser or vehicle attachment. The second drogue remained on the vehicle but seemed to slip in the reefed state. This chute was recovered and inspection confirmed the canopy failure. The Air Force parachute system which was to recover the vehicle also failed in the reefed state.

TWX, George M. Low, MSC, to NASA Hq., Att: Director, Apollo Program Office, March 23, 1968.

March 27

ASPO documented its reasons for using nitrogen rather than helium (as the Air Force had done) as the diluent in the Apollo spacecraft's cabin atmosphere, in response to a suggestion from Julian M. West of NASA Hq. Aaron Cohen, Assistant Chief of the MSC Systems Engineering Division, recounted that the

Atmosphere Selection Task Team had addressed the question of nitrogen versus helium (regardless of percentage) and had rejected helium because of uncertainty of the compatibility of spacecraft equipment with helium. Further, helium presented the same physiological problems as did nitrogen, and whatever flammabilities advantages helium possessed were extremely small. For all these reasons, Cohen explained, the team had early elected to concentrate on nitrogen- mixed atmospheres.

Memo, George M. Low, MSC, to West, "Selection of nitrogen as a diluent for the Apollo launch atmosphere," March 27, 1968, with encl., memo, Cohen to Low, "Nitrogen selection as a diluent," March 25, 1968.

March 27-28

A LM prelaunch atmosphere selection and repressurization meeting was held at MSC, attended by representatives of MSC, MSFC, KSC, North American Rockwell, and Grumman. The rationale for MSC selection of 100 percent oxygen as the LM cabin launch atmosphere was based on three factors: use of other than 100 percent oxygen in the LM cabin would entail additional crew procedural workloads at transposition and docking; excessive risk to crew due to depletion of the CM emergency oxygen consumables would be added; and it would require use of 2.7 kilograms of onboard CM oxygen. Two problems were identified with use of 100 percent oxygen in the LM cabin at launch: LM cabin flammability on the pad and LM venting oxygen into the SLA during boost. If air were used in the LM cabin at launch and the LM vent valve opened during boost, the full CM stored-oxygen capacity would be required to pressurize the LM and LM tunnel for umbilical mating. For a lunar mission, this situation would be similar to that before lunar orbital insertion, but would subject the crew to a condition of no stored oxygen for an emergency. For an earth-orbital mission this situation would be objectionable because CM stored oxygen would be lacking for an emergency entry into the atmosphere. (See also April 22 entry.)

Ltr., Low to addressees, April 17, 1968, with encl., memo, Assistant Chief, Systems Engineering Div. to addressees, "Minutes of LM Repressurization Meeting," April 8, 1968.

March 29

Scott H. Simpkinson, Acting Chief of ASPO Test Division, authorized assignment of Boeing-TIE personnel to Downey, Calif., and Bethpage. N.Y., to support test evaluation areas - because of fixed limitations on the number of resident NASA personnel at the prime contractors' locations.

Memos, Simpkinson to Chief, Program Control, "Boeing-TIE support," March 29. 1968.

March 29

Samuel C. Phillips, NASA Apollo Program Director, wrote ASPO Manager George M. Low to express concern about two particular technical problems in the Apollo Lunar Surface Experiments Package:

1. a system for on-the-pad cooling of the SNAP-27 radioactive fuel cask and
2. the overall weight status of the ALSEP (especially the recent decision to charge the weight penalty of the remote deployment mechanism to the ALSEP weight budget itself).

Because ALSEP was the key to success of the Apollo science program. Phillips asked that Low take the lead in reviewing these and any other pertinent technical problems to effect early resolution and ensure success of the program.

Ltr., Phillips to Low, March 29, 1968.

March 29

NASA Hq. asked that MSC consider a variety of lunar photographic operations from orbit during manned landing missions. Cancellation from Apollo of the lunar mapping and survey system had eliminated any specially designed lunar photographic capability; but photography was still desired for scientific, operational, and contingency purposes. Presence of the CSM in orbit during manned landing missions, Headquarters OMSF said, would be a valuable opportunity, however limited, for photographic operations. MSC was asked to evaluate these operations to define whatever hardware and operational changes in Apollo might be required to capitalize upon this opportunity.

Ltr., Samuel C. Phillips, Apollo Program Director, NASA Hq., to Director Robert R. Gilruth. MSC, "Lunar Photography from the CSM," March 29, 1968.

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Part 2 (K)

Recovery, Spacecraft Redefinition, and First Manned Apollo Flight

April 1968

1968

April 2

NASA Hq. confirmed oral instructions to MSC and KSC to use 60 percent oxygen and 40 percent nitrogen to pressurize the Apollo CM cabin in prelaunch checkout operations and during manned chamber testing, as recommended by the Design Certification Review Board on March 7 and confirmed by the NASA Administrator on March 12. This instruction was applicable to flight and test articles at all locations.

TWX, Samuel C. Phillips to MSC, Attn: G. M. Low and KSC, Attn: R. O. Middleton, April 2, 1968.

April 2

Eberhard F. M. Rees, Director of the Special Task Team at North American Rockwell, spearheaded a design review of the CM water sterilization system at Downey, Calif. (The review had resulted as an action item from the March 21 Configuration Control Board meeting in Downey.) Rees and a team of North American engineers reviewed the design of the system and test results and problems to date. Chief among performance concerns seemed to be compatibility of the chlorine solution with several materials in the system, maximum allowable concentration of chlorine in the water supply from the medical aspect, and contamination of the system during storage, handling, and filling. Assuming North American's successful completion of qualification testing and attention to the foregoing action items, said Rees, the system design was judged satisfactory.

Ltr., Dale D. Myers to George M. Low, April 8, 1968, with encl., "CSM Water Sterilization System CDR, April 2, 1968."

April 4

Apollo 6 (AS-502) was launched from Complex 39A at Kennedy Space Center. The space vehicle consisted of a Saturn V launch vehicle with an unmanned, modified Block I command and service module (CSM 020) and a lunar module test article (LTA-2R).

Liftoff at 7:00 a.m. EST was normal but, during the first-stage (S-IC) boost phase, oscillations and abrupt measurement changes were observed. During the second-stage (S-II) boost phase, two of the J-2 engines shut down early and the remaining three were extended approximately one minute to compensate. The third stage (S-IVB) firing was also longer than planned and at termination of thrust the orbit was 177.7 x 362.9 kilometers rather than the 160.9-kilometer near-circular orbit planned. The attempt to reignite the S-IVB engine for the translunar injection was unsuccessful. Reentry speed was 10 kilometers per second rather than the planned 11.1, and the spacecraft landed 90.7 kilometers uprange of the targeted landing point.

The most significant spacecraft anomaly occurred at about 2 minutes 13 seconds after liftoff, when abrupt changes were indicated by strain, vibration, and acceleration measurements in the S-IVB, instrument unit, adapter, lunar module test article, and CSM. Apparently oscillations induced by the launch vehicle exceeded the spacecraft design criteria.

The second-stage (S-II) burn was normal until about 4 minutes 38 seconds after liftoff; then difficulties were recorded. Engine 2 cutoff was recorded about 6 minutes 53 seconds into the flight and engine 3 cutoff less than 3 seconds later. The remaining second-stage engines shut down at 9 minutes 36 seconds - 58 seconds later than planned.

The S-IVB engine during its first burn, which was normal, operated 29 seconds longer than programmed. After two revolutions in a parking orbit, during which the systems were checked, operational tests performed, and several attitude maneuvers made, preparations were completed for the S-IVB engine restart. The firing was scheduled to occur on the Cape Kennedy pass at the end of the second revolution, but could not be accomplished. A ground command was sent to the CSM to carry out a planned alternate mission, and the CSM separated from the S-IVB stage.

A service propulsion system (SPS) engine firing sequence resulted in a 442-second burn and an accompanying free-return orbit of 22,259.1 x 33.3 kilometers. Since the SPS was used to attain the desired high apogee, there was insufficient propellant left to gain the high-velocity increase desired for the entry. For this reason, a complete firing sequence was performed except that the thrust was inhibited.

Parachute deployment was normal and the spacecraft landed about 9 hours 50 minutes after liftoff, in the mid-Pacific, 90.7 kilometers uprange from the predicted landing area. A normal retrieval was made by the U.S.S. *Okinawa*, with waves of 2.1 to 2.4 meters.

The spacecraft was in good condition, including the unified crew hatch, flown for the first time. Charring of the thermal protection was about the same as that experienced on the Apollo 4 spacecraft (CM 017).

Of the five primary objectives, three - demonstrating separation of launch vehicle stages, performance of the emergency detection system (EDS) in a close-loop mode, and mission support facilities and operations - were achieved. Only partially achieved were the objectives of confirming structure and thermal integrity, compatibility of launch vehicle and spacecraft, and launch loads and dynamic characteristics; and of verifying operation of launch vehicle propulsion, guidance and control, and electrical systems. Apollo 6, therefore, was officially judged in December as "not a success in accordance with . . . NASA mission objectives."

Memos, Chief, Landing and Recovery Div. to Director of Flight Operations, MSC, "Apollo 6 preliminary recovery information," April 5, 1968; Apollo Program Director Samuel C. Phillips to Administrator, NASA, "Apollo 6 Mission (AS-502) Post Launch Report #1," April 18, 1968, with attachment, "Post Launch Mission Operation Report No. M-932-68-06"; Phillips to Acting Administrator, "Apollo 6 Mission (AS-502) Post Launch Report #2," Dec 27, 1968; "Apollo 6 Mission Report," prepared by Apollo 6 Mission Evaluation Team, approved by George M. Low, June 1968.

April 4

Howard W. Tindall, Jr., Chief of Apollo Data Priority Coordination, reported that several meetings devoted to the question of the LM's status immediately after touching down on the lunar surface, had reached agreement on several operational techniques for a "go/no go" decision. Basically, the period immediately after landing constituted a system evaluation phase (in which both crew and ground controllers assessed the spacecraft's status) - a period of about two minutes, during which immediate abort and ascent was possible. Given a decision at that point not to abort, the crew would then remove the guidance system from the descent mode and proceed with the normal ascent-powered flight program (and an immediate abort was no longer possible). Assuming permission to stay beyond this initial "make ready" phase, the crew would then carry out most of the normal procedures required to launch when the CM next passed over the landing site (some two hours later).

Memo, Tindall to distr., "Mission techniques for the LM lunar stay go/no go," April 4, 1968.

April 5-7

Astronauts James A. Lovell, Jr., Stuart A. Roosa, and Charles M. Duke, Jr., participated in a recovery test of spacecraft 007, conducted by the MSC Landing and Recovery Division in the Gulf of Mexico. The test crew reported that while they did not "recommend the Apollo spacecraft for any extended sea voyages they encountered no serious habitability problems during the 48-hour test. If a comparison can be made, the interior configurations and seaworthiness make the Apollo spacecraft a much better vessel than the Gemini spacecraft." The following conclusions were reached:

1. The Apollo spacecraft, as represented by spacecraft 007 and under ambient conditions tested, was suitable for a 48-hour delayed recovery.
2. The interference between the survival radio beacon and VHF communications was

unsatisfactory. Spacecraft to aircraft communication ranges seemed unusually low.

3. There was no requirement for the seawater hand pump.

Memo, Donald K. Slayton to Director of Flight Operations, "Crew report on 48-hour recovery test of spacecraft 007 on April 5-7, 1968," April 12, 1968.

April 10

The Apollo spacecraft Configuration Control Board (CCB) had endorsed changes in lunar orbit insertion and LM extraction on the lunar mission flight profile, the MSC Director notified the Apollo Program Director. ASPO had reviewed the changes with William Schneider of NASA OMSF the same day and Schneider was to present the changes to George E. Mueller and Samuel C. Phillips for approval.

The two-burn lunar orbit insertion (LOI) was an operational procedure to desensitize the maneuver to system uncertainties and would allow for optimization of a lunar orbit trim burn. The procedure would be used for lunar orbit and lunar landing missions. The spacecraft lunar-adaptor spring-ejection system was required to ensure adequate clearance during separation of the LM/CSM from the S-IVB/instrument unit and would be used on the first manned CSM/LM mission.

Ltr., Robert R. Gilruth to Phillips, "Proposed changes to Lunar Orbit Insertion and LM extraction on the Lunar Mission Flight Profile," April 10, 1968.

April 10

A TV camera would be carried in CM 101 on the first manned Apollo flight, Apollo Program Director Samuel C. Phillips, wrote the ASPO Manager (confirming their discussions). Incorporation and use of the camera in CM 101 would conform to the following ground rules:

1. The TV camera and associated hardware would be installed at KSC with no impact on launch schedule;
2. the camera would be stowed during the launch phase;
3. a mounting bracket for the camera would be provided in the CM to permit simultaneous viewing of all three couch assemblies, for use in monitoring prelaunch hazardous tests and in flight;
4. the camera could be hand-held for viewing outside the CM during flight; and
5. use of the camera would not be specified on the astronaut's flight planning timeline of essential activities but would be incorporated in the mission as time and opportunity would permit.

Ltr., Director, Apollo Program, NASA OMSF, to Manager ASPO, "Apollo On-Board TV," April 10, 1968.

April 12

A number of decisions were made at the completion of a parachute review at Northrop-Ventura:

1. The spacecraft 101 parachute system would be flown without further changes.
2. A higher drogue-mortar muzzle velocity would be planned, with a possible effectivity for spacecraft 103. North American Rockwell would determine what ground tests were required, when flight hardware would be ready, and what additional qualification tests were needed.
3. Proposed Northrop-Ventura changes in drogue riser size and riser length would be considered only for design and ground testing activities.
4. North American would propose to NASA an augmented confidence-level test program.
5. For follow-on work, NASA would contract directly with Northrop-Ventura only for analytical work (all test effort would be contracted through North American).
6. Northrop-Ventura would examine the swagged fittings to determine whether a possible stress corrosion problem might exist.
7. Northrop-Ventura would obtain sufficient documentary photography during parachute packing for manned flight vehicles to provide subsequent quality examination.
8. Northrop-Ventura would prepare a package depicting the flight and design envelope of the parachutes, together with tests already achieved and tests planned.
9. Finn direction to Northrop-Ventura in all applicable areas would be provided by North American.

Memo, George M. Low to Kenneth S. Kleinknecht, "Action items from the Northrop Ventura meeting," April 15, 1968.

April 12

Apollo Special Task Team Director Eberhard Rees wrote Dale D. Myers at North American Rockwell: "As you are well aware, many manhours have been spent investigating and discussing the radially cracked insulation on wire supplied by Haveg Industries. On March 27, 1968, NR [North American Rockwell] made a presentation on this problem and reported the action taken to correct the problem and to prevent defective wire from being used. . . . It was disturbing to me to learn that with all the additional actions. . . cracked insulation again was found, this time during the manufacture of harnesses for C/M 110, 111, 112 and S/M 111. This raises the question as to whether the total problem has really been identified and whether or not sufficient corrective action has been taken. . . ." Rees then requested a reply to 10 questions he submitted as to reasons for the problem and possible actions that might be taken.

Ltr., Rees to Myers, April 12, 1968.

April 16

A meeting at MSC with Irving Pinkel of Lewis Research Center and Robert Van Dolah of the Bureau of Mines reviewed results of boilerplate 1224 tests at 11.4 newtons per square centimeter (16.5 pounds per square inch) in a 60-percent-oxygen and 40-percent-nitrogen atmosphere. (Both Pinkel and Van Dolah had been members of the Apollo 204 Review Board. Others attending were Jerry Craig, Richard

Johnston, and George Abbey, all of MSC; and George Gill and Fred Yeamans, both of GE.) The total boilerplate 1224 test program was reviewed as well as test results at 11 newtons per sq cm (16 psi) in 60 percent oxygen and 40 percent nitrogen and also in 95 percent oxygen. Both Pinkel and Van Dolah agreed with the MSC position that the tests proved the spacecraft was qualified for testing and flight in the 60-40 environment. They expressed the opinion that the 60-40 atmosphere seemed a reasonable compromise between flammability, physiological, and operational considerations.

Memo, Chief, Thermodynamics and Materials Br., to Chief, Systems Engineering Div., "Review of BP 1224 test data with I. Pinkel and R. Van Dolah," April 19, 1968.

April 17

MSC Engineering and Development Director Maxime Faget reported to George Low that his directorate had investigated numerous radiation detectors, ionization particle detectors, and chemical reactive detectors. The directorate had also obtained information from outside sources such as the National Bureau of Standards, Mine Safety Appliances, Parmalee Plastics, Wright-Patterson Air Force Base, and the Air Force Manned Orbiting Laboratory organization. None of the methods investigated could meet the stated requirements for a spacecraft fire detection system.

Memo, Faget to Low, "Status of development effort for fire detection system," April 17, 1968.

April 17

MSC Director Robert R. Gilruth recommended to NASA Associate Administrator for Manned Space Flight George E. Mueller that MSC's Sigurd A. Sjoberg be approved as the U.S. Representative to the International Committee for Aeronautics of the Federation Aeronautique Internationale. Robert Dillaway of North American Rockwell, who had been serving as U.S. Representative, had accepted a position with the Navy and recommended Sjoberg to James F. Nields, President of the National Aeronautic Association, and to Major General Brooke F. Allen, Executive Director of the Association, and they had concurred in the recommendation. NASA Hq. approved the request May 20.

Ltrs., Gilruth to Mueller, April 17, 1968; Mueller to Gilruth, May 20, 1968.

April 18

Two major requirements existed for further service propulsion system (SPS) testing at the Arnold Engineering Development Center (AEDC), ASPO Manager George M. Low advised Apollo Program Director Samuel C. Phillips. First, the LM docking structure was marginal at peak SPS start transient. While evaluation of the redesigned docking mechanism was under way, final hardware design and production could not be completed until positive identification of the start transient was made through the AEDC test series. Secondly, a modified engine valve had been incorporated into the SPS for CSM 101, which thus necessitated further certification testing before flight (comprising sea-level static firings,

simulated altitude firings, and component endurance tests). Low emphasized the need to complete this testing as soon as possible, to isolate any potential problems.

Ltr., Low to Phillips, April 18, 1968.

April 22

ASPO Manager George M. Low advised top officials in Headquarters, MSFC, and KSC that he was recommending the use of 100 percent oxygen in the cabin of the LM at launch. MSC had reached this decision, Low said, after thorough evaluation of system capabilities, requirements, safety, and crew procedures. The selection of pure oxygen was based on several important factors: reduced demand on the CSM's oxygen supply by some 2.7 kilograms; simplified crew procedures; the capability for immediate return to earth during earth-orbital missions in which docking was performed; and safe physiological characteristics. All of these factors, the ASPO Chief stated, outweighed the flammability question. Because the LM was unmanned on the pad, there was little electrical power in the vehicle at launch and therefore few ignition sources. Further, the adapter was filled with inert nitrogen and the danger of a hazardous condition was therefore minimal. Also, temperature and pressure sensors inside the LM could be used for fire detection, and fire could be fought while the mobile service structure was in place. As a result, Low stated, use of oxygen in the LM on the pad posed no more of a hazard than did hypergolics and liquid hydrogen and oxygen.

Ltr., Low to Samuel C. Phillips, R. O. Middleton, KSC, and Arthur Rudolph, MSFC, April 22, 1968.

April 22

MSC Director Robert R. Gilruth observed that the Engineering and Development Directorate would be conducting two thermal-vacuum test programs during the next several months, following the April 9 shipment of the Block II thermal vacuum test article 2TV-1 to MSC from Downey. (The second test article was the LM counterpart, LTA-8.) Both programs were of major importance, Gilruth told his organization. However, because the 2TV-1 test program directly supported - and constrained - the first manned Apollo mission, he said that, in the event of any conflict between the two test programs, 2TV-1 had clear priority.

Memo, Gilruth to distr., "Program Priority," April 22, 1968.

April 23

ASPO Manager George M. Low requested Joseph N. Kotanchik to establish a task team to pull together all participants in the dynamic analysis of the Saturn V and boost environment. He suggested that Donald C. Wade should lead the effort and that he should work with George Jeffs of North American Rockwell, Tom Kelly of Grumman and Wayne Klopfenstein of Boeing, and that Lee James of MSFC could be contacted for any desired support or coordination. The team would define the allowable

oscillations at the interface of the spacecraft-LM adapter with the instrument unit for the existing Block II configuration, possible changes in the hardware to detune the CSM and the LM, and the combined effects of pogo and the S-IC single-engine-out case. Low also said he was establishing a task team under Richard Colonna to define a test program related to the same problem area and felt that Wade and Colonna would want to work together.

Memo, Low to J. N. Kotanchik through M. A. Faget, "CSM/LM/SLA dynamic analysis," April 23, 1968.

April 27

NASA Administrator James E. Webb approved plans to proceed with preparation of the third Saturn V space vehicle for a manned mission in the fourth quarter of 1968. The planned mission was to follow the unmanned November 9, 1967, *Apollo 4* and April 4, 1968, *Apollo 6* flights, launched on the first two Saturn V vehicles. NASA kept the option of flying another unmanned mission if further analysis and testing indicated that was the best course. Engineers had been working around the clock to determine causes of and solutions to problems met on the *Apollo 6* flight.

NASA News Release 68-81, "Manned Apollo Flight," April 29, 1968.

April 27

ASPO Manager George M. Low explained to the Apollo Program Director the underlying causes of slips in CSM and LM delivery dates since establishment of contract dates during the fall of 1967. The general excuse, Low said, was that slips were the result of NASA-directed hardware changes. "This excuse is not valid." He recounted how NASA-imposed changes had been under strict control and only essential changes had been approved by the MSC Level II Configuration Control Board (CCB). For early spacecraft (CSM 101 and 103 and LM-3), the CCB had agreed some six months earlier that only flight safety changes would be approved. To achieve firm understandings with the two prime spacecraft contractors regarding the responsibilities for schedule slips, Low had asked MSC procurement expert Dave W. Lang to negotiate new contract delivery dates based on changes since the last round of negotiations. These negotiations with North American Rockwell were now completed. (Talks at Grumman had not yet started.) Despite a leniency in the negotiations on early spacecraft, Low said, results clearly indicated that most schedule delays were attributable to North American and not to NASA. On 2TV-1, for example, delivered two months late, analysis proved that less than three weeks of this delay derived from customer-dictated changes. The situation for CSM 101, though not yet delivered, was comparable. Moreover, a similar situation existed within the LM program: LM-3 would be delivered some five weeks behind the contract date, with only two of those weeks caused by NASA changes. Despite this attempt to set the record straight regarding schedule slippages, Low stressed that he did not wish to be over critical of the contractors' performance. Because schedules over the past year had been based on three-shift, seven-day-per-week operation, little or no time existed for troubleshooting and "make work", changes that inevitably cropped up during checkout activities.

Ltr., Low to Samuel C. Phillips, NASA Hq., April 27, 1968.

April 30

ASPO was implementing actions recommended by Edgar M. Cortright following his review of Apollo subsystem programs and visits to Apollo subcontractors (see March 12), ASPO Manager George Low advised Apollo Program Director Sam Phillips. These additional steps included further testing of hardware (including "augmented" testing to define nominal and off-nominal operating conditions better); better NASA overseeing of certification test requirements and results; a reexamination by the Crew Safety Review Board of system operating procedures, with emphasis on crew operations; closer subcontractor participation in program decisionmaking, chiefly through the proposed augmented tests and product improvement program; and greater emphasis at the subcontractor plants on the manned flight awareness program.

Ltr., Low to Phillips, "Apollo Subcontractor Review," April 30, 1968.

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Part 2 (L)

Recovery, Spacecraft Redefinition, and First Manned Apollo Flight

May 1968

1968

May 1

ASPO Manager George M. Low ordered LM Manager C. H. Bolender to establish a firm baseline configuration for the LM ascent engine to use during the entire series of qualification tests (including any penalty runs that might be required). Low's memo followed a telephone conversation the previous day with Apollo Program Director Samuel C. Phillips. Low cited to Bolender the need for a rigid design control on the engine. During a recent technical review, he explained, NASA officials learned that most qualification tests had been performed on one model (the E2CA injector), while all of the bomb stability tests had used another (the E2C injector). Ostensibly, the only difference between the two injectors was in the welding techniques. However, the first E2CA injector that was bomb-tested showed a combustion instability. Low emphasized that he was not charging that the different welding technique had caused the instability. Nevertheless, "this supposedly minor change [has] again served to emphasize the importance of making no changes, no matter how small, in the configuration of this engine." Once Bolender had set up the requested baseline configuration, Low stated, no change either in design or process should be made without approval by the Configuration Control Board.

Phillips followed up his conversation with Low a week later to express a deep concern regarding the ascent engine program, particularly small improvements in the engine, which could very likely delay the entire Apollo program beyond the present goal. The sensitivity of the engine to even minor design, fabrication, and testing changes dictated absolute control over all such changes. The ascent engine, Phillips told Low, was one of a very few Apollo hardware items in which even the most insignificant change must be elevated to top-level management review before implementation.

Memo, Low to Bolender, "Design freeze of ascent engine," May 1, 1968; ltr., Phillips to Low. May 6, 1968.

May 6

Lunar landing research vehicle (LLRV) No. 1 crashed at Ellington Air Force Base, Tex. The pilot, astronaut Neil A. Armstrong, ejected after losing control of the vehicle, landing by parachute with minor injury. Estimated altitude of the LLRV at the time of ejection was 60 meters. LLRV No. 1, which had been on a standard training mission, was a total loss - estimated at \$1.5 million. LLRV No. 2 would not begin flight status until the accident investigation had been completed and the cause determined. (The LLTV's had not completed their ground test phase and were not included in this category.) MSC Director Robert R. Gilruth appointed a Board of Investigation, composed of: Joseph S. Algranti, Chief, Aircraft Operations Office, MSC; William A. Anders, Astronaut Office, qualified pilot; Charles Conrad, qualified pilot (temporary member, to be replaced by Donald L. Mallick); Donald L. Mallick, Chief, Research Pilots Branch, Flight Research Center; George L. Bosworth, Aircraft Maintenance - Quality Assurance Branch, Maintenance Officer; and C. H. Roberts, Aircraft Operations Office, Acting Flying Safety Officer. (See also May 16 and October 17.)

TWX, Richard H. Holzapfel, MSC, to NASA, Attn: B. P. Helgeson, May 7, 1968.

May 13

During an Apollo flight test program review at MSC, the question was left unresolved whether or not to perform a "fire-in-the-hole" test of the LM ascent engine (i.e., start the engine at the same instant the two stages of the spacecraft were disjoined - as the engine would have to be fired upon takeoff from the lunar surface) on either the D or E mission. At the review, several participants had suggested that the test be performed on the D mission because that would be the last Apollo flight containing development flight instrumentation (DFI). Later that day, ASPO Manager George M. Low met with several of the Center's Associate Directors (Christopher C. Kraft, Jr., Donald K. Slayton, and Maxime A. Faget) to pursue the issue further. At that time, Faget stated that, although desirable, DFI was not essential for the test objective. Most important, he said, was obtaining photographs of the base of the ascent engine following the burn. In view of Faget's contention - and because the fire-in-the-hole test added greatly to the complexity and risk of the D mission at the time the engine was first fired in space, Low and the others agreed not to include such an ascent engine burn in the flight. Low asked Faget to analyze ascent engine test experience and results of the LM-1 ascent engine burn before making any decision on such a test during the E mission.

Memo, Low to Faget, "Fire-in-the-Hole Test," May 13, 1968.

May 14

Robert R. Gilruth, MSC Director, announced reassignment of three officials. John D. Hodge was assigned as Director of the newly established Lunar Exploration Working Group. Aleck C. Bond, Manager of the Reliability and Quality Assurance Office and the Flight Safety Office, would be reassigned effective June 1 as Manager, Systems Test and Evaluation, Engineering and Development Directorate. Martin L. Raines, Manager, White Sands Test Facility, would become acting manager of the Reliability and Quality Assurance Office and the Flight Safety Office, in addition to his White Sands

assignment.

MSC News Release 68-35, May 14, 1968.

May 16

NASA Headquarters established the LLRV-1 Review Board to investigate the May 6 accidental crash of Lunar Landing Research Vehicle No. 1 at Ellington Air Force Base. The Board would consist of: Bruce T. Lundin, Lewis Research Center, chairman; John Stevenson, OMSF; Miles Ross, KSC; James Whitten, Langley Research Center; and Lt. Col. Jephtha D. Oliver (USAF), Norton Air Force Base. J. Wallace Ould, MSC Chief Counsel, would serve as counsel to the group. The board would

1. determine the probable cause or causes of the accident,
2. identify and evaluate proposed corrective actions,
3. evaluate the implications of the accident for LLRV and LM design and operations,
4. report its findings to the NASA Administrator as expeditiously as possible but no later than July 15, and
5. document its findings and submit a final report to the Administrator with a copy to the NASA Safety Director. (See October 17.)

Memo, Thomas O. Paine to LLRV-1 Review Board, "Investigation and Review of Crash of Lunar Landing Research Vehicle #1," May 16, 1968.

May 17

Christopher C. Kraft, Jr., MSC Director of Flight Operations, expressed concern to ASPO Manager George M. Low over the escalation of E-mission objectives; the flight now loomed as an extremely complex and ambitious mission. The probability of accomplishing all the objectives set forth for the mission, said Kraft, was very low. He did not propose changing the mission plan, however. "If we are fortunate," he said, "then certainly the quickest way to the moon will be achieved." Kraft did suggest caution in setting mission priorities and in "apply[ing] adjectives to the objectives." Specifically, he advised a realistic allowance of delta V limits at various points in the rendezvous portion of the mission, to ensure safe termination of the exercise if required. Also, he saw little value in a fire-in-the-hole burn of the ascent engine at stage separation of the LM. He believed that ground tests were adequate to provide answers on pressure and temperature rises on the ascent stage during launch from the lunar surface. The situation Kraft said was indicative of the engineer's desire to test fully all systems in flight in both normal and backup modes. However, reliance must be placed largely on the wealth of ground testing and analysis carried on to date in the Apollo program.

Memo, Kraft to Manager, Apollo Program, "Apollo Flight Test Program," May 17, 1968.

May 21

Following up on an earlier request to examine the potential for lunar photography of the moon from the CSM during Apollo lunar missions (see March 29), Apollo Program Director Samuel C. Phillips asked MSC Director Robert R. Gilruth to expand MSC's effort to include the potential for a range of scientific investigations. Specifically, he asked that MSC study the overall potential of the CSM for lunar science and the modification needed to support increasingly complex experiment payloads. Among experiments that might be carried out from the CSM Phillips cited infrared spectrometer radiometer, ultraviolet absorption spectrometer, passive microwave, radar-laser altimetry, and subsatellites.

Ltr., Phillips to Gilruth, "Lunar Scientific Experiments from the CSM," May 21, 1968.

May 22

Twist-and-solder wire splices were evaluated for ASPO Manager Low by Systems Engineering Division. The evaluation stated that twist-and-solder wire splices with shrink sleeve tubing had been used for many years and when properly done were adequate. It then listed three advantages and six disadvantages of this kind of splice. In summary, it stated that the splice could be phased into the LM program but was not recommended by the division because:

1. there are too many variables;
2. the present solder splice (either heat or ZAP gun) had none of the disadvantages or variables mentioned;
3. a substantial amount of time would be required to establish and implement qualification; and
4. qualification testing had proven the present solder splices adequate.

LM Program Manager C. H. Bolender had the memo hand-carried to George Low's office, since he was temporarily withholding approval of an engineering change proposal for Grumman to implement use of the ZAP gun for solder splices. Low, in turn, sent an "Urgent Action" note to his Assistant Manager for Flight Safety, Scott H. Simpkinson, asking his views on the problem and saying, in part, "Personally, I would only use the twist-and-solder splice - but I may be old fashioned." Simpkinson replied to Low with an informal note on May 23, agreeing with the recommendations of the Systems Engineering Division. Simpkinson said, ". . . The worst wire splice in the *production* world is the twist-and-solder, and cover with tubing. . . . I believe we should use the present LM splice method which has been qualified." He recommended the ZAP gun, "which controls the heat properly so that all the advantages of the present LM wire splices can be realized," recalling the phrase, 'Let's not improve ourselves into a new set of problems.'" On that same day Low instructed Bolender to proceed with the ZAP gun Grumman splices.

Memo, Owen E. Maynard, Chief, Systems Engineering Div., ASPO, to Manager, ASPO, "Evaluation of the twist-and-solder wire splice," May 22, 1968; note, Lyle D. White, Systems Engineering Div., to Low, May 22, 1968; Urgent Action note, Low to Simpkinson, undated; note, Simpkinson to Low, May 23, 1968; note, Low to Bolender, May 23, 1968.

May 24

Apollo Program Director Samuel C. Phillips requested from MSC Director Robert R. Gilruth a recommended program for spacesuit modifications to achieve greater astronaut maneuverability. The modifications were required for lunar landing missions, because extravehicular activities such as sampling and instrument deployment were difficult and time consuming with the present suit configuration. Phillips asked for trade-off studies to achieve optimized life support systems, an analysis of mobility requirements and techniques to enhance mobility, and studies of crew station requirements and problem areas such as suit repair, storage, and checkout.

Ltr., Phillips to Gilruth "Improvement of Apollo Spacesuit for Lunar Surface EVA Tasks," May 24, 1968.

May 25

ASPO Manager George M. Low informed Apollo Program Director Samuel C. Phillips of recent MSC work on the effects of launch vehicle-induced oscillations - i.e., "pogo" vibrations - on the spacecraft and its subsystems. MSC had made two key personnel assignments in this area:

1. Rolf W. Lanzkron managed all MSC activities in connection with the space vehicle dynamic integrity problem; and
2. astronaut Charles M. Duke coordinated all MSC's efforts with related work at MSFC.

Low also cited a number of decisions in the hardware and testing areas. He had decided to use CM 002B, SM 105, and LM-2 for pogo dynamics testing. Other ground test hardware included LTA-3 for manned drop tests and for additional structural verification tests, CM 102 to verify parachute-imposed loads on the spacecraft structure, and CMs 014 and 102 for additional structural tests at North American Rockwell. In deciding upon uses for these and other spacecraft hardware items, MSC had assigned first priority to the ground test program, second to another potential unmanned Saturn V flight, and third to the dual launch capability.

Ltr., Low to Phillips, May 25, 1968.

May 28

NASA and Grumman officials met to resolve the issue of the injector for the LM ascent engine. Chief NASA Apollo spacecraft program officials present included Director Samuel C. Phillips and MSC's ASPO Manager George M. Low and LM Manager C. H. Bolender; Grumman LM directors and engineers included LM Program Director Joseph G. Gavin. Several alternatives seemed feasible: continue the program with the existing Bell Aerosystems Co. engine and injector; furnish Bell Aerosystems Co. engines to Rocketdyne to be mated to the Rocketdyne injector; or ship Rocketdyne

injectors to Bell for installation in the engine. After what Low termed "considerable discussion," he dictated the course to be followed:

- The LM ascent engine would comprise Bell's engine with the Rocketdyne injector. Rocketdyne would be responsible for delivery of the complete engine, and would thus become a subcontractor to Grumman. (Bell could either remain as subcontractor to Grumman or become a subcontractor to Rocketdyne.)
- An engine with the Rocketdyne injector would be immediately installed in LM-3, as well as in LM-4 and LM-5, with minimum schedule impact.
- Grumman was to proceed forthwith on contract negotiations with Bell and Rocketdyne to cover these procurements.
- Rocketdyne was to continue qualification on the present injector design, and engine firings at White Sands Test Facility in support of LM-3 were to use the Rocketdyne injector.

Grumman participants at this meeting, as Low almost casually phrased it, "indicated that they would interpose no objections to this set of decisions." After long months of technical effort and almost agonizing hardware and managerial debate, the issue of an ascent engine for the LM was settled.

Memo for Record, Low, "Ascent engine injector," May 31, 1968.

May 29

NASA's North American Management Performance Award Board sent a summary of its findings for the first interim period, from September 1967 through March 1968, to North American Rockwell's Space Division. The review board had been charged with assessing the company's performance under spacecraft contract NAS 9-150 and determining an award fee under the contract's incentive agreements. Board Chairman B. L. Dorman wrote Space Division President William B. Bergen that the Board had been impressed by the attention of North American's top management to the CSM program. Moreover, a cooperative attitude from top to bottom had afforded NASA an excellent view into problem areas, while the company's assessment of problems had helped to produce high-quality hardware. On the other hand, several activities needed improvement: cost control; tighter management control over change traffic; stronger management of subcontractors; and better planning and implementation of test and checkout functions.

Ltr., Dorman to Bergen, May 29, 1968.

During the Month

NASA Associate Administrator for Manned Space Flight George E. Mueller recommended to the Administrator several alternative uses for the LM-2 vehicle, since that spacecraft was no longer destined for flight. (The successful LM-1 flight during the *Apollo 5* mission in January had obviated the need for a second such unmanned flight.) Mueller suggested that LM-2 be used for nondestructive tests and for

documentary photography. Additional drop tests with the craft, he said, would enhance confidence in the strength of the LM to withstand the impact of landing on the moon, with all subsystems functioning. (The LM drop test program using Lunar Test Article 3, Mueller said, would verify the LM structure itself; however, LTA-3 contained no operational subsystems, wiring, or plumbing and therefore could not verify the total flight vehicle.) Among several other possible uses for the vehicle examined but rejected, Mueller cited modifying the craft into a manned configuration for Apollo or using it for an early Apollo Applications flight. LM-2 was unsuitable for both these alternatives, he stated, because of the extensive structural modifications needed to make it a flightworthy Apollo spacecraft - and the attendant disruption of vehicle flow within the Grumman production line - and because of the many fire-proofing changes that would be required. The launch vehicle (SA-206), LM adapter, and protective shroud were to be placed in storage for further Saturn tests if needed.

Memo, Mueller to NASA Administrator, "Disposition and Usage of AS-206/LM-2 Hardware," n.d.

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June 3

ASPO Manager George Low advised Apollo program officials at KSC that, to collect adequate data for evaluating any potential toxicological hazard inside the spacecraft, collection of gas samples of the cabin atmosphere must be made for 12 hours during the unmanned altitude chamber test with all systems operating. Low asked that this requirement be included in the spacecraft test procedures. (Purpose of a total CSM 101 and LM-3 toxicological evaluation was to verify that no toxic contaminants were given off by the nonmetallic materials used in the crew compartments.)

Ltr., Low to R. O. Middleton, KSC, "Toxicological evaluation of CSM 101 and LM-3," June 3, 1968.

June 3

Apollo Program Director Sam Phillips asked ASPO Manager George Low to investigate the value of using freon as a fire extinguishing agent inside the spacecraft. Admittedly, Phillips said, MSC had considered using a freon extinguisher system shortly after the AS-204 accident, but it had been rejected, largely because of toxicity factors and because tests had shown the agent ineffective in extinguishing combustion of polyurethane in a pure oxygen atmosphere. A number of factors now dictated a reevaluation of such an extinguisher system, however:

- Additional testing of late had indicated a lower toxicity problem than earlier believed.

- The addition of oxygen masks to the spacecraft now afforded some protection against a toxic atmosphere.
- Because of post-accident changes inside the cabin, the flammability problem had been reduced to a few specific materials (quite different from polyurethane foam) sited in compartmentalized locations inside the cabin.
- The oxygen-nitrogen mixed gas had been selected as the prelaunch atmosphere inside the cabin.

In view of these changes, Phillips said, a freon extinguishing system might be better than the present jelled water extinguisher (quicker activation and reduced equipment damage). He asked that Low not overlook this potential improvement in crew safety, which could be of particular value during the high-risk period of launch, when the crew was essentially immobilized by the forces of acceleration.

Ltr., Phillips to Low, "CBrF3 (Freon 1301) as a Fire Extinguishing Agent," June 3, 1968.

June 5

George E. Mueller, Associate Administrator for Manned Space Flight, wrote MSC Director Robert R. Gilruth to express his personal interest in lunar extravehicular activity (EVA) training for the Apollo crews of the F and G missions (i.e., the initial lunar landing and subsequent flights). Because of the complexity of the EVA tasks that the astronauts must perform, Mueller said, crews for those missions should be selected as early as possible. Also, realistic training - including a realistic run-through of many of the lunar surface tasks, especially development of the S-band antenna and the Apollo Lunar Surface Experiments Package and sampling operations - must be conducted to ensure that the crews competently carried out the various scientific experiments and other tasks during their brief stays on the moon.

Ltr., Mueller to Gilruth, June 5, 1968.

June 7

ASPO Manager George M. Low and others from MSC met with Grumman's LM engineering staff, headed by Thomas J. Kelly, to discuss the descent stage heatshield and thermal blanket problems associated with reduced thrust decay of the descent engine at lunar touchdown. Several significant decisions were reached:

- The touchdown probe was lengthened to 1.6 meters.
- Effective on LM-5 and later vehicles, Grumman would "beef up" (both structurally and thermally) the base heatshield.
- Grumman was to conduct a series of tests on overpressure of the descent engine.
- Grumman would begin design studies of a jettisonable descent engine skirt.
- Landing stability would be reexamined with the existing thrust tailoff profile (a study to be made either by Grumman or by Boeing; Low asked Maxime A. Faget, Director of Engineering and Development at MSC, to review this proposed test plan and to recommend where it should be

conducted, for best cost, schedule, and technical capabilities).

Memo, Low to C. H. Bolender, "LM descent stage base heatshield," June 8, 1968.

June 10

In his weekly progress report to the NASA Administrator, Deputy Administrator for Manned Space Flight George E. Mueller cited several important Apollo events during the first week of June:

1. On June 1, technicians at MSC completed thermal-vacuum testing on LTA-8 to support LM-3, including 45% hours of manned testing. All spacecraft systems functioned normally, and preliminary results indicated that all significant test objectives had been realized.
2. Engineers and technicians at KSC completed receiving inspection of CSM 101 on June 3. That inspection revealed fewer discrepancies than had been present on any other spacecraft delivered to the Cape. Pre-mate inspection of CM 101 also was completed, as were leakage and functional tests on the electrical power and reaction control systems. SM 101 was in the altitude chamber being prepared for combined systems testing.

Memo, Mueller to NASA Administrator, "Manned Space Flight Weekly Report - June 7, 1968," June 10, 1968.

June 10

ASPO Manager George M. Low met with Christopher C. Kraft, Jr., and Donald K. Slayton, Directors of MSC Flight and Flight Crew Operations, and several members of their staffs (including astronaut Walter M. Schirra, Jr.) to discuss using the flight combustion stability monitor (FCSM) on the Apollo 7 flight. (The FCSM was a safety device to shut down the service propulsion system [SPS] automatically in the event of rough combustion or instability.) At the insistence of the Propulsion and Power Division, they agreed to use the FCSM for all SPS burns on Apollo 7. On all "noncritical" burns, two attempts to start the engine would be made with the FCSM active. Should the stability monitor shut down the engine on both those attempts, a detailed review of the situation would be made before again attempting to start the engine. On "critical" burns (i.e., the abort-to-orbit and reentry burns), should the FCSM halt the burn the SPS engine would be restarted immediately with the FCSM inactive on the assumption that the shutdown was caused either by an FCSM malfunction or by an engine instability that would not reoccur on the next start.

Low, Kraft, and the others unanimously wanted to eliminate the FCSM before a lunar mission, because on this mission lunar orbit and transearth insertion burns were highly critical and inadvertent shutdowns would cause major trajectory perturbations. Representatives from the Propulsion and Power Division (PPD) contended that, because of the relatively small number of bomb tests carried out on the Block II SPS engine, flight-testing of the engine before the lunar mission would be inadequate to demonstrate engine stability under all conditions. Low therefore asked Engineering and Development Director

Maxime A. Faget and PPD Chief Joseph G. Thibodaux, Jr., to plan a ground test program that would give sufficient confidence in the SPS engine to eliminate the FCSM before undertaking lunar missions.

Ltr., Low to Thibodaux, "Use of FCSM on Apollo 7," June 11, 1968.

June 11

Dale D. Myers, Apollo CSM Program Manager at North American Rockwell, advised MSC officials of his company's investigation of two pilot-chute riser failures during recent drop tests of the Block II earth-landing system. Should there be any imperfections in either hardware or assembly techniques, Myers explained, the Block II pilot chute and riser system could be a marginal-strength item. Investigations had determined that early manufacturing processes had allowed a differential length between the two plies of nylon webbing in the pilot-chute riser which caused unequal load distribution between the two plies and low total riser strength. Because of the earlier test failures, Myers said, the pilot chute riser had been redesigned. The two-ply nylon webbing had been replaced by continuous suspension lines (i.e., 12 nylon cords) and the 5.5-millimeter-diameter cable was changed to 6.3-millimeter cable. He then cited a series of recent tests that verified the redesigned pilot-chute riser's strength to meet deployment under worst-case operational conditions.

Ltr., Myers to K. S. Kleinknecht, MSC, June 11, 1968.

June 17

Apollo Program Director Phillips wrote MSC Director Gilruth concerning the April 10 proposal for a two-burn lunar orbit insertion (LOI) maneuver and a spring ejection of the LM from the spacecraft-lunar module adapter. Phillips agreed to the two-burn LOI in place of the originally planned one burn if results of an analysis should prove the requirement. He specified that an analysis be made of the tradeoffs and that the analysis include the risk of crash, the assumed risks due to lengthening the lunar orbit time (about four hours), and risks due to an additional spacecraft propulsion system burn, as well as the effect of the lunar gravitational potential on the ability to target the LOI maneuver to achieve the desired vector at the time of LM descent. The proposal for spring ejection of the LM from the SLA was approved with the provision that a failure analysis be made in order to understand the risks in the change.

Ltr., Samuel C. Phillips, OMSF, to Robert R. Gilruth, MSC, June 17, 1968.

July 3

NASA and contractor technicians successfully conducted the final parachute drop test to qualify the Apollo CSM earth-landing system. The Block II ELS thus was considered ready for manned flight after 12 Block I, 4 Block II, and 7 increased-capability Block II Qualification Tests - that had followed 77 Block I, 6 Block II, and 25 increased-capability Block II Development Drop Tests.

Memo, George E. Mueller, NASA OMSF, to NASA Administrator and Deputy Administrator. "Manned Space Flight Weekly Report - July 5, 1968," July 8, 1968; NASA Technical Note (NASA TN D-7437), "Apollo Experience Report-Earth Landing System."

July 5

ASPO Manager George M. Low asked Aaron Cohen, one of his chief technical assistants, to investigate the ability of the Apollo spacecraft to withstand bending loads imposed by a failure of one or more engines on the Saturn V launch vehicle (as well as actual loads that would be imposed on the spacecraft). During the previous week, Low and the Configuration Control Board had ruled out making any significant design changes to cope with a Saturn V engine failure. Specifically, Low asked how bending loads on the spacecraft were derived; what bending loads were imposed on the spacecraft during the *Apollo 6* mission, where two J-2 engines were cut off during the flight; what was the probability - and criticality - of an S-IC engine's failing and thereby imposing high bending loads; and whether abort limits should be established for an engine failure.

Memo, Low to Cohen, "Saturn V single engine out problems," July 5, 1968.

July 10-11

The Apollo Design Certification Review (DCR) Board met in Houston to examine CSM 101 and the Block II CSM for proof of design and development maturity and to certify the designs for flightworthiness and manned flight safety. (Three earlier reviews directly supported this penultimate scrutiny of the vehicle's development: the CSM 101 Design Certification Review March 6-7, the Block II environmental control system and spacesuit DCR May 8, and the DCR covering the CM land and water impact test program June 6.) The board concluded that design certification on CSM 101 was complete. Action and open items were subsequently forwarded to the Centers for resolution, to be closed before the Apollo 7 Flight Readiness Review.

Ltr., Samuel C. Phillips, NASA Hq., to distr., "CSM 101 and Block II CSM Delta Design Certification Review," Aug. 28, 1968.

July 11

ASPO Manager Low informed Apollo Program Director Phillips of several changes in the LM vibration testing program. Before beginning the series of tests, he told Phillips, red line values were established on critical components that were not to be exceeded. However, because of the most recent test effort on LM-2, which resulted from the pogo problem experienced during the flight of *Apollo 6*, Low was forced to authorize vibration testing beyond the red line values initially set for the spacecraft. This action, in turn, forced an inspection and possible refurbishment of LM-2 to make it available for an unmanned flight, should such a second unmanned LM test mission be required. He then cited MSC's future plans for LM-2:

- For the planned drop tests with the vehicle, the upper decks would be inspected and repaired or replaced where necessary.
- Should a LM-2 flight become necessary, all of the descent stage upper decks would probably be replaced.

Phillips approved Low's action immediately. He urged Low to "continue to give priority to that work which is necessary for full and early resolution of the POGO and spacecraft structural dynamics questions."

Ltr., George M. Low to Samuel C. Phillips, July 11, 1968, with handwritten notation by Phillips dated July 11, 1968.

July 13

ASPO Manager George M. Low wrote to Grumman President Llewellyn J. Evans to call his attention to the problem of continued propellant leaks in the LM. "In spite of all of our efforts, last summer" (i.e., with the extensive plumbing rework done on LM-1 after its delivery to Florida), Low said, technicians at KSC found a leak on one of the lines on LM-3, even though no leaks had been observed during checkout at Bethpage. Investigating the problem, Low had learned that Grumman had made some propellant-system design changes that had led to installation of four-bolt flanges with single teflon O-ring seals - despite the fact that during the preceding summer NASA and Grumman had jointly agreed not to use this joint on the LM vehicle. This most recent problem, said Low, again points up the importance of strictest control of all design changes in the spacecraft. Because of the need for maintaining a lunar-configured LM as a design baseline, all spacecraft design changes had to be carried through the Apollo Configuration Control Board before implementation.

Ltr., Low to Evans, July 13, 1968.

July 15

NASA Apollo Program Director Samuel C. Phillips laid down Headquarters and MSC interfaces with the Atomic Energy Commission (AEC) regarding the SNAP-27 radioisotope thermoelectric generator for the Apollo Lunar Surface Experiments Package (ALSEP). The Lunar Surface Program Office at MSC was the field project office responsible for developing the ALSEP system, and the radioisotope generator - as part of the ALSEP - had been assigned to that office for system integration. Thus, the Lunar Surface Program Office served as the AEC's primary contact on the SNAP-27 both for ALSEP program matters and for data pertaining to flight safety and documentation for flight approval. Phillips stressed that all data be fully coordinated with Headquarters before being submitted to the AEC. (Approval for the flight of any nuclear device rested ultimately with the President, but formal documentation had to be concurred in by the NASA Administrator, the AEC Commissioners, the Secretary of Defense, and the National Aeronautics and Space Council.)

Memo, Phillips to George M. Low, ASPO, MSC, "Atomic Energy Commission Interfaces," July 15, 1968.

July 17

NASA Associate Administrator George E. Mueller, Apollo Program Director Samuel C. Phillips, and other high-ranking manned space flight officials from Headquarters visited Bethpage for an overall review of the LM program. Greatest emphasis during their review was on schedules, technical problems, and qualification of the spacecraft's principal subsystems. Mueller and Phillips cited several areas that most concerned NASA:

- Delivery schedules from subcontractors and vendors had slipped significantly during the past year, to the point where many components were only marginally supporting spacecraft deliveries.
- The large number of hardware changes made during the past year was affecting costs and schedules.
- Costs forecast for Fiscal Year 1969 exceeded the current LM budget.

Mueller also suggested that Grumman consider eliminating the LM rendezvous radar to save weight aboard the vehicle. He stated that VHF ranging would be more accurate and would probably be the preferred mode of operation.

Memo, C. H. Bolender, MSC LM Manager, to Manager, Apollo Spacecraft Program, MSC, "Dr. Mueller's visit to GAEC on July 17, 1968," July 19, 1968.

July 22

In the continuing effort to reduce costs while still maintaining a balanced and viable program, ASPO Manager George M. Low recommended to NASA Hq. that CSM 102 be deleted from the manned flight program. He estimated total savings at \$25.5 million (excluding cost of refurbishment after the current ground test program). In addition, he said, during the static structural test program at North American Rockwell, CSM 102 would be subjected to loads that would compromise structural integrity of the vehicle for manned flight.

Ltr., Low to Samuel C. Phillips, "Deletion of CSM 102 from the manned flight program," July 22, 1968.

July 23

Prompted by a request from MSC to increase the Saturn V's performance to 46,070 kilograms for lunar missions, Samuel C. Phillips sought to strike a balance between spacecraft and launch vehicle weight-performance demands. He established as a new payload interface definition at translunar injection a payload of 46,040 kilograms. Should the vehicle per se be incapable of achieving this figure, said

Phillips, he would relax certain flight constraints to achieve the best possible balance between the space vehicle and the specific mission to be flown. But he implored both ASPO Manager George M. Low and Lee B. James, Saturn V Program Manager at MSFC, to work toward this balance between spacecraft and launch vehicle and to avoid any hardware changes in the Saturn V solely to meet the new payload interface weight.

Ltr., Phillips to James and Low, "Saturn V Payload Interface Definition," July 23, 1968.

July 30

F. A. Speer, Mission Operations Manager at MSFC, advised NASA Hq. of plans for S-IVB and spacecraft separation and employment of a "slingshot" trajectory following insertion into the trajectory toward the moon. Residuals in the S-IVB, said Speer, could be used to place the stage in a trajectory that would avoid recontact with the spacecraft and impact on either the earth or the moon - with preclusion of spacecraft-launch vehicle collision as the most important priority.

Ltr., Speer to William C. Schneider, Apollo Mission Director, NASA, "Lunar Debris," July 30, 1968.

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August 1

Howard W. Tindall, Jr., Deputy Division Chief, MSC Mission Planning and Analysis, wrote ASPO Manager George M. Low: "A rather unbelievable proposal has been bouncing around lately. Because it is seriously ascribed to a high ranking official, MSC and Grumman are both on the verge of initiating activities - feasibility studies, procedures development, etc. - in accord with it. . . . The matter to which I refer is the possibility of deleting the rendezvous radar from the LM. The first thing that comes to mind, although not perhaps the most important, is that the uproar from the astronaut office will be fantastic - and I'll join in with my small voice too. Without rendezvous radar there is absolutely no observational data going into the LM to support rendezvous maneuvers. . . . Please see if you can stop this if it's real and save both MSC and GAEC a lot of trouble." On August 9 Low wrote NASA Apollo Program Manager Samuel Phillips that, shortly after Associate Administrator for Manned Space George Mueller had visited Grumman, Low had calls from both C. H. Bolender, MSC, and Joseph Gavin, Grumman, indicating that Mueller had made a suggestion "that we should eliminate the LM rendezvous radar as a weight saving device." He forwarded Tindall's memorandum as the basis for "why we should not consider deleting the radar and why we shouldn't spend any more effort on this work." Low added that MSC was discontinuing "any work that we may have started as a result of George's comments." In a reply on August 28, Phillips told Low, "I am in complete agreement . . . that all work toward deleting the LM rendezvous radar should be discouraged and I have written to George Mueller to that effect."

Memo, Tindall to Manager, ASPO, "LM rendezvous radar is essential," Aug. 1, 1968; ltrs., Low to Phillips, Aug. 9, 1968, Phillips to Low, Aug. 28, 1968.

August 2

In an effort to stem the number of hardware changes at KSC, Apollo Program Director Samuel C. Phillips instituted a weekly review of all changes that produced additional work at KSC in excess of normal checkout flow. Phillips stressed the extraordinary importance of change control and the requirement that only mandatory changes be approved through the control boards at MSC and MSFC. The volume of changes currently under way at KSC constituted a major concern. Key program objectives, he said, were in jeopardy.

TWXs, Phillips to distr., Aug. 2 and 19, 1968.

August 7

The Apollo Design Certification Review (DCR) Board convened at MSC to examine LM-3 further for proof of design and development maturity and to assess and certify the design of the LM-3 as flightworthy and safe for manned flight. This Delta review was identified as a requirement at the March 6 LM-3 DCR. The Board concluded at the close of the Delta DCR that LM-3 was safe to fly manned with the completion of open work and action items identified during the review.

Ltr., Apollo Program Director to distr., "LM-3 Delta Design Certification Review," Sept. 12, 1968.

August 8

ASPO Manager George M. Low and several members of his staff met at KSC with Center Director Kurt H. Debus, Launch Operations Director Rocco A. Petrone, and KSC Apollo Program Manager R. O. Middleton to discuss test and checkout problems for AS-503 and AS-504. They collectively agreed that only mandatory changes - i.e., changes for flight safety or to ensure mission success - could be made once the spacecraft reached KSC. (Changes that would speed the KSC checkout flow also were permitted.) Furthermore, two separate work packages would be prepared for each spacecraft customer acceptance readiness review board. The first package comprised normal work to be performed at KSC on all spacecraft. The second included special work normally done at the factory, but which for that specific vehicle was being transferred to the Cape (installation, retesting, etc.). The group also reviewed recent Apollo checkout experiences - especially test failures and open items - in an effort to improve these areas for subsequent missions.

Memo for record, Low, "Report of meeting at KSC," Aug. 10, 1968.

August 9 - November 12

ASPO Manager George M. Low initiated a series of actions that led to the eventual decision that AS-503 (Apollo 8) should be a lunar orbital mission. Events and the situation during June and July had indicated

to Low that the only way for the "in this decade" goal to be attained was to launch the Saturn 503/CSM 103 LM-3 mission in 1968. During June and July the projected launch slipped from November to December, with no assurance of a December launch. Later, Low recalled "the possibility of a circumlunar or lunar orbit mission during 1968, using AS-503 and CSM 103 first occurred to me as a contingency mission."

During the period of July 20-August 5, pogo problems that had arisen on *Apollo 6* seemed headed toward resolution; work on the CSM slowed, but progress was satisfactory; delivery was scheduled at KSC during the second week in August and the spacecraft was exceptionally clean. The LM still required a lot of work and chances were slim for a 1968 launch.

On August 7, Low asked MSC's Director of Flight Operations Christopher C. Kraft, Jr., to look into the feasibility of a lunar orbit mission for Apollo 8 without carrying the LM. A mission with the LM looked as if it might slip until February or March 1969. The following day Low traveled to KSC for an AS-503 review, and from the work schedule it looked like a January 1969 launch.

August 9 was probably one of the busiest days in George Low's life; the activities of that and the following days enabled the United States to meet the "in this decade" goal. At 8 :45 a.m. he met with MSC Director Robert R. Gilruth and told him he had been considering a lunar orbit mission. Gilruth was highly enthusiastic. At 9:00 a.m. Low met with Kraft and was informed that the mission was technically feasible from ground control and spacecraft computer standpoint. (A decision had been made several months earlier to put a Colossus onboard computer program on the 103 spacecraft.)

At 9:30 a.m. Low met with Gilruth, Kraft, and Director of Flight Crew Operations Donald K. Slayton, and they unanimously decided to seek support from MSFC Director Wernher von Braun and Apollo Program Director Samuel C. Phillips. Gilruth called von Braun and, after briefly outlining the plan, asked if they could meet in Huntsville that afternoon. Low called Phillips, who was at KSC, and asked whether he and KSC Director Kurt Debus could participate and a meeting was set up for 2:30.

Present at the 2:30 p.m. meeting at MSFC were von Braun, Eberhard Rees, Lee James, and Ludie Richard, all of MSFC; Phillips and George Hage, both of OMSF; Debus and Rocco Petrone, MSFC; and Gilruth, Low, Kraft, and Slayton of MSC. Low outlined the hardware situation and told the group it was technically feasible to fly the lunar orbit mission in December 1968, with the qualification that Apollo 7 would have to be a very successful mission. If not successful, Apollo 8 would be another earth-orbital mission. Kraft made a strong point that to gain lunar landing benefits Apollo 8 would have to be a lunar orbital rather than a circumlunar mission. All were enthusiastic. Phillips began outlining necessary events: KSC said it would be ready to support such a launch by December 1; MSFC felt it would have no difficulties; MSC needed to look at the differences between spacecraft 103 and 106 (the first spacecraft scheduled to leave earth's atmosphere) and had to find a substitute for the LM. The meeting was concluded at 5:00 p.m. with an agreement to meet in Washington August 14. This would be decision day and, if "GO," Phillips planned to go to Vienna and discuss the plan with Associate Administrator for Manned Space Flight George E. Mueller and NASA Administrator James E. Webb

(who were attending a United Nations Conference). Preliminary planning would be secret, but if and when adopted by the agency the plan would be made public immediately.

Still on August 9, in another meeting at MSC at 8:30 p.m., Low met with Kenneth S. Kleinknecht, George Abbey, and C. H. Bolender of MSC, and Dale Myers, North American Rockwell. Bolender left immediately for Bethpage, N.Y., to find a substitute for the LM; and Myers left for Downey, Calif., to get the CM going.

On the following day there were still no obvious insurmountable problems that might block the plan. Kleinknecht was studying the differences between spacecraft 103 and 106, where the high-gain antenna might be a problem. It seemed possible to use LM-2 to support the flight, but Joseph Kotanchik, MSC, suggested flying a simple crossbeam instead of a LM in the event the pogo oscillation problem remained and pointed out that even if pogo was solved the LM would not be needed. Low called Richard and Hage, who agreed with Kotanchik but still wanted mass representation to avoid possible dynamic problems. Low then called William Bergen, of North American, who was not too receptive to the plan.

On August 12 Kraft informed Low that December 20 was the day if they wanted to launch in daylight. With everyone agreeing to a daylight launch, the launch was planned for December 1 with a "built-in hold" until the 20th, which would have the effect of giving assurance of meeting the schedule. LTA (LM test article)-B was considered as a substitute; it had been through a dynamic test vehicle program, and all except Kotanchik agreed this would be a good substitute. Grumman suggested LTA-4 but Low decided on LTA-B.

Kleinknecht had concluded his CSM 103-106 configuration study by August 13 and determined the high-gain antenna was the most critical item. Kraft was still "GO" and said December 20-26 (except December 25) offered best launch times; he had also looked at January launch possibilities. Slayton had decided to assign the 104 crew to the mission. He had talked to crew commander Frank Borman and Borman was interested.

Participants in the August 14 meeting in Washington were Low, Gilruth, Kraft, and Slayton from MSC; von Braun, James, and Richard from MSFC; Debus and Petrone from KSC; and Deputy Administrator Thomas Paine, William Schneider, Julian Bowman, Phillips, and Hage from NASA Hq. Low reviewed the spacecraft aspects; Kraft, flight operations; and Slayton, flight crew support. MSFC had agreed on the LTA-B as the substitute and were still ready to go; and KSC said they would be ready by December 6.

While the meeting was in progress, Mueller called from Vienna to talk to Phillips. He was cool to the proposed idea, especially since it preceded Apollo 7, and urged Phillips not to come to Vienna, adding that he could not meet with the group before August 22. The group agreed they could not wait until August 22 for a decision and agreed to keep going, urging again that Phillips go to Vienna and present their case.

At this point Paine reminded them that not too long before they were making a decision whether to man 503, and now they were proposing a bold mission. He then asked for comments by those around the table and received the following responses:

von Braun - Once you decided to man 503 it did not matter how far you went.

Hage - There were a number of places in the mission where the decision could be made, minimizing the risk.

Slayton - Only chance to get to the moon before the end of 1969.

Debus - I have no technical reservations.

Petrone - I have no reservations.

Bowman - A shot in the arm for manned space flight.

James - Manned safety in this and following flights enhanced.

Richard - Our lunar capability will be enhanced by flying this mission.

Schneider - My wholehearted endorsement.

Gilruth - Although this may not be the only way to meet our goal, it enhances our possibility. There is always risk, but this is in path of less risk. In fact, the minimum risk of all Apollo plans.

Kraft - Flight operations has a difficult job here. We need all kind of priorities; it will not be easy to do, but I have confidence. It should be lunar orbit and not circumlunar.

Low - Assuming Apollo 7 is a success there is no other choice.

After receiving this response, Paine congratulated them on not being prisoners of previous plans and said he personally felt it was the right thing to do. Phillips then said the plan did not represent shortcuts and planned to meet with Mueller on August 22. He reiterated Mueller's reservations, and then agreed to move out on a limited basis, since time was critical.

On August 15 Phillips and Paine discussed the plan with Webb. Webb wanted to think about it, and requested further information by diplomatic carrier. That same day Phillips called Low and informed him that Mueller had agreed to the plan with the provisions that no full announcement would be made until after the Apollo 7 flight; that it could be announced that 503 would be manned and possible missions were being studied; and that an internal document could be prepared for a planned lunar orbit

for December.

Phillips and Hage visited MSC August 17, bringing the news that Webb had given clear-cut authority to prepare for a December 6 launch, but that they could not proceed with clearance for lunar orbit until after the Apollo 7 flight, which would be an earth-orbital mission with basic objectives of proving the CSM and Saturn V systems. Phillips said that Webb had been "shocked and fairly negative" when he talked to him about the plan on August 15. Subsequently, Paine and Phillips sent Webb a lengthy discourse on why the mission should be changed, and it was felt he would change his mind with a successful Apollo 7 mission.

Apollo 7 - flown October 11-22 - far exceeded Low's expectations in results and left no doubts that they should go for lunar orbit on Apollo 8. At the November 10 Apollo Executive meeting Phillips presented a summary of the activities; James gave the launch vehicle status; Low reported on the spacecraft status and said he was impressed with the way KSC had handled its tight checkout schedule; Slayton reported on the flight plan; and Petrone on checkout readiness. Petrone said KSC could launch as early as December 10 or 12. Phillips said he would recommend to the Management Council the next day for Apollo 8 to go lunar orbit. Following are the reactions of the Committee members:

Walter Burke, McDonnell Douglas - the S-IVB was ready but McDonnell Douglas favored circumlunar rather than lunar orbit;

Hilliard Paige, GE - favored lunar orbit;

Paul Blasingame, AC - guidance and navigation hardware was ready, lunar orbit;

C. Stark Draper, Massachusetts Institute of Technology - we should go ahead;

Bob Evans, IBM - go;

George Bunker of Martin, T. A. Wilson of Boeing, Lee Atwood of North American, Bob Hunter of Philco-Ford, and Tom Morrow of Chrysler - lunar orbit.

At the Manned Space Flight Management Council Meeting on November 11 Mueller reported that the proposal had been discussed with the Apollo Executive Committee, Department of Defense, the Scientific and Technical Advisory Committee (STAC), and the President's Science Advisory Committee (PSAC). STAC had made a penetrating review and reacted positively and PSAC was favorably disposed toward the plan but made no firm recommendation.

After a series of meetings, on November 11 Paine said Apollo 8 was to go lunar orbit. The decision was announced publicly the following day. Low's initiative had paid off; the final decision to go to the moon in 1968 was made with the blessings of all of NASA's decision-makers, the Apollo Executive Committee, STAC, and PSAC.

ASPO Manager George M. Low, "Special Notes for August 9, 1968, and Subsequent."

August 10

Capping off a considerable exchange of views between MSC and NASA Headquarters, ASPO Manager George Low advised Apollo Program Director Sam Phillips that Houston was going ahead with mission planning that employed a two-burn orbit insertion maneuver. He forwarded to Phillips a lengthy memorandum from one of his staff, Howard W. Tindall, Jr., that explained in detail MSC's rationale for this two-stage orbital maneuver, the most important of which derived from crew safety and simplified orbital mission procedures. The overriding factor, Tindall explained, was a "concern for the consequences of the many things we will not have thought about but will encounter on the first lunar flight. Anything that can be done to keep the dispersions small and the procedures simple provides that much more tolerance for the unexpected. . . . The cost of the two-stage LOI is a small price to pay for these intangible but important benefits."

Ltr., George M. Low to Samuel C. Phillips, Aug. 10, 1968, with encl., memo, Tindall to ASPO Manager, "Recommendation to retain the Two-Stage Lunar Orbit Insertion (LOI) Maneuver," Aug. 5, 1968.

August 12

Dieter Grau, Director of Quality and Reliability Assurance at MSFC, sent his Houston counterpart Martin Raines a memorandum of understanding covering exchanges of quality surveillance responsibility in support of pogo structural testing under way both in Huntsville, Ala., and at MSC. Testing was being conducted simultaneously at the Wyle Laboratories in Huntsville (under contract to North American Rockwell, primarily static loading and referred to as shell stability tests); and dynamic load testing at MSC (called the "short stack" dynamic tests). In effect, each Center assumed the task of overseeing the complete test article (spacecraft, instrument unit, and S-IVB forward skirt) being tested at its own location.

Ltr., Grau to Raines, Aug. 12, 1968, with encl., memorandum of agreement, "Quality Coverage of POGO Structural Testing," Aug. 12, 1968.

August 13

George M. Low, MSC, in a letter to Samuel C. Phillips, OMSF, said that the Design Certification Review (DCR) for spacecraft 101 had been completed; that assigned action items had been resolved; and most of the open items had been closed. Several open issues would be closed at the 101 Flight Readiness Review. Low said: "The MSC subsystem managers have reviewed all the documentation supporting the DCR. I have reviewed the statements of certification by the North American and MSC subsystem managers. I have personally watched the design of Spacecraft 101 develop to a stage of maturity. As a

result, I am taking this opportunity to certify that Spacecraft 101 is ready to perform the Apollo 7 mission once the open items are closed."

Ltr., Low to Phillips, "Design Certification of Apollo 7," Aug. 13, 1968.

August 16

NASA Associate Administrator for Manned Space Flight George E. Mueller reported to his superiors that launch preparations for the Apollo 7 mission were running ahead of schedule. Spacecraft 101 had been erected and mated with the launch vehicle on August 9. Integrated systems testing had begun on August 15. Preparation for the next mission, Apollo 8, were not proceeding as well. Checkout of the launch vehicle and CSM 103 were on schedule, but work on LM-3 was some seven days behind schedule. Though LM-3's problems were under intensive investigation, they were directly holding up the simulated mission run and transfer to the altitude test chamber.

Memo, Mueller to Administrator, "Manned Space Flight Weekly Report - August 16, 1968."

August 17

ASPO Manager George M. Low wrote Program Director Samuel C. Phillips seeking to halt further development of a pogo sensor for the CSM. (MSC had undertaken development of the device shortly after the *Apollo 6* flight as "insurance" should the sensor prove necessary.) No requirement for a pogo sensor had been identified, said Low. In fact, it was by no means certain how the sensor could be used in flight. Because MSFC was highly confident that the pogo problem encountered on *Apollo 6* had been solved, and because no abort criteria could be based on pogo alone, Low argued against the sensor. Even in the unlikely event that pogo occurred on the next Saturn V flight, he argued against an abort unless there was a catastrophic effect on the launch vehicle, in which case abort would be effected using normal abort criteria. For these reasons, no pogo sensor was to be installed on the CSM. A week later, Phillips approved Low's recommendation to halt the pogo sensor development.

Ltrs., Low to Phillips, Aug. 17, 1968; Phillips to Low, Aug. 24, 1968.

August 19

In a Mission Preparation Directive sent to the three manned space flight Centers, NASA Apollo Program Director Samuel C. Phillips stated that the following changes would be effected in planning and preparation for Apollo flights:

Apollo-Saturn 503

- Assignment of Saturn V 503, CSM 103, and LM-3 to Mission D was canceled.
- Saturn V 503 would be prepared to carry CSM 103 and LTA (LM test article)-B on a

manned CSM-only mission to be designated the C prime mission.

- The objectives and profile of the C prime mission would be developed to provide maximum gain consistent with standing flight safety requirements. Studies would be carried out and plans prepared so as to provide reasonable flexibility in establishing final mission objectives.
- All planning and preparations for the C prime mission would proceed toward launch readiness on December 6, 1968.

Apollo-Saturn 504

Saturn V 504, CSM 104, and LM-3 were assigned to the D mission, scheduled for launch readiness no earlier than February 20, 1969. The crew assigned to the D mission would remain assigned to that mission. The crew assigned to the E mission (Frank Borman, James A. Lovell, Jr., and William Anders) would be reassigned to the C prime mission. Training and equipping the C prime crews and operational preparations would proceed as required to meet mission requirements and to meet the newly established flight readiness date.

A memorandum from the ASPO Manager on September 3 summarized the basic and alternate missions for which detailed planning and preparation would be performed. In the basic earth-orbital C prime mission the vehicle configuration would consist of the Saturn V 503 with a payload of 39,780 kilograms (CSM 103 and LTA-B with the service propulsion subsystem fully loaded). Insertion would be into low circular orbit of the earth. The earth-parking-orbit activities would include crew and ground support exercises related to spacecraft system checkout and preparation for translunar injection (TLI; i.e., transfer into a trajectory toward the moon). CSM separation maneuver would occur before TLI.

Alternate earth-orbital missions would include a manned TLI burn to a 6440-km apogee or an SPS burn to achieve a 6,440-km apogee. An alternate lunar orbit mission would include mission planning, crew training, spacecraft hardware, and software to support the mission. In providing support, top priority would be assigned to the lunar orbit mission. The memo indicated that following TLI, simulated transposition and docking maneuvers would be conducted; midcourse corrections and star horizon/ star landmark sightings would be performed during the translunar coast; lunar orbit insertion would be accomplished and a lunar parking orbit established for 20 hours.

On September 13, MSC Director of Flight Operations Christopher C. Kraft affirmed that the impact of supporting the described mission plan had been assessed and no constraints were seen to prevent meeting the launch readiness date. He added that the lunar parking orbit would be established during the course of two elliptic orbits and would be of 16 hours duration, thus giving a total lunar vicinity time of 20 hours.

Ltr., Phillips to Directors, KSC, MSFC, and MSC, "Apollo Mission Preparation Directive," Aug. 19, 1968; memos, Manager, ASPO, to distr., "C Prime Mission," Sept. 3, 1968; MSC Director of Flight Operations to Manager, ASPO, "C Prime Mission," Sept. 13, 1968.

August 26

ASPO Manager George M. Low asked Joseph N. Kotanchik, head of the Structures and Mechanics Division, to verify that all spacecraft load analyses and safety factors were compatible with the recently agreed-on payload weight of 39,780 kilograms for the AS-503 mission. Low passed along the concern voiced by Lee B. James, Saturn V Program Manager at MSFC, that the problem of an S-IC engine failure in the Saturn launch vehicle might be more severe for the 503 mission than for a heavier payload. Had adequate stress analysis been done on the high-gain antenna attachments and its support inside the adapter? When would pogo dynamic analysis of the actual 503 payload be completed? And finally, what was the situation regarding loads on LTA-B, the LM test article to be substituted in place of an actual lunar lander aboard the flight?

Memo, Low to Kotanchik, "AS-503 Loads," Aug. 26, 1968.

August 27

George M. Low, ASPO Manager, set forth the rationale for using LTA-B (as opposed to some other LM test article or even a full-blown LM) as payload ballast on the AS-503 mission. That decision had been a joint one by Headquarters, MSFC, and MSC. Perhaps the chief reason for the decision was Marshall's position that the Saturn V's control system was extremely sensitive to payload weight. Numerous tests had been made for payloads of around 38,555 kilograms but none for those in the 29,435- to 31,750-kilogram range. MSFC had therefore asked that the minimum payload for AS-503 be set at 38,555 kilograms. Because LTA-B brought the total payload weight to 39,780 kilograms, that vehicle had been selected for the Apollo 8 mission. All dynamic analyses in connection with the pogo problem had to be verified, but MSFC engineers were not concerned that the established weight would affect pogo performance. Because NASA had been prepared to fly AS-503 with a heavier payload - i.e., originally including LM-3 - Low saw "no reason to be concerned about the decision made to fly the somewhat lighter and more symmetrical LTA-B."

Memo, Low to Joseph N. Kotanchik, MSC, "Use of LTA-B for AS-503," Aug. 27, 1968.

August 28

NASA asked Grumman to make a detailed study of LM-4 to determine any constraints that might prevent accomplishment of a lunar orbit mission. All such constraints were to be defined in sufficient detail to facilitate a NASA review, and NASA expected Grumman-recommended action in each case. The information was requested before the LM-4 Customer Acceptance Readiness Review. Grumman was further asked to study LM-5 to determine constraints that might prevent accomplishment of the lunar landing mission. Again, all constraints were to include recommended action.

Ltr., Frank X. Battersby, RASPO, to Joseph Gavin, LM Program Director, Grumman, Aug. 28, 1968.

August 30

Eberhard Rees, Director of the Apollo Special Task Team at North American Rockwell, notified the contractor that facilities the team had used at Downey, Calif., were relinquished to the company. Thus ended the mission of the group formed some nine months earlier to oversee the contractor's preparations during the period of adjustment following the Apollo 1 accident.

Ltr., Rees to C. F. Wetter, Aug. 30, 1968.

September 3

Apollo Program Director Samuel C. Phillips notified the three manned space flight Centers that the Apollo 8 launch readiness working-schedule date had been changed to December 13, 1968.

TWX, Phillips to MSC, KSC, MSFC, "Apollo 8 (AS-503) Launch Readiness Working Schedule," Sept. 3, 1968.

September 6

In response to a letter from Apollo Program Director Samuel C. Phillips concerning proposed revisions of the first lunar landing mission plan, MSC Director Robert R. Gilruth presented MSC's position on the three major topics:

1. deletion of the lunar geology investigation (LGI) and the Apollo Lunar Surface Experiments Package (ALSEP),
2. television coverage, and
3. extravehicular excursion.

Concerning the first item, Gilruth said, "Our lunar surface exploration and scientific activities should be progressive as we extend our knowledge and obtain a better understanding of operational limitations and capabilities in a 1/6g environment. . . . By embarking on too ambitious an effort on our first mission, we may well jeopardize our capability to accomplish manned . . . activities on subsequent flights. . . ." It was "recommended that the LGI (with the exception of the contingency sample and preliminary sample portion) and the ALSEP be deleted from the first lunar landing mission."

With reference to television coverage, Gilruth cited Houston's position that "it would be extremely desirable to provide adequate television coverage during the extravehicular excursion. Coverage can be obtained through the LM steerable antenna and the Goldstone 210-foot [64-meter] antenna while in view of Goldstone." MSC proposed to provide "the capability to transmit the television signal directly through the high gain antenna; but we would also like to maintain the capability to carry the erectable antenna, in the event that it will not be feasible to adjust the timeline to provide Goldstone coverage for all planned extravehicular activities. . . ."

On the subject of extravehicular excursion, he said, ". . . we strongly believe that, on the first lunar landing mission, only a single extravehicular activity should be carried out. You have stated that the simplest and safest excursion should be conducted by one man alone. However, it is clear that we have to maintain the basic capability for a two-man excursion so that the second man can assist the first in the event of trouble or difficulties. Also, further studies and simulations in this area might identify new reasons why a planned two-man excursion is more desirable than a one-man excursion. . . ."

Gilruth said that MSC officials Charles A. Berry, Maxime A. Faget, Christopher C. Kraft, Jr., George M. Low, and Donald K. Slayton were in full accord with all of these recommendations. He added, however, that Wilmot N. Hess felt that "these changes represent a serious compromise to the scientific program." Hess felt that the EVA period should be open ended and that it would be worthwhile to carry ALSEP and attempt its deployment. Hess also recommended that if a decision were made not to carry ALSEP, some easily deployed contingency experiments might be added, such as: Solar Wind Composition experiment, High-Z Cosmic Ray experiment, and a simplified Corner Reflector for Laser Ranging experiment.

Gilruth said that he himself believed, "that it is essential that EVA on the first lunar landing mission be limited to a single excursion and that ALSEP and LGI be eliminated as experiments from that flight. . . . I believe that the maximum scientific gains on this and future missions will be achieved if we limit our objectives as proposed. . . . I am sure that all will agree that if we successfully land on the moon and return to earth, bring back samples of lunar soil, transmit television directly from the moon, and return with detailed photographic coverage, our achievement will have been tremendous by both scientific and technological standards."

Ltr., Gilruth to Phillips, "Proposed revisions to the first lunar landing mission plan," Sept. 6, 1968.

September 10

ASPO Manager George M. Low advised Headquarters of the status of MSC's work on action items assigned as a result of the Apollo Crew Safety Review Board presentation on June 17. Among those items were:

1. Switching procedures for the emergency detection system - the crew would manually disable the automatic abort device at 1 minute 40 seconds after liftoff.
2. High-altitude abort procedures - these procedures were being reevaluated by the CSM 101 crew on the spacecraft simulator; following completion (scheduled for September 23), a decision would be made whether to retain the procedure for optional tower jettison.
3. Rescue of an incapacitated crew - emergency access procedures were being demonstrated at Downey using CSM 008. Any procedural revisions required would be made accordingly.

Completion of these actions, said Low, fulfilled the recommendations of the Crew Safety Review Board.

Ltr., Low to Samuel C. Phillips, "Actions from Apollo Crew Safety Review Board and Presentation," Sept. 10, 1968.

September 10-11

The Apollo Crew Safety Review Board, headed by William C. Schneider, met for the third time at MSFC, a meeting devoted primarily to safety factors for the Saturn V launch vehicle. Of particular concern was the capability to shut down the vehicle during the period between ignition and liftoff should some problem arise (it could be shut down by several methods, including both manual and automatic engine shutdown). The Board also reviewed in detail Saturn V modifications that had eliminated more than 50 engine and electrical circuitry potential single-point failures (primarily through increased redundancy and circuitry checkout). Similarly the Board examined the reliability of guidance failure indicators and checkout of the emergency detection system during the final portion of the countdown. No additional action was needed, members concluded, because all functions in the launch vehicle were checked during the terminal count and tank pressure gauges were checked out by disconnecting the transducers and testing them individually several days before launch.

At the end of the meeting, Board members attended the POGO Management Review, where they were favorably impressed by the optimism among Saturn V program officials that the pogo problem had been solved (although contingency planning for a pogo occurrence should continue through AS-503).

Ltr., Schneider to distr., "Minutes of Third Meeting on September 10-11, 1968, at Marshall Space Flight Center," Sept. 16, 1968.

September 11

At a meeting of the MSF Management Council, Apollo Program Director Samuel C. Phillips put forth a number of recommendations regarding planning for extravehicular and scientific activities during the first lunar landing missions:

- During the first mission, extravehicular activities (EVA) should be limited to three hours, with the spacecraft manned by one of the two crewmen at all times.
- The Apollo Lunar Surface Experiments Package should be deleted from the earliest missions (although the present preliminary sample must be improved scientifically).
- Television must be carried aboard the LM, for benefits both for operational and public information.
- To realize the maximum scientific return on the second and subsequent flights, MSC must, during the first landing mission, assess the astronauts' capabilities to conduct lunar surface activities. Also, MSC should study and recommend changes in LM hardware that would lengthen EVA time available for scientific investigations during future Apollo missions.

The Management Council approved Phillips' recommendations and carried them to Administrator James E. Webb for final approval. In Houston, ASPO Manager George M. Low ordered his organization to begin planning for the first landing mission in accordance with these recommendations.

Memo, Low to O. E. Maynard, "G Mission Planning," Sept. 13, 1968.

September 12

Dale D. Myers, North American Rockwell's Apollo CSM Program Manager, wrote George M. Low: "With the recent shipment of CSM 101 to KSC and preparations for the first manned Apollo flight, attention is centered on the various aspects of crew safety. In this regard, I recently instructed our system safety people to review the action items that resulted from the S/C 012 fire [January 27, 1967], identify those with safety content or implications, determine what corrective action had been accomplished, and assess the adequacy of the closeout actions." Myers went on to say that out of a total of 137 North American action items, 70 were related to safety; and combining similar and identical items resulted in identification of 41 specific safety-oriented action items. An exhaustive study by safety personnel had indicated that all items had been closed out and that corrective actions were adequate.

Ltr., Myers to Low, ASPO, MSC, Sept. 12, 1968.

September 16

Apollo Program Director Samuel C. Phillips formally notified ASPO Manager George M. Low at MSC and Saturn V Program Manager Lee B. James at MSFC of changes in the Apollo Program Specification. As agreed on during the MSF Management Council meeting on August 6, the Apollo payload interface was set at 46,040 kilograms (with a flight geometry reserve of 137 kilometers per hour). Also, the present spacecraft loading philosophy allowed a total spacecraft weight of 46,266 kilograms for lunar missions having less than maximum flight geometry requirements. Phillips repeated his earlier statement that he was prepared to relax some flight constraints to achieve the best possible balance on each space vehicle. (Although with recent changes in Saturn V loading, residuals, and J-2 engine thrust, apparently few if any of these constraints would have to be relaxed.)

Ltr., Phillips to James and Low, "Apollo Program Specification Changes," Sept. 16, 1968.

September 17

Ernest B. Nathan, MSFC Cochairman of the Saturn-Apollo Flight Evaluation Panel, sent to MSC Marshall's requirements for the flight crew debriefing for the AS-205 mission. Generally, these requirements called for the crew's visual and sensory evaluation of the launch vehicle's performance and behavior.

Ltr., Nathan to Helmut A. Kuehnel, MSC, Sept. 17, 1968, with encl., "MSFC Flight Crew Debriefing

Requirements, AS-205/SC-101 Mission."

September 18

Dale D. Myers, Apollo CSM Program Manager at North American Rockwell, wrote to CSM Manager Kenneth S. Kleinknecht at MSC to apprise him of the company's response to an earlier review of the CSM subsystems development program. During February a small task team from MSFC, headed by William A. Mrazek, had surveyed the design, manufacture, and checkout of several of the spacecraft's subsystems. Findings of the team had been reviewed with Eberhard F. M. Rees, then at Downey as head of the Apollo Special Task Team. Myers sent Kleinknecht briefing notes of a presentation to Rees and others of the special team describing North American's responses to specific issues raised by Mrazek's group. These issues, Myers reported, had been resolved to the satisfaction of both contractor and customer.

Ltr., Myers to Kleinknecht, Sept. 18, 1968.

September 18

ASPO officials headed by Manager George M. Low met with spacecraft managers from North American Rockwell and Grumman to discuss configuration management for the remainder of the Apollo program and to set forth clear ground rules regarding kinds of changes (described as Class I and Class II) and the requisite level of authority for such changes. The outcome of this meeting, as Low told Apollo Program Director Samuel C. Phillips, was that MSC would pass judgment on all Class I changes and that "nearly every change [would] fall in this category." Minor design changes might still be approved at the contractor or subcontractor levels, said Low, but MSC would judge whether those changes were indeed Class II changes. The overall result of this policy, he told Phillips, would be a better awareness by NASA of all changes made by spacecraft subcontractors and a firm understanding that only NASA could approve Class I design modifications.

Ltr., Low to Phillips, Sept. 19, 1968.

September 23

The Apollo Guidance Software Task Force, which NASA Associate Administrator for Manned Space Flight George E. Mueller had convened in December 1967, submitted its final report. Purpose of the task force, as Mueller had stated at the time, was to determine whether "additional actions . . . could be taken to improve the software development and verification process and control of it." Between December and July 1968, the group met 14 times at NASA and contractor locations to review the historical evolution of software programs within the Apollo project. Because of the great complexity of this entire field, the task force members recommended that it continue to receive attention by top management levels at both MSC and MSFC. And drawing upon experience learned in the Apollo program, the task force recommended that software not be slighted during any advanced manned programs and that adequate

resources and experienced personnel be assigned early in the program to this vital and easily underestimated area.

Ltr., Mueller to Harold T. Luskin, Apollo Applications Program Director, NASA, Sept. 23, 1968, with encl., "Final Report: Apollo Guidance Software Task Force," Sept. 23, 1968.

September 24

Samuel C. Phillips announced membership of the OMSF Apollo Site Selection Board, which was to meet September 26: Phillips, chairman; Lee R. Scherer, OMSF, secretary; John D. Stevenson and Harold D. Luskin, both of OMSF; Oran W. Nicks, NASA Hq., John D. Hodge, Owen E. Maynard, and Wilmot N. Hess, all of MSC; Ernst Stuhlinger, MSFC; and Roderick O. Middleton, KSC. J. H. Turnock and Charles W. Mathews had been deleted from the previous membership list and Hodge, Luskin, and Scherer added.

Memo, Apollo Program Director to distr., "Membership of the OMSF Apollo Site Selection Board," Sept. 24, 1968.

September 24

Apollo Program Director Samuel C. Phillips wrote to his two principal counterparts at MSFC and MSC, Lee B. James and George M. Low, to express his concern that the launch-release wind constraint for the Saturn IB, currently 45 kilometers, was perhaps the most restrictive of all such constraints. Phillips emphasized his need for a complete understanding of all tradeoffs associated with this figure, to allow a real-time estimate of the requirement to hold. He asked James and Low to summarize for him several such tradeoffs before the Apollo 7 flight readiness review: wind versus safety, velocity versus direction, and conservative assumption versus technical accuracy. Also, he asked for criticality and failure mode for each of the above tradeoffs to allow a technical evaluation of increasing the 45-kilometer constraint. At the same time, he asked that a similar effort be initiated for the Saturn V.

TWX, Phillips to Low and James, "Apollo Saturn Release Wind Constraints," Sept. 24, 1968.

September 25

NASA Resident ASPO Manager Wilbur H. Gray at Downey told Dale D. Myers, North American Rockwell CSM Manager, that NR quality coverage of spacecraft testing no longer provided NASA with confidence in test results and that NASA Quality Control would return to monitoring test activities in and from the ACE (acceptance checkout equipment) control room. Gray charged that North American had progressively backed away from contractually agreed steps of the November 30, 1967, Quality Program Plan, and that these actions had affected test readiness, testing, and trouble shooting to the point that test acceptance could not be accepted with any reasonable assurance. Gray said that - unless North American responded by immediate reinstatement of the procedures which, as a minimum, were those

that worked satisfactorily on CSMs 103 and 104 - NASA formal acceptance of operational checkout procedures would be discontinued and contractual action initiated. An annotation to George Low from Kenneth S. Kleinknecht, MSC's CSM Manager, indicated the letter had been written with the concurrence and at the suggestion of Kleinknecht.

Myers replied: "I regret that NASA feels any lack of confidence in current test results. . . . For the past year, there has been a constant improvement program carried out in Test Quality Assurance to (1) perform quality evaluation and acceptance of test results in real time and (2) upgrade the test discipline to be consistent with good quality practice. I believe that this improvement program has been effective and is evidenced by the current efficiency of test and expedient manner in which test paper work is being closed out. While there is naturally some cost benefit experienced from the successful improvements, cost never has been placed as a criteria above quality. . . .

"Again, I want to emphasize that the CSM Program has not nor will not intentionally place cost ahead of quality. . . . The procedures which worked satisfactorily on CSM 103 and 104 are being improved to provide better test discipline and more effective Quality Assurance coverage. Test progress on CSM 106 to date indicates a greater test effectiveness and a greater confidence in test results than any previous CSM's."

Ltr., Gray to Myers, Sept. 25, 1968; annotation, Kleinknecht to Low, Sept. 26, 1968; ltr., Myers to Gray, Oct. 17, 1968.

September 25

The LM ascent engine to be flown in LM-3 and subsequent missions would incorporate the Rocketdyne injector, Apollo Program Director Phillips informed ASPO Manager Low. The engine would be assembled and delivered by Rocketdyne under subcontract to Grumman. MSC was authorized to inform those concerned of these decisions but would not issue contractual direction until an agreed course of contractual action had been approved by NASA Hq. Two days later, on September 27, Phillips advised Low that MSC was authorized to take all proper contract actions to implement the decision to contract with Grumman for ascent-stage engines assembled by Rocketdyne with the latter's injector.

TWXs, NASA Headquarters to MSC, Attn: George Low, "LM Ascent Engine Program Decision," Sept. 25, 1968; and "LM Ascent Engine Program," Sept. 27, 1968.

September 26

MSC Director Robert R. Gilruth sent Eberhard F. M. Rees, MSFC Deputy Director, his "personal commendation" and appreciation for Rees's leadership of the Apollo Special Task Team and its efforts to bring the CSM program out of the difficult period early in 1967. The work of Rees and his group, said Gilruth, had made an outstanding contribution to the Apollo program and had given NASA management "a significantly higher level of technical confidence" that the Block II spacecraft could safely perform its

mission. In addition, Gilruth noted, Rees's "diplomacy in interfacing with North American management also created a much better NASA-contractor relationship and mutual understanding of program technical requirements."

Ltr., Gilruth to Rees, Sept. 26, 1968.

Week Ending September 27

The Allison descent-stage propellant tank, being redesigned at Airite Division of Sargent Industries to a "lidless" configuration, blew up during qualification test at Airite. The crew noticed loss of pressure and therefore tightened fittings and repressurized. As the pressure went up, the tank blew into several pieces. Grumman dispatched a team to Airite to determine the cause and the necessary corrective action.

Memo, Frank X. Battersby, RASPO, Bethpage, to Chief, Apollo Procurement Br., Procurement and Contracts Div., MSC, "Weekly Activities Report, BMR, Bethpage, Week Ending September 27," Oct. 3, 1968.

September 28

Results of a joint MSFC-MSC review of functional interfaces between the launch vehicle and spacecraft for Apollo 7 were forwarded to NASA Hq. (The review had originally been requested by the Apollo 7 Crew Safety Review Board, headed by John D. Hodge.) The two Centers had tackled the task by identifying all electrical wiring between payload and booster, the requirement for each wire, a verification that the circuits indeed satisfied requirements, and an evaluation of the adequacy of test and checkout procedures. Several months of investigation, reported Teir and Low, had uncovered no areas of concern. Definition and function of the CSM instrument unit were both accurate and valid and ensured flight readiness.

Ltr., Saturn IB Manager William Teir, MSFC, and ASPO Manager George M. Low, MSC, to Samuel C. Phillips, NASA Hq., "Apollo 7 Launch Vehicle to Spacecraft Functional Interface Review," Sept. 28, 1968, with encl., "AS-205 Launch Vehicle/Spacecraft (LV/SC) Electrical Interface Review."

September 30

NASA Associate Administrator for Manned Space Flight George E. Mueller summarized for his superiors launch preparation for the near-term missions Apollo 7 and Apollo 8:

- Apollo 7 - Space vehicle testing was on schedule (despite a delay in start of the flight readiness test caused by a liquid hydrogen leak due to a faulty pneumatic valve). The flight readiness test began on September 25 and went smoothly through T minus 0 two days later. Countdown for launch would begin as scheduled on October 6, leading to launch readiness on October 11.
- Apollo 8 - Both launch vehicle (503) and spacecraft (103) were several days behind schedule.

CSM 103 was tested in the altitude chamber while manned by the prime and backup crews on September 20 and 22. The spacecraft was undergoing several modifications and equipment installations (including the high-gain antenna, which was delivered to KSC on September 23); KSC and contractor technicians also were making leak and functional checks on the S-II stage and subsystem checks on the S-IVB stage of the launch vehicle. Rollout of the space vehicle from the assembly building to the pad was planned for October 10.

Memo, Mueller to Administrator and Deputy Administrator, "Manned Space Flight Weekly Report - September 30, 1968," Sept. 30, 1968.

September 30

Apollo Program Director Samuel C. Phillips asked ASPO Manager George M. Low to investigate the feasibility of using data from the D and G missions to increase NASA's knowledge of and confidence in the operational capabilities of the extravehicular mobility unit (EMU). Phillips included in his request specific recommendations for additional instrumentation to obtain the necessary data. His action stemmed from a general concern about the extent and complexity of surface operations on the first lunar landing flight (which might substantially reduce chances for successful completion). For this reason, he and other program officials had stringently limited the number of objectives and the extent of those surface activities. But to plan confidently for surface EVA during follow-on Apollo landing missions, Phillips said, as much information as possible had to be gathered about the operational capability of the crew and the EMU.

Ltr., Phillips to Low, "Data for an EVA Capability Assessment," Sept. 30, 1968.

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Part 2 (O)

Recovery, Spacecraft Redefinition, and First Manned Apollo Flight

October 1 through October 21, 1968

1968

October 1-2

The Apollo Crew Safety Review Board held its fourth meeting at MSC. Discussions centered chiefly on Saturn V engine-out abort situations and the ability of the CSM to withstand structural loads imposed by such vehicle failures. In fact, however, it was unlikely that any problem would be experienced, because of a controlled S-IC engine shutdown. Loads because of catastrophic engine failure greatly exceeded spacecraft capability, but the Board ruled such an occurrence as remote and accepted it as a flight risk. Also, evaluation of testing results demonstrated that overall loads because of pogo vibration were not a problem. Board Chairman William C. Schneider reported that, in general, action items assigned to MSC as a result of the Apollo 7 review had been satisfactorily closed.

Ltr., Schneider to distr., "Minutes of Fourth Meeting on October 1-2, 1968, at the Manned Spacecraft Center," Oct. 11, 1968.

October 2

George E. Mueller, NASA Associate Administrator for Manned Space Flight, wrote MSC Director Robert R. Gilruth to reemphasize the operational philosophy for the Apollo 7 mission. That flight, Mueller said, was the first in the manned program - including Mercury and Gemini programs - to employ fully the "open ended" mission concept. Rather than the Gemini process, in which a series of missions verified the spacecraft design for 3, 6, and ultimately 14 days, with Apollo 7 the first flight was to verify the CSM, evaluating the vehicle via telemetry through each successive mission step. Also, to ensure maximum return from the mission, primary and secondary objectives would be completed as early in the flight as possible (approximately two-thirds of those objectives to be completed by the end of the first day and more than 90 percent by end of the second day). Mueller emphasized the importance of the agency's emphasizing this open-ended mission concept during public announcements of Apollo 7's flight plan and objectives.

Ltr., Mueller to Gilruth, Oct. 2, 1968.

October 3

Senior management from NASA Hq. and the three manned Centers conducted the Apollo 7 flight readiness review at KSC. Crew, space vehicle, and all supporting elements were ready for flight. Countdown-to-launch sequence had started on October 6, and flight preparations were on schedule for launch readiness at 11:00 a.m. EDT on October 11.

OMSF, NASA Hq., to NASA Administrator and Deputy Administrator, "Manned Space Flight Weekly Report - October 7, 1968," Oct. 7, 1968.

October 4

MSC spacecraft and mission planning experts met to discuss mission techniques for the D mission, specifically the rendezvous exercise. Because of the slow progress in reviewing a draft of the D Rendezvous Mission Techniques document, Apollo Data Priority Coordinator Howard W. Tindall reported that the Center's effort in this area needed to be strengthened. Participants did identify exactly what spacecraft equipment had to be working at the start of each segment of the rendezvous exercise. A general principle was that the CSM must at all times be prepared to rescue the LM. Participants therefore insisted on having a redundant capability in the CSM for all crucial operations. This rescue capability by the CSM provided an adequate backup for each possible LM system failure except braking. This general philosophy, stated Tindall, "seemed to provide the best tradeoff between crew safety and assurance of meeting mission objectives." Memo, Tindall to distr., "D Rendezvous Mission Techniques," Oct. 10, 1968.

October 7

In preparation for the flight of Apollo 8, NASA and industry technicians at KSC placed CSM 103 atop the Saturn V launch vehicle. The launch escape system was installed the following day; and on October 9 the complete AS-503 space vehicle was rolled out of the Vehicle Assembly Building and moved to the launch pad, where launch preparations were resumed.

Memo, George E. Mueller, NASA Associate Administrator for Manned Flight, to Acting NASA Administrator, "Manned Space Flight Weekly Report - October 14, 1968," Oct. 14, 1968.

October 7

Ralph H. Tripp, LM Program Manager at Grumman, forwarded his company's plan for control of configuration changes on the LM. The need for such a formal statement had been discussed at a meeting in Bethpage on September 25 between ASPO Manager George M. Low; his deputy for the LM, C. H.

Bolender; other Apollo engineers from Houston; and Tripp, LM Program Director Joseph G. Gavin, Jr., and others from Grumman. Grumman's ground rules set forth explicit guidelines governing change approval levels, specifically those changes which the contractor might make without obtaining prior specific approval from NASA (defined as "compatibility changes" that did not have significant cost, weight, performance, schedule, or safety effects) - although Grumman must continue to inform MSC of these changes as they occurred.

Ltr., Tripp to Low, "Configuration Change Control, LM Program," Oct. 7, 1968, with encl., "Configuration Change Control - Ground Rules," Oct. 7, 1968.

October 7

In compliance with Apollo Program Directive 29 of July 6, 1967, ASPO Manager George M. Low informed Apollo Program Director Samuel C. Phillips that "the private umbilical connection between the astro-communicator and the astronauts, the private administrative telephone connection via the umbilical cable to the astronauts, and the private aeromed communications in the MSOB [Manned Spacecraft Operations Building] will be recorded during all hazardous spacecraft tests. The recording will be placed in the hands of the Director of Flight Crew Operations, who will keep this recording for a period of 30 days following mission completion. After that time the recording may be destroyed."

Ltr., Low to Phillips, Oct. 7, 1968; TWX, Phillips to Low, "Recording of Voice Communications at KSC," Sept. 30, 1968.

October 9

Members of the MSF Management Council considered scientific experiments and surface extravehicular activities (EVA) for the first Apollo lunar landing mission. They decided to go ahead with development of three proposed experiments, the passive seismometer, laser reflector, and solar wind collector. They made no commitment to fly any of the three, however, pending development schedules and a clear understanding of timelines required for their deployment during the EVA portion of the mission. Other issues examined by the Council still were unresolved: one versus two-man EVA, use of television, and timeline allocations for EVA trials and development by the crew. During the discussions, ASPO Manager George M. Low recommended attempting television transmission via the Goldstone antenna (although the operational procedures would further burden an already heavily constrained mission). The erectable antenna would also be carried and used if the landing site and EVA period precluded sight of the Goldstone antenna. Charles W. Mathews and others from Washington voiced concern that the EVA timeline did not allow sufficient time for learning about EVA per se in the one-sixth-gravity environment of the moon. The astronaut must perform some special tasks, but must also have some time for personal movements and evaluation of EVA capabilities in order to build confidence toward a fairly complex EVA exercise during the second landing mission. Low asked his chief system engineering assistant, Owen E. Maynard, to incorporate these operational decisions into the Apollo mission planning and to define mounting of the television camera and its early use in the mission.

Memo, Low to Maynard, "First G mission science package," Oct. 9, 1968.

October 9

NASA Apollo Mission Director William C. Schneider reported completion of all action items pertinent to Apollo 7 assigned by Apollo Program Director Samuel C. Phillips as a result of recommendations by the Apollo Crew Safety Review Board on May 27, 1968. These actions had included qualification of critical subsystems; a review of the AS-205 launch vehicle test history; a review of Saturn IB 205 and CSM 101 functional interfaces; a manned test readiness review, which was completed at KSC on August 28; and issuance of an Emergency Actions Summary Document containing emergency and contingency situations and appropriate procedures for pad operations, which had won approval on September 27.

Memo, Schneider to Flight Readiness Review Secretariat for Apollo, "Crew Safety Review Board Action," Oct. 9, 1968.

October 10

Because of the continuing problem of hardware changes, Apollo Program Director Samuel C. Phillips revised policies and procedures for control of changes for AS-503 and subsequent missions. Level II Configuration Control Boards, said Phillips, would have authority to implement several categories of engineering changes: mandatory changes to ensure crew safety or mission success, changes that would substantially reduce workload or checkout time at KSC, and changes to improve the probability of launch and to reduce the possibility of launch delays or scrubs, based on engineering analysis and failure history. Phillips admitted that other essential changes might be needed that did not fulfil these criteria, but such "down-the-line" changes must be held to an absolute minimum, he told ASPO Manager George M. Low. All changes that affected deliveries or launch schedules, on the other hand, must still be submitted to the Level I CCB for approval before implementation. These revised procedures, Phillips believed, would produce the control of changes needed to ensure an operationally suitable Apollo space vehicle, yet allow the secondary-level CCB to exercise "tough and critical judgment" of the change decision process, to allow needed flexibility within the overall program.

Ltr., Phillips to Low, "Change Policies and Procedures," Oct. 10, 1968.

October 11-22

Apollo 7 (AS-205), the first manned Apollo flight, lifted off from Launch Complex 34 at Cape Kennedy Oct. 11, carrying Walter M. Schirra, Jr., Donn F. Eisele, and R. Walter Cunningham. The countdown had proceeded smoothly, with only a slight delay because of additional time required to chill the hydrogen system in the S-IVB stage of the Saturn launch vehicle. Liftoff came at 11:03 a.m. EDT. Shortly after insertion into orbit, the S-IVB stage separated from the CSM, and Schirra and his crew performed a simulated docking with the S-IVB stage, maneuvering to within 1.2 meters of the rocket. Although spacecraft separation was normal, the crew reported that one adapter panel had not fully

deployed. Two burns using the reaction control system separated the spacecraft and launch stage and set the stage for an orbital rendezvous maneuver, which the crew made on the second day of the flight, using the service propulsion engine.

Crew and spacecraft performed well throughout the mission. During eight burns of the service propulsion system during the flight, the engine functioned normally. October 14, third day of the mission, witnessed the first live television broadcast from a manned American spacecraft. The SPS engine was used to deorbit after 259 hours 39 minutes of flight. CM-SM separation and operation of the earth landing system were normal, and the spacecraft splashed down about 13 kilometers from the recovery ship, the U.S.S. *Essex*, at 7:11 a.m. EDT October 22. Although the vehicle initially settled in an apex-down ("stable 2") attitude, upright bags functioned normally and returned the CSM to an upright position in the water. Schirra, Eisele, and Cunningham were quickly picked up by a recovery helicopter and were safe aboard the recovery vessel less than an hour after splashdown.

All primary *Apollo 7* mission objectives were met, as well as every detailed test objective (and three test objectives not originally planned). Engineering firsts from *Apollo 7*, aside from live television from space, included drinking water for the crew produced as a by-product of the fuel cells. Piloting and navigation accomplishments included an optical rendezvous, daylight platform realignment, and orbital determination via sextant tracking of another vehicle. All spacecraft systems performed satisfactorily. Minor anomalies were countered by backup systems or changes in procedures. With successful completion of the *Apollo 7* mission, which proved out the design of the Block II CSM (CSM 101), NASA and the nation had taken the first step on the pathway to the moon.

TWX, William C. Schneider to distr., "Apollo 7 Mission, Mission Director's 24-Hour Report," Oct. 22, 1968; memos, George E. Mueller to Acting Administrator, "Manned Space Flight Weekly Report - October 14, 1968," Oct. 14, 1968, and "Manned Space Flight Weekly Report - October 21, 1968," Oct. 21, 1968.

October 16

Apollo Program Director Samuel C. Phillips ordered that the Saturn IB program be placed in a standby status pending any future requirements for Apollo or the Apollo Applications program. Phillips' action signaled the shift in Apollo to the Saturn V vehicle, effective with AS-503.

TWX, Phillips to distr., "Saturn IB Program Planning," Oct. 16, 1968.

October 17

Dale D. Myers, Apollo CSM Manager at North American Rockwell, wrote ASPO Manager George Low on the policy question of contractor and subcontractor support of the current Apollo flight program and potential follow-on activities. Support for such activities, Myers said, "can be seriously jeopardized if we permit . . . experienced, specialized personnel and unique facilities to become irretrievably lost to the

program." He emphasized in particular the case of Aeronca, Inc., of Middletown, Ohio, manufacturer of stainless steel honeycomb panels that formed the structure of the CSM heatshield. Without some sort of sustaining activity, manufacturing skills and capabilities at Aeronca - and numerous other subcontractors and vendors - would rapidly wither. Myers earnestly solicited Low's views on the subject of subcontractor capability retention. In Low's response, he indicated that immediate action was being initiated to establish capability retention for the three most critical sources, Aeronca, Beech, and Pratt and Whitney, and a plan of action was being prepared for others.

Ltrs., Myers to Low, Oct. 17, 1968; Low to Myers, Nov. 15, 1968.

October 17

Two NASA investigation boards had reported that loss of attitude control caused the May 6 accident that destroyed lunar landing research vehicle No. 1, NASA announced (see May 6 and May 16). Helium in propellant tanks had been depleted earlier than normal, dropping pressure needed to force hydrogen peroxide propellant to the attitude-control lift rockets and thrusters. Warning to the pilot was too late for him to take necessary action for landing. The boards called for improvements in LLRV and LLTV design and operating practices and more stringent control over flying programs. No bad effects on the Apollo lunar landing program had been found and no changes were recommended for the LM.

NASA Release 68-182, "LLRV Accident Report," Oct. 17, 1968.

October 18

David B. Pendley, Technical Assistant for Flight Safety at MSC, recommended to ASPO Manager George M. Low an official policy position for landings on land. Pendley stated that despite all efforts by the Center's Engineering and Development Directorate to develop a safe land-landing capability with the CSM, the goal could not be attained. The best course, he told Low, was to accept the risk inherent in the fact that a land landing could not be avoided in an early launch abort-accept the risk openly and frankly and to plan rescue operations on the premise of major structural damage to the spacecraft. "If we do not officially recognize the land landing hazard," Pendley said, "this will place us in an untenable position should an accident occur, and will further prejudice the safety of the crew by continuing a false feeling of security on the subject."

Memo, Pendley to Low, "Land landings," Oct. 18, 1968.

October 19

NASA Apollo Program Director Samuel C. Phillips apprised Associate Administrator for Manned Space Flight George E. Mueller of recent program decisions and planning for extravehicular activities (EVA) on the first Apollo lunar landing mission. Primary objective on that first flight, Phillips said, had from the inception of the program been a safe manned landing and return. However, in light of current

schedules, mission planning, and crew training activities, the agency must now commit itself to a definite scope for EVA activities on the first flight. After thorough review of the mission, a tentative EVA outline had been drawn up at the end of August and distributed to the Centers and Headquarters offices for comment. On September 11 the Manned Space Flight Management Council reviewed the proposed EVA scheme and criticisms and approved a formal EVA mission plan:

- The first mission would include a single EVA period of up to three hours. Training experience and simulations would form the basis for a decision on one- versus two-man EVAs during the period.
- The Apollo Lunar Surface Experiments Package and the Lunar Geology Investigation experiment would not be carried aboard the flight. Lunar soil samples would be collected. Also, other candidate experiments would be considered for inclusion on the flight.
- Television would be carried aboard the flight, both for operational and public information benefits.
- A paramount objective on the first landing would be to assess limitations and capabilities of the astronauts and their equipment in the lunar surface environment, to enhance the scientific return from the second and subsequent missions. (MSC was to structure detailed test objectives and experiments to satisfy this goal.)
- And MSC would recommend to Headquarters (including cost and schedule impacts) hardware changes that would lengthen the EVA time available for scientific investigations during subsequent flights.

Memo, Phillips to Mueller, "Extravehicular Activities for the First Lunar Landing Mission," Oct. 19, 1968.

October 21

MSC Director Robert R. Gilruth formally constituted an Operational Readiness Inspection Committee to inspect the Lunar Receiving Laboratory to demonstrate its suitability to accomplish its mission. John D. Hodge of MSC was appointed Chairman of the ORI and Peter J. Armitage, MSC, Executive Secretary. Other members were Aleck C. Bond, John W. Conlon, D. O. Coons, Joseph P. Kerwin, Paul H. Vavra, and Earle B. Young, all of MSC; E. Barton Geer, LaRC; A. G. Wedum, Ft. Detrick, Md.; and Donald U. Wise, NASA Hq.

Memo, Gilruth to distr., "Operational Readiness Inspection of the Lunar Receiving Laboratory," Oct. 21, 1968.

October 21

While the flight of *Apollo 7* was still in progress, ASPO Manager George M. Low ordered that CSM 101 be returned to Downey as quickly as possible at the end of the mission to begin postflight testing as quickly as possible. Therefore, no public affairs showing of the spacecraft could be permitted.

Memo, Low to Kenneth S. Kleinknecht, "Spacecraft 101 postflight activities," Oct. 21, 1968.

October 21

Associate Administrator for Manned Space Flight George E. Mueller summarized launch preparations for the near-term missions Apollo 8 and Apollo 9. Hurricane Gladys had interrupted work on the Apollo 8 spacecraft and launch vehicle and work was now about two days behind schedule. (Because winds from the storm did not exceed Apollo design values, however, Apollo 8 remained at Pad A and was not returned to the assembly building.) Checkout of LM-3 and CSM 104 for Apollo 9 were on schedule. The CSM had been stacked and would undergo combined systems tests shortly. Ascent and descent stages of the lander would be joined immediately after docking tests had been completed.

Memo, Mueller to Acting Administrator, "Manned Space Flight Weekly Report - October 21, 1968," Oct. 21, 1968.

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Part 3 (A)

Man Circles the Moon, the Eagle Lands, and Manned Lunar Exploration

October 23, 1968 through November 1968

1968

October 23

LeRoy E. Day, Apollo Test Director, NASA Hq., informed Apollo Program Director Samuel C. Phillips of two failures of LM propellant tanks during testing, a problem that might have significant program impact on LMs 6 and 7 and subsequent vehicles. The particular tanks in question were those manufactured by Allison Division of General Motors but reworked under separate contract by Airite Division of Sargent Industries. The two tanks, lightweight SWIP II models slated for LM-6 and subsequent vehicles, had suffered small cracks in the welds. So far, said Day, the weld process used in manufacture of the tanks was "highly suspect." Cryogenic proof-testing probably would be required to validate the tanks and to give confidence in the tank welds. Meantime, he said, the problem was receiving high-level attention both at Grumman and in Houston.

Memo, Day to Apollo Program Director, "LM Descent Propellant Tank Failures," Oct. 23, 1968.

October 24

Howard D. Burns, Chief of the Saturn V Test Management Office at MSFC, sent to Apollo launch operations officials at KSC a list of requirements for retesting the Saturn V following a lightning strike on the vehicle while on the pad. These requirements were to be included in the next revision of the overall test and checkout requirements documents at KSC. (Burns' action came largely as a result of discussions at the AS-503 Crew Safety Review Board meeting at KSC on August 20-21, 1968.) Burns recommended that KSC prepare a contingency plan specifying various stage and launch vehicle test and checkout procedures that would satisfy MSFC's requirements. The most immediate assessment must be the overall safety of the launch vehicle. Electronic and electrical components headed the list of specific hardware systems to be assessed.

Ltr., Burns to KSC, Attn: A. G. Smith, "AS-503-10 Launch Vehicle Test and Retest Requirements

Following a Lightning Strike on the Saturn V Launch Vehicle/LUT/MSS," Oct. 24, 1968, with encl., same subj.

October 26

In a memorandum for the record, MSC's Apollo LM Program Manager C. H. Bolender reviewed results of the receiving inspection performed on LM-4 at KSC on October 21. Only 59 valid "crabs" were reported, 44 of them by Grumman's receiving personnel. None of the discrepancies noted involved major hardware damage or serious procedural faults. Significant progress had been made in reducing receiving discrepancies between LM-3 and LM-4. This improvement Bolender attributed to the addition of surveillance inspectors at Grumman and to the emphasis being placed on quality control by the resident ASPO personnel at Bethpage.

Memo for Record, Bolender, "Review of LM-4 Receiving Inspection at KSC," Oct. 26, 1968.

October 28

MSC Apollo Spacecraft Program Office Manager George M. Low deleted the requirement for a short static-firing of the Apollo 8 service module reaction control system on the pad before launch (the so-called "burp" firing). He took this move in line with a recommendation from NASA Apollo Program Director Samuel C. Phillips and in light of the nominal performance of the RCS during the *Apollo 7* flight. By thus eliminating the burp firings - and not allowing any contact of the system's hypergolic propellants - the spacecraft could be maintained in a loaded condition through the December and January launch windows and gain the maximum launch flexibility for the Apollo 8 flight. (Decisions not to static-fire the RCS systems on spacecraft following 103 had been made some time earlier.)

TWX, Phillips to Low, "Apollo 8 Pre-Launch Burp Firing," Oct. 25, 1968; ltr., Low to Phillips, Oct. 28, 1968.

October 31

NASA Apollo Program Director Samuel C. Phillips officially designated the AS-504 and AS-505 missions as Apollo 9 and Apollo 10.

TWX, Phillips, NASA Hq., to KSC, MSFC, and MSC, "Apollo Mission Designations," Oct. 31.

November 7

The Configuration Control Board had decided in favor of an informal crew log for each Apollo spacecraft, ASPO Manager George M. Low informed MSC Director of Flight Crew Operations Donald K. Slayton. The log would be an unofficial document kept by consulting pilots at the spacecraft contractor plants during checkout and test of the vehicles and by the flight crew support team at KSC.

Although not intended to replace other, more formal procedures for recording hardware discrepancies, the log would contain such items as switching anomalies, meter bias, and what Low termed "bona fide 'ghosts'" which had no reasonable engineering explanation, as well as audible and visual "idiosyncrasies" in spacecraft operation.

Memo, Low to Slayton, "Spacecraft crew log," Nov. 7, 1968.

November 8

ASPO Manager George M. Low asked Rocco A. Petrone, Launch Operations Director at KSC, to set up a special task team to review all paperwork and to inspect visually all hardware, to ensure proper spacecraft deployment during the Apollo 8 flight. Apollo 8 contained a novel set of mechanical and electrical interfaces (CSM, LTA-B lunar module dummy, launch adapter, and Saturn V vehicle), Low observed. Furthermore, concern about these complex interfaces had increased because one of the adapter panels on *Apollo 7* had not opened properly. What Low - as well as MSC Director Robert R. Gilruth - desired foremost was to preclude repetition of another situation such as had occurred during the *Gemini IX* mission, when the shroud panels covering the Agena target vehicle had only partially deployed and had produced the "angry alligator" that forced cancellation of docking plans on that earlier flight.

Ltr., Low to Petrone, Nov. 8, 1968.

November 12

The Apollo Crew Safety Review Board met to assess land landing of the CSM in the area of the launch site if a flight were aborted just before launch or during the initial phase of a flight. In general the Board was satisfied with overall planned recovery and medical operations. The only specific item to be acted on was some means of purging the interior of the spacecraft to expel any coolant or propellant fumes that might be trapped inside the cabin. The Board was also concerned about the likelihood of residual propellants trapped inside the vehicle even after abort sequence purging, a problem that MSC secured assistance from both the Ames and Lewis Research Centers to solve. At the Board's suggestion, MSC's Crew Systems Division also investigated the use of a helmet liner for the astronauts to prevent head injury upon impact. Finally, the Board recommended continued egress training with fully suited crews, including some night training.

Memo, David B. Pendley, MSC Flight Control Div., to ASPO Manager, "Land landing in the launch site area," Nov. 18, 1968.

November 13

ASPO Manager Low asked Aaron Cohen, one of his staff assistants, to lead an investigation to determine detrimental effects of moisture on the strength of the bonded covering of the launch adapter structure. His action stemmed directly from a presentation the same day by James A. Chamberlin to the

Structures Advisory Board explaining the adapter failure on *Apollo 6*. Moisture in the adapter not only raised the pressures generated by heating during the boost phase of the flight through the atmosphere, but it also weakened the structural bonding either directly or by hampering venting through the holes in the honeycomb material. Low asked Cohen to take precautions that no water be allowed to enter the adapter. All joints in the material should be sealed with a waterproof tape even before the countdown demonstration test and should remain on the vehicle throughout the flight, so that the adapter would absorb no moisture even if it rained during the final count before launch. On the other hand, the tape must then withstand boost phase heating and must not impair spacecraft separation and panel jettisoning. (North American Rockwell, in compliance with CCBD, August 10, 1968, Master Change Record 7727, modified the SLA panels by drilling vent holes in the inner skin of the panels of all subsequent SLAs to allow release of moisture during ascent. These holes were to be kept sealed until immediately before launch to avoid collection of moisture in the honeycomb.)

Memo, Low to Cohen, "Verification of spacecraft/LM adapter," Nov. 13, 1968.

November 19

Martin L. Raines, MSC's Manager at the White Sands Test Facility, recommended to ASPO Manager George M. Low that he issue official direction to the two spacecraft contractors, North American Rockwell and Grumman, governing the phasedown of operations at the engine test site. Early action was needed, Raines said, for proper contractual action on the phasedown and for proper disposition of equipment and supplies. This action signaled the end of the long and difficult supportive development effort to prove out the Apollo spacecraft rocket engines for flight.

Memo, Raines to ASPO Manager, "WSTF Phasedown Plan," Nov. 19, 1968.

November 22

Howard W. Tindall, Jr., Chief of Apollo Data Priority Coordination within ASPO, reported an operational system problem aboard the LM. To give a returning Apollo crew an indication of time remaining to perform a landing maneuver or to abort, a light on the LM instrument panel would come on when about two minutes worth of propellants remained in the descent propellant system tanks with the descent engine running at 25-percent thrust. The present LM weight and descent trajectory were such that the light would always come on before touchdown. The only hitch, said Tindall, was that the signal was connected to the spacecraft master alarm. "Just at the most critical time in the most critical operation of a perfectly nominal lunar landing mission, the master alarm with all its lights, bells, and whistles will go off." Tindall related that some four or five years earlier, astronaut Pete Conrad had called the arrangement "completely unacceptable . . . but he was probably just an Ensign at the time and apparently no one paid any attention." If this "is not fixed," Tindall said, "I predict the first words uttered by the first astronaut to land on the moon will be 'Gee whiz, that master alarm certainly startled me.'" Tindall recommended either rerouting the signal wiring to bypass the alarm or cutting the signal wire and relying solely on the propellant gauges to assess flight time remaining.

Memo to distr., Tindall, "LM DPS low level light fixing," Nov. 22, 1968.

November 22

In a memorandum for the record, ASPO Manager George M. Low summarized results of November 19 and 22 meetings on procedures for astronaut training runs with the Apollo extravehicular mobility unit (EMU) under simulated space conditions. The runs would be in the two vacuum test chambers of the Center's Space Environment Simulation Laboratory. MSC Director Robert R. Gilruth had attended the meetings. Training runs were always to be preceded by a run also under altitude conditions and using a gas umbilical from the life support system of the facility itself. Although connected to the crewman, the facility umbilical would not be used as a gas supply under normal test conditions. For the final training run, the astronaut would wear a complete flight-configured EMU without any other link with the facility. Although several participants objected that training runs using the EMU alone ran greater risk than normal in chamber tests, the decision to conduct the exercises using the all-up flight configuration was reaffirmed.

Memo for Record, Low, "EMU activities in the SESL," Nov. 22, 1968.

November 22

NASA Associate Administrator for Manned Space Flight George E. Mueller reviewed for NASA Acting Administrator Thomas O. Paine the development of the Apollo service propulsion system (SPS) engine. (Earlier, Paine had asked whether the SPS engine had ever failed to fire during all of this developmental program.) Mueller reported that a review of the test history showed that no complete flight-configuration engine had ever failed to fire. In fact, during the entire development program (comprising some 3,200 engine starts and more than 90,000 seconds of firing time) only four engines had failed to start. In all of these cases, the cause of the ignition failures could be traced to faulty ground support equipment or to inadequate or improper operational procedures. No engine failure could be attributed solely to the SPS engine itself. Mueller's response to Paine - with obvious overtones for the upcoming Apollo 8 circumlunar mission - bespoke a supreme confidence in the safety and reliability of the all-important main engine of the spacecraft.

Memo, Mueller to Acting Administrator, "Response to Question on Apollo Service Propulsion System Engine," Nov. 22, 1968.

November 27

The LM-11 midsection assembly collapsed in the assembly jig during the bulkhead prefitting stage of construction at Grumman. The structure buckled when the bulkheads, which had just been prefitted and drilled, were removed to permit deburring the drilled holes. Jig gates that were supposed to hold up the assembly were not in position, nor was the safety line properly installed. The structure was supported by hand. Damage to the skin of the structure was not severe, although a small radius bend was put in one of

the upper skins.

Memo, Samuel A. Gentile, Bethpage RASPO Contracting Officer, to distr., "Report of Damage of LM-11 Midsection Assembly during Manufacturing Phase, this date," Nov. 27, 1968.

November 27

The need to flight-test manual control of the light LM ascent configuration had been discussed at the October 15 MSC Flight Program Review, MSC Director Robert R. Gilruth informed NASA Apollo Program Director Samuel C. Phillips. There was an implication that a control problem could exist for this configuration. Gilruth said he had stated that MSC should be able to establish manual control handling qualities of the LM through proper simulation and be confident about the adequacy of the control system.

Subsequently, Gilruth had reviewed the operating characteristics of the LM control system and the status of the simulation program related to manual control of the light ascent stage during docking. He said that the most demanding requirement for precision manual attitude control was the docking maneuver. Docking control had been simulated extensively at MSC, Grumman, and LaRC using functional representation of the control system and these simulations established the capability of docking the LM well within the specified docking criteria. In addition, other LM control tasks had been simulated at MSC and Grumman, and the LM was found to have satisfactory handling qualities for all manual control tasks.

Ltr., Gilruth to Phillips, "Manual Control of the Light Lunar Module Ascent Configuration," Nov. 27, 1968.

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Part 3 (B)

Man Circles the Moon, the Eagle Lands, and Manned Lunar Exploration

December 1968

1968

December 6

Several scientific experiments had been deferred from the first to the second lunar landing mission, Apollo Program Director Phillips informed the ASPO Manager at MSC: S-031, Lunar Passive Seismology; S-034, Lunar Tri-axis Magnetometer; S-035, Medium Energy Solar Wind; S-036, Suprathermal Ion Detection; S-058, Cold Cathode Ionization Gauge; and S-059, Lunar Geology Investigation. Substituted was a more conservative group that included Lunar Passive Seismology (S-031); a Laser Ranging Retroreflector (S-078); and Solar Wind Composition (S-080). Also assigned to the first landing mission, included among operational tasks, were sampling activities and observations of lunar soil mechanics.

TWX, Phillips to Low, "Experiment Assignments to Lunar Missions," Dec. 6, 1968.

December 8

During a routine flight of lunar landing training vehicle (LLTV) No. 1, MSC test pilot Joseph S. Algranti was forced to eject from the craft when it became unstable and he could no longer control the vehicle. The LLTV crashed and burned. A flight readiness review at MSC on November 26 had found the LLTV ready for use in astronaut training, and 10 flight tests had been made before the accident. An investigating board headed by astronaut Walter M. Schirra, Jr., was set up to find the cause of the accident. And on January 8, 1969, NASA Acting Administrator Thomas O. Paine asked the review board that was established in May 1968 to restudy its findings on the May 6 crash of lunar landing research vehicle No. 1 (LLTV-1).

Memo, George E. Mueller, OMSF, NASA, to Acting Administrator, "Manned Space Flight Weekly Report - December 9, 1968," Dec. 9, 1968; NASA Release 69-5, "Review Board Reconvened," Jan. 8, 1969.

December 9

Launch preparations for Apollo 8, scheduled for flight December 21, were on schedule, the NASA Associate Administrator for Manned Space Flight reported. Recent significant steps included a leak and functional test of the service propulsion system on November 26, fuel servicing of the CM reaction control system and the SPS on the following day, hypergolic loading on November 30, and loading of the S-IC stage with RP-1 fuel on December 2. All testing of the Mission Control Center in Houston and the Manned Space Flight Network had also been completed; both support systems were ready for full operational support. Recovery briefings had been given to the flight crew and the final flight plan for Apollo 8 had been issued. If all preparations continued to go smoothly, the final countdown for launch would begin on December 16.

Memo, Mueller to Acting Administrator, "Manned Space Flight Weekly Report - December 9, 1968," Dec. 9, 1968.

December 14

The ASPO Manager asked Wilmot N. Hess, MSC Director of Science and Applications, to devise a crew fit and functional check of lunar handtools before the LM-5 crew training tests. Functional check of the handtools, as well as the Early Apollo Science Experiments Package (EASEP), had been agreed on at a November 26 review. Actual flight hardware would be used by the crewmen to verify operation of tools and experiments. Flight handtools - as well as the EASEP, if available - would also be subjected to thermal vacuum tests in the Space Environment Simulation Laboratory, preferably during LM-5 crew training in the facility.

Memo, George M. Low to Hess, "Lunar Handtools and EASEP (Early Apollo Science Experiments Package)," Dec. 14, 1968.

December 15

Final countdown for the launch of Apollo 8, the second manned Apollo mission, began on schedule at KSC. Significant launch preparation events included the "wet" countdown demonstration test on December 10, three days of flight simulations, an operational review, and launch site recovery exercises. Mission preparations were on schedule for launch on December 21. Launch preparations were also on schedule for the next two flights, Apollo 9 and 10.

Memo, George E. Mueller, NASA Associate Administrator for Manned Space Flight, to Acting Administrator, "Manned Space Flight Weekly Report - December 16, 1968," Dec. 16, 1968.

December 16

NASA Apollo Program Director Samuel C. Phillips asked ASPO Manager George M. Low for comments on potential uses for television aboard all Apollo spacecraft (both CMs and LMs). Although plans called for TV cameras in both spacecraft for the F and G missions, on the combined CSM-LM earth-orbital D mission only the LM was to contain a camera. Phillips asked Low to assess the feasibility and schedule impact of including a TV camera on the D-mission CSM as well (CM 104), thus employing television on all the remaining Apollo spacecraft. In particular, the Apollo Director sought Low's advice on the feasibility and usefulness of television transmissions for engineering, operations, scientific, and public information purposes. (See December 24.)

Ltr., Phillips to Low, "Apollo On-board TV," Dec. 16, 1968.

December 17

Apollo Program Director Phillips described to MSC Director Robert R. Gilruth two reviews of testing and checkout procedures, conducted by the Apollo Test Office and MSC's Crew Systems Division, at Hamilton Standard September 23-26 and at International Latex September 30-October 4. (The reviews were a follow-on to similar test and checkout reviews at North American Rockwell and at Grumman earlier in the year.) The review at "Ham-Standard," manufacturer of the portable life support system, uncovered only two minor discrepancies, which the company immediately corrected. At International Latex, manufacturer of the Apollo spacesuit, however, the review teams found what Phillips termed a "disappointing situation despite extensive management direction by the Crew Systems Division." The NASA review group made several recommendations to improve the situation:

- Improved management control of suit processing and checkout to afford higher confidence in configuration, inspection, and performance integrity.
- Stricter enforcement of the acceptance data package on each delivered suit.
- Compulsory contractor updating and enforcement of specifications to meet MSC spacesuit requirements.
- Improved and rigidly enforced discipline and cleanliness.

These problems, Phillips noted, had not impaired flight readiness of the spacesuit, "but it does explain the delivery problems we have been experiencing."

Ltr., Phillips to Gilruth, Dec. 17, 1968.

December 17

Apollo Program Director Phillips asked ASPO Manager Low to hasten work on the study at North American to define reusability of systems aboard the CM. He asked Low for a review of the area in mid-February 1969 if sufficient data were available by then. Also, Phillips asked Low's recommendations for an effectivity date on any recovery operations to increase reusability of either spacecraft systems or of the complete vehicle. (North American submitted Space Division Report No. 69-463, dated August 29,

1969, recommending preflight preservation treatment and postflight refurbishment that could be accomplished on CMs and its components to enhance reusability. Removal of heatshield access ports and flushing with fresh water on the recovery ship was the only recommendation implemented, because the others were not judged cost effective.)

Ltr., Phillips to Low, Dec. 17, 1968.

December 19

Crew briefings on flammability tests and fire extinguishing methods should be expanded, ASPO Manager Low recommended to MSC Director of Flight Operations Donald K. Slayton. Short briefings had been given to the crews of spacecraft 101 and 103, Low said, but these limited briefings should be expanded to ensure further a fire-safe spacecraft. At a minimum, he urged review of all flammability deviations inside the spacecraft, review of flammable crew storage items, review of significant fire testing films on propagation paths, and review of emergency procedures for extinguishing fires. The chief objective of this expanded program, said Low, was to familiarize the crews with the flammable items in the cockpit that could not be replaced, with potential propagation paths, and with methods of extinguishing fires.

Memo, Low to Director of Flight Crew Operations, "Crew training program on fire safety," Dec. 19, 1968.

December 20

The lunar closeup stereo camera on Apollo missions was not a separate scientific experiment, NASA Associate Administrator for Manned Space Flight wrote MSC Deputy Director George S. Trimble. An adjunct to the field geology experiment, the camera's stereoscopic photographs of fine details on the lunar surface would document individual material samples. Additional photography where no samples were taken would provide information on the range of surface textures near the landing site. Following deployment by the crew of emplaced experiments, the field geology investigation - and thus the stereo camera - had priority. Mueller stated that inclusion of the camera on all early Apollo landing missions was desirable, including the first. However, it was doubtful that the contractor could deliver the first flight article in time for that mission, although the camera could be ready for the second landing if granted waivers in documentation, reliability, and quality controls. Mueller affirmed his desire to grant these relaxations in the normally rigid Apollo hardware demands - to the extent that such waivers could be granted without jeopardizing crew safety or overall mission success. As an added benefit, the Associate Administrator said, "the experiment of giving a qualified contractor a relatively free hand in managing a development project within his particular field of competence should be instructive in the planning of future procurements of this type."

Ltr., Mueller to Trimble, Dec. 20, 1968.

December 21-27

Apollo 8 (AS-503) was launched from KSC Launch Complex 39, Pad A, at 7:51 a.m. EST Dec. 21 on a Saturn V booster. The spacecraft crew was made up of Frank Borman, James A. Lovell, Jr., and William A. Anders. *Apollo 8* was the first spacecraft to be launched by a Saturn V with a crew on board, and that crew became the first men to fly around the moon.

All launch and boost phases were normal and the spacecraft with the S-IVB stage was inserted into an earth-parking orbit of 190.6 by 183.2 kilometers above the earth. After post-insertion checkout of spacecraft systems, the S-IVB stage was reignited and burned 5 minutes 9 seconds to place the spacecraft and stage in a trajectory toward the moon - and the *Apollo 8* crew became the first men to leave the earth's gravitational field.

The spacecraft separated from the S-IVB 3 hours 20 minutes after launch and made two separation maneuvers using the SM's reaction control system. Eleven hours after liftoff, the first midcourse correction increased velocity by 26.4 kilometers per hour. The coast phase was devoted to navigation sightings, two television transmissions, and system checks. The second midcourse correction, about 61 hours into the flight, changed velocity by 1.5 kilometers per hour.

The 4-minute 15-second lunar-orbit-insertion maneuver was made 69 hours after launch, placing the spacecraft in an initial lunar orbit of 310.6 by 111.2 kilometers from the moon's surface - later circularized to 112.4 by 110.6 kilometers. During the lunar coast phase the crew made numerous landing-site and landmark sightings, took lunar photos, and prepared for the later maneuver to enter the trajectory back to the earth.

On the fourth day, Christmas Eve, communications were interrupted as *Apollo 8* passed behind the moon, and the astronauts became the first men to see the moon's far side. Later that day, during the evening hours in the United States, the crew read the first 10 verses of Genesis on television to earth and wished viewers "goodnight, good luck, a Merry Christmas and God bless all of you - all of you on the good earth."

Subsequently, *TV Guide* for May 10-16, 1969, claimed that one out of every four persons on earth - nearly 1 billion people in 64 countries - heard the astronauts' reading and greeting, either on radio or on TV; and delayed broadcasts that same day reached 30 additional countries.

On Christmas Day, while the spacecraft was completing its 10th revolution of the moon, the service propulsion system engine was fired for three minutes 24 seconds, increasing the velocity by 3,875 km per hr and propelling *Apollo 8* back toward the earth, after 20 hours 11 minutes in lunar orbit. More television was sent to earth on the way back and, on the sixth day, the crew prepared for reentry and the SM separated from the CM on schedule.

Parachute deployment and other reentry events were normal. The *Apollo 8* CM splashed down in the

Pacific, apex down, at 10:51 a.m. EST, December 27 - 147 hours and 42 seconds after liftoff. As planned, helicopters and aircraft hovered over the spacecraft and pararescue personnel were not deployed until local sunrise, 50 minutes after splashdown. The crew was picked up and reached the recovery ship U.S.S. *Yorktown* at 12:20 p.m. EST. All mission objectives and detailed test objectives were achieved, as well as five that were not originally planned (see Appendix 5).

The crew was in excellent condition, and another major step toward the first lunar landing had been accomplished.

MSC, "Apollo 8 Mission Report," Feb. 1969, pp. 1-1, 1-2; NASA OMSF, "Apollo Program Flight Summary Report, Apollo Missions AS-201 through Apollo 8," Jan. 1969, pp. 32-35; *Astronautics and Aeronautics*, 1968, (NASA SP-4010, 1969), pp. 318-23.

December 24

ASPO Manager George M. Low apprised Program Director Samuel C. Phillips of MSC's plans for television cameras aboard remaining Apollo missions. With the exception of spacecraft 104 (scheduled for flight as Apollo 9), television cameras were to be flown in all CMs. Also, cameras would be included in *all* manned LMs (LM-3 through LM-14).

Ltr., Low to Phillips, "Television," Dec. 24, 1968.

December 27

C. H. Bolender, ASPO LM Manager at MSC, wrote Ralph H. Tripp, LM Program Manager at Grumman, regarding open spacecraft failure items. Although he acknowledged Grumman's recent progress in reducing the number of open failures, Bolender said that the approaching manned phase of the LM program dictated a fundamental change in the method of handling those open problems. Apollo required "zero open problems." Moreover, all failures must receive NASA approval of closeout before launch. Bolender called on Tripp to revamp his failure closeout procedures with several objectives: all closeout packages must contain sufficient documentation to permit NASA approval of the action; each package should be available as a reference for any future review of problem definition, analysis, and correction; and the contractor should further improve the discipline applied to technical resolution of open items and to the preparation of closeout packages. Bolender anticipated that Grumman's actions to meet these objectives would greatly reduce the number of open failure closeout disapprovals by NASA. But when a disagreement did exist, both parties must act quickly to resolve the issue. "Prompt attention to NASA disapprovals has been a problem," noted the LM Program Manager.

Ltr., Bolender to Tripp, Dec. 27, 1968.

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Part 3 (C)

Man Circles the Moon, the Eagle Lands, and Manned Lunar Exploration

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1969

January 3

Mission preparation for Apollo 9 continued on schedule. Rollout of the space vehicle from the Vehicle Assembly Building, KSC, began. Mission Control Center simulations checkout, which began at MSC on December 20, 1968, was proceeding on schedule. Also, a series of thermal vacuum tests was completed, with the Apollo 9 crew using extravehicular mobility unit (EMU) flight equipment. Wind up of these tests completed the required EMU testing for the Apollo 9 flight.

NASA OMSF, "Manned Space Flight Weekly Report - January 6, 1969."

January 14

MSFC announced that Arthur Rudolph, special assistant to the MSFC Director, would retire January 31. Rudolph had served as the manager of the Saturn V rocket program from August 1963 to May 1968. He was one of the more than 100 rocket experts who came to the United States from Germany in 1945. The MSC ASPO Manager, in a congratulatory letter said, "I will always consider Saturn V to be one of the outstanding achievements that occurred during my lifetime. Its sheer size is simply fantastic. But even more astounding was its performance in its first flights." Rudolph's work in bringing the nation's most powerful launch vehicle to flight status was rewarded when the first Saturn V lifted off from KSC and

performed flawlessly on November 9, 1967, Rudolph's birthday.

MSFC Release 69-10, Jan. 14, 1969; ltr., George M. Low, MSC, to Arthur Rudolph, MSFC, Jan. 16, 1969; NASA OMSF, "Manned Space Flight Weekly Report - January 27, 1969."

January 15

The Apollo Program Director expressed concern to the Director of MSC over the lack of guidelines of sufficient scope and depth for the lunar missions that would be flown after the first lunar landing and before the proposed lunar exploration program tentatively scheduled to begin in 1973. He asked each of the manned space flight Centers to appoint a working group to define guidelines and to outline program objectives and content for the period of lunar exploration immediately following the first lunar landing. Areas requiring study were: scientific exploration, mission planning rationale, flight schedules and program impact, and vehicle product improvement.

Ltr., Samuel C. Phillips, NASA OMSF, to Robert R. Gilruth, MSC, Jan. 15, 1969.

January 15-17

The final flight program for Apollo 9 was verified; the emergency egress test with the prime and backup crew was conducted; and the software integration test between the lunar module and Mission Control Center, MSC, was completed on January 15. On January 16 the Saturn V/Mission Control Center-Houston integration testing was conducted. Additionally, a critical design review of the Launch Complex 39 slide wire system was conducted on January 17. Launch preparations for Apollo 9 continued to proceed on schedule.

NASA OMSF, "Manned Space Flight Weekly Report - January 21, 1969."

January 16

In response to a query, the ASPO Manager responded: "Insofar as the astronauts' 'call of nature' is handled, they urinate through a tube into a plastic bag. The bag is periodically emptied through an overboard dump nozzle. Although we have considered using an aircraft type relief tube that would dump overboard directly, we have not yet adopted this approach since an uncontrolled dump would most likely freeze the liquid in the tube or the dump nozzle. Defecation is handled through the use of a plastic bag, part of which fits over the hand like a glove. Although this method is primitive, it was found to work reasonably well, both in Gemini and in Apollo. A disinfectant pill is then placed in the bag and it is stowed in a special container in the spacecraft. The astronauts' diet, both before and during the flight, is such that the need to use this bag may only arise once or twice during the flight."

Ltr., George M. Low, MSC, to Larry Megow, Houston, Tex., Jan. 16, 1969.

January 16

The Apollo Program Director requested that MSC present a Lunar Receiving Laboratory (LRL) review like that for design certification. The presentation would cover

1. landing and recovery procedures,
2. LRL operations,
3. release scheme for astronauts and samples,
4. sample processing and distribution plans, and
5. scientific investigations.

The purpose would be to assess overall readiness following the first lunar landing in these five areas.

Ltr., Samuel C. Phillips, NASA OMSF, to Robert R. Gilruth, Director, MSC, "Lunar Receiving Laboratory Readiness Review," Jan. 16, 1969.

January 17-20

Checkout was on schedule for an Apollo 10 launch readiness date of May 17. On January 17 the backup crew participated in an altitude test run. The spacecraft docking test, using a simulated adapter, was completed January 20. All three fuel cells were being replaced because of suspected contamination in fuel cell No. 1 and the failure of fuel cell No. 2 to take any voltage load during the power-up for the manned altitude run.

NASA OMSF, "Manned Space Flight Weekly Report - January 27, 1969."

January 19-22

The Apollo 9 flight readiness test began on January 19 and was successfully completed January 22, in preparation for a February launch (see March 3-13). A one-day delay in the testing was caused by a loss of air conditioning for the RCA-110A computer. The hatch and side windows of the spacecraft were being modified to overcome the fogging effect experienced during the *Apollo 8* mission.

Ibid.

January 24

The CSM Flight Readiness Review Board convened at MSC. Martin L. Raines presented the Reliability and Quality Assurance assessment and pointed out the improvement in discrepancy reports between spacecraft 101, 103, and 104 and concluded that 104 was better than 103 and ready to fly. George M. Low noted that the CSM Review had been outstanding.

Minutes of Meeting, CSM 104, Flight Readiness Review Board, approved by Robert R. Gilruth, Director, MSC, Feb. 7, 1969.

January 24

In an exchange of letters, the feasibility and compatibility of experiments covering contrast perception, color perception, and distance estimation on the moon were discussed. Incorporation of the three experiments in the lunar landing mission's detailed test objective "Lunar Environment Visibility" for Apollo 11 was recommended.

Ltrs., Samuel C. Phillips, NASA OMSF, to George M. Low, MSC, "Lunar Surface Life Sciences Observation Experiments T033, Contrast Perception on Moon; T034, Color Perception on Moon; T035, Distance Estimation on Moon," Jan. 24, 1969; Low to Phillips, Feb. 25, 1969.

January 24-29

The following tests were completed in preparation for the planned February Apollo 9 launch: all Mission Control Center data system integration tests, MSC preflight readiness test, KSC launch readiness test, and MSFC preflight test. In addition, recovery training exercises were conducted aboard the U.S.S. *Guadalcanal*, the prime recovery ship for Apollo 9.

NASA OMSF, "Manned Space Flight Weekly Report - February 3, 1969."

January 27

MSC and North American Rockwell reached agreement on certification reviews for parachute packers in the Apollo program. The certification was effective for all parachute packers not previously certified, with upgrading of packers and recertification of present Apollo packers when required.

Ltrs., Dale D. Myers, North American Rockwell, to Kenneth S. Kleinknecht, MSC, Jan. 27, 1969; Kleinknecht to Myers, Nov. 8, 1968.

January 31

About 30 small aluminum brackets and fittings were replaced or reinforced in Apollo lunar modules to rule out the possibility of cracking from stress corrosion. Stress corrosion monitoring began in December 1967 when small cracks were discovered in LM landing gear struts. Nine fittings were replaced in LM-3, scheduled for the Apollo 9 mission, and six fittings were repaired in LM-4, scheduled for the Apollo 10 flight. About 25 fittings were being replaced on LM-5 and LM-6 and 8 fittings on each of these vehicles were being reinforced.

NASA News Release 69-24, "LM Fittings Changed," Jan. 31, 1969.

January 31

NASA Hq. asked Center directors for ideas for symbolic activities on the moon during the first landing to dramatize international agreements regarding exploration of the moon. Possible ideas were flying a U. N. flag with the U.S. flag on the moon; placing decal flags of the U.N. member nations on the LM descent stage; and leaving an appropriate information capsule at the landing site.

TWX, Samuel C. Phillips, NASA OMSF, to Robert R. Gilruth, MSC; Kurt H. Debus, KSC, and Wernher von Braun, MSFC, Jan. 31, 1969; ltr., Gilruth to Phillips, March 3, 1969.

January 31

During integrated testing of the Apollo spacecraft, a well-qualified test pilot accidentally threw two guarded switches marked "CM/SM Separation" instead of the intended adjacent switches marked "CSM/ LM Final Sep" to separate the lunar module from the command and service modules. Had the error occurred in a lunar flight, the CM would have separated from the SM, with a high probability of leaving the crew stranded in lunar orbit. Studies of methods to preclude such an accident in actual flight led later to provisions for visual differences in switch covers.

Memos, Robert R. Frazer, MSC, to Resident Manager Apollo Spacecraft Program, "CSM 108 Erroneous Switch Closure," Jan. 31, 1969; David B. Pendley, MSC, to Manager, Apollo Spacecraft Program, "CM/ SM separation switches," Feb. 17, 1969.

February 3

In response to a query, a study indicated that, because of the temperature on the moon's surface, lunar samples would cool the LM cabin when placed in the rock box inside the cabin.

Memo, Wilmot N. Hess, MSC, to ASPO Manager, "Temperature of lunar samples," Feb. 3, 1969; ltr., George M. Low, MSC, to Samuel C. Phillips, NASA OMSF, Feb. 7, 1969.

February 3

NASA Hq. released a 12-month forecast of manned space flight missions, reflecting an assessment of launch schedules for planning purposes. Five flights were scheduled for the remainder of 1969:

- Apollo 9 - February 28, SA-504, CSM 104, LM-3; manned orbital; up to 10 days' duration; Atlantic recovery.
- Apollo 10 - May 17, SA-505, CSM 106, LM-4; manned lunar mission, Pacific recovery.
- Apollo 11 - SA-506, CSM 107, LM-5; manned lunar mission; up to 11 days' duration; Pacific

recovery.

- Apollo 12 - SA-507, CSM 108, LM-6; manned lunar mission; up to 11 days; Pacific recovery.
- Apollo 13 - SA-508, CSM 109, LM-7; manned lunar mission; up to 11 days' duration; Pacific recovery.

TWX, John D. Stevenson, NASA Hq., to addressees, "MSF Mission Operations Forecast for February 1969," Feb. 3, 1969.

February 5

The MSF Management Council, meeting at KSC, agreed that MSC would take the following actions for augmenting the capability of the Apollo system to accomplish a successful lunar landing mission and for planning further lunar exploration:

Capability Augmentation:

- Submit for Apollo Level I approval a plan for developing and procuring the A9L spacesuit.
- Submit a plan to the Apollo program Director describing how the portable life support system's improvement program procurement would be done.
- Proceed with the 1/6-g special test equipment. The plan - including scope, schedule, and cost estimates for this simulator - would be submitted to Apollo Program Director by 1 March.
- Proceed with the engineering definition of software and hardware required to precision-land the LM at sites anywhere on the front surface of the moon.

Lunar Exploration:

- Submit a plan for the buildup of the cannibalized ALSEP, listing experiments to be included, the estimated cost, and delivery schedule.
- Submit a plan for the procurement of additional ALSEPs including proposed quantities, estimated costs, and experiments.
- Proceed to define further a CSM lunar orbital science package and a lunar polar orbit mission science package, including instruments, costs, delivery schedule, and approach to CSM integration. Costs would include instruments and spacecraft integration.
- Proceed with the definition to increase the size of LM descent stage tanks and to improve the propellant pressurization system.
- Submit a plan for the procurement of a constant volume suit, including a description of any further development not under contract that MSC planned to add to any present

contract by change order.

- Proceed with engineering change analysis of performance (including habitability) improvements to the CSM and LM.

Ltr., George E. Mueller, NASA OMSF, to Robert R. Gilruth, MSC, Feb. 14, 1969.

February 8

The permanently mounted spacecraft hoisting loop was inadequate for expected spacecraft loads and had failed on *Apollo 8*, ASPO Manager George M. Low informed Apollo Program Director Samuel C. Phillips. The auxiliary nylon loop installed by the recovery forces had adequate strength but its installation was not as well controlled as work on the spacecraft was generally. For these reasons, Low said, the astronauts would be required to leave the spacecraft before it was hoisted aboard the carrier. Low enclosed a memorandum from Don Arabian, "Hoisting spacecraft from sea," and minutes of a February 4 discussion at MSC on the subject.

Ltr., Low to Phillips, Feb. 8, 1969; memo, Donald D. Arabian to distr., "Hoisting spacecraft from sea," Feb. 6, 1969; Minutes of Discussion Concerning Hoisting Spacecraft from the Sea, W. F. Hoyler, Feb. 4, 1969.

February 11

The possibility of an unmanned LM landing was discussed at NASA Hq. The consensus was that such a landing would be a risky venture. Proposals had been made which included an unmanned LM landing as a prerequisite to a manned landing on the moon. However, the capability to land the LM unmanned did not exist and development of the capability would seriously delay the program.

NASA Routing Slip, R. L. Wagner, Bellcomm, to Samuel C. Phillips, NASA OMSF, Feb. 11, 1969; draft memo, George E. Mueller, OMSF, to NASA Acting Administrator, "Unmanned LM Landing," undated, unsigned.

February 12

Three members of the Interagency Committee on Back Contamination met at MSC to review Apollo operational plans and procedures. Some concern was expressed about the lack of a bacterial filter on the spacecraft postlanding system. However, the committee representatives indicated that the approach was reasonable in terms of the tradeoff on operational recovery problems. The full committee was scheduled to meet in March.

NASA OMSF, "Manned Space Flight Weekly Report - February 17, 1969."

February 12

George M. Low, MSC, told Maxime A. Faget, MSC, that he had recently learned the Apollo Operations Handbook (AOH) was prepared for the Flight Crew Operations Directorate by prime contractors without any formalized review by engineering elements of MSC. On several occasions, when the Engineering and Development (E&D) subsystems managers looked at a section of the handbook in connection with problem areas they found the handbook in error. Low proposed that E&D should

1. verify technical accuracy of the baseline issue of the handbook before its final issue for the F mission,
2. verify all changes in the AOH in a timely manner, and
3. verify any crew checklist changes made during the last 45 days before launch.

Memo, Low to Faget, "Review of Apollo Operations Handbook," Feb. 12, 1969.

February 14

Flammability tests of the Sony tape/voice recorder were made to determine if the recorder met crew-cabin use requirements. Testing was by electrical overloads of nichrome wire ignitors in an atmosphere of 100 percent oxygen at 4.3 newtons per square centimeter (6.2 psia). Post-test evaluations indicated that flammability requirements had been met, since ignitions were self-extinguishing and only localized internal damage occurred.

Memo, Joseph N. Kotanchik, MSC, to Chief, Systems Engineering Div., MSC, "Flammability tests on Sony tape/voice recorder," Feb. 14, 1969.

February 17

MSC was urged to reconstitute the Crew Safety Review Board to determine if the following questions could be affirmatively answered concerning the LM, extravehicular activity, portable life support system, and emergency procedures. Were all likely failure modes or anomalies that could jeopardize the crew from entrance to mission systematically analyzed? Were proper and timely cues coupled with a safe egress, abort, or contingency capability prepared for use in each of these? Was there a plan for the timely solution of the known crew safety-related problems?

Ltr., Samuel C. Phillips, NASA OMSF, to George M. Low, MSC, Feb. 17, 1969.

February 22

The Apollo 9 countdown to launch began, with launch scheduled for liftoff February 28. The 10-day flight would mark the first manned earth orbital flight of the lunar module, the first Apollo spacewalk,

and the first manned checkout, rendezvous, and docking operations of the complete Apollo spacecraft. The Apollo 9 mission would be open-ended, allowing the mission plan to progress from one step to the next on the basis of real-time success.

NASA OMSF, "Manned Space Flight Weekly Report - February 25, 1969."

February 27

Maxime A. Faget, MSC Director of Engineering and Development, said he believed the Preliminary Lunar Landing Phase Photographic Operations Plan was seriously deficient in meeting its stated objectives. "From the standpoint of public information and historical documentation, I'm terribly disappointed to find that although 560 feet [170 meters] of movie film has been set aside for lunar surface use none will be exposed with the intent of providing first-class visual appreciation of the astronaut's activity on the moon during this singularly historical event. Everyone's impression of this occasion will be marred and distorted by the fact that the greatest frame rate is 12 frames per second. One can argue that 'suitable' (although jerky) motion rendition is produced by 'double-framing.' Nevertheless, it is almost unbelievable that the culmination of a 20 billion dollar program is to be recorded in such a stingy manner and the low-quality public information and historical material is in keeping with an otherwise high-quality program." Faget also noted he felt that, from a historical standpoint, both the lunar module pilot and the commander should be photographed with the Hasselblad camera while on the surface.

Memo, Faget, MSC, to Chief, Mission Operations Br., "Comments on 'Preliminary Lunar Landing Phase Photographic Operations Plan,'" Feb. 27, 1969.

March 1

The Apollo Program Director expressed concern about the inability to obtain adequate data on the expenditure of energy by astronauts during lunar exploration. The problem was discussed with the medical and crew systems personnel. The consensus was that the only meaningful indicator of human energy expenditure which could be developed into an operational procedure in time for lunar landings would be measurement of carbon dioxide production. From a technical standpoint the most feasible means of doing this would be incorporating a carbon dioxide measurement system in the portable life support system. A study was initiated to determine how quickly a measurement system could be developed and to estimate the cost.

Ltrs., Samuel C. Phillips to Manager, Apollo Spacecraft Program Office, "Initiation of a Program for the Measurement of Carbon Dioxide Production during Lunar Exploration," March 1, 1969; George M. Low to Phillips, May 5, 1969.

March 3-13

Apollo 9 (AS-504), the first manned flight with the lunar module (LM-3), was launched from Pad A, Launch Complex 39, KSC, on a Saturn V launch vehicle at 11:00 a.m. EST March 3. Originally scheduled for a February 28 liftoff, the launch had been delayed to allow crew members James A. McDivitt, David R. Scott, and Russell L. Schweickart to recover from a mild virus respiratory illness. Following a normal launch phase, the S-IVB stage inserted the spacecraft into an orbit of 192.3 by 189.3 kilometers. After post-insertion checkout, CSM 104 separated from the S-IVB, was transposed, and docked with the LM. At 3:08 p.m. EST, the docked spacecraft were separated from the S-IVB, which was then placed on an earth-escape trajectory.



LM-3 is still attached to the S-IVB stage after launch on the Apollo 9 mission March 3, 1969.



Spider flies in lunar landing configuration, upside down to earth, with lunar surface probes extending from deployed foot pads. Apollo 9 commander James A. McDivitt flies with Schweickart in the LM, photographed by Scott from the CM Gumdrop.

On March 4 the crew tracked landmarks, conducted pitch and roll yaw maneuvers, and increased the apogee by service propulsion system burns.

On March 5 McDivitt and Schweickart entered the LM through the docking tunnel, evaluated the LM systems, transmitted the first of two series of telecasts, and fired the LM descent propulsion system. They then returned to the CM.

McDivitt and Schweickart reentered the LM on March 6. After transmitting a second telecast, Schweickart performed a 37-minute extravehicular activity (EVA), walking between the LM and CSM hatches, maneuvering on handrails, taking photographs, and describing rain squalls over KSC.

On March 7, with McDivitt and Schweickart once more in the LM, Scott separated the CSM from the LM and fired the reaction control system thrusters to obtain a distance of 5.5 kilometers between the two spacecraft. McDivitt and Schweickart then performed a lunar-module active rendezvous. The LM successfully docked with the CSM after being up to 183.5 kilometers away from it during the six-and-one-half-hour separation. After McDivitt and Schweickart returned to the CSM, the LM ascent stage was jettisoned.

During the remainder of the mission, the crew tracked *Pegasus III*, NASA's meteoroid detection satellite that had been launched July 30, 1965; took multispectral photos of the earth; exercised the spacecraft systems; and prepared for reentry.

The *Apollo 9* CM splashed down in the Atlantic 290 kilometers east of the Bahamas at 12:01 p.m. EST. The crew was picked up by helicopter and flown to the recovery ship U.S.S. *Guadalcanal* within one hour after splashdown. Primary objectives of the flight were successfully accomplished. (Objectives of all Apollo flights are listed in Appendix 5.)

MSC, "Apollo 9 (AS-504) Flight Summary," undated; MSC, "Apollo 9 Mission Report" (MSC-PA-R-69-2), May 1969; NASA OMSF, "Manned Space Flight Weekly Report," March 4, 17, 1969.

March 5

President Nixon, at a White House ceremony, announced the nomination of Acting Administrator Thomas O. Paine to be the NASA Administrator.

Office of the Federal Register, National Archives and Records Service, *Weekly Compilation of Presidential Documents*, March 10, 1969, pp. 369- 71.

March 6

NASA Associate Administrator for Manned Space Flight George E. Mueller, wrote MSC Director Robert R. Gilruth of his concern about Apollo software. "Software as I mean it to be understood in this letter includes computer programs, mission profiles and procedures (training). As I recall, the Apollo project started with a legacy of warnings from other programs about the rigors and pitfalls of software development. . . . I believe we are giving far more management attention to hardware changes than to software changes of similar impact." He questioned "whether some of these changes make the system better or safer when the disruptive effects of change are also considered. . . . We are making too many discretionary software changes. These are costing money and effort which could better be used elsewhere. . . ."

Gilruth replied March 11: "I cannot agree with your contention that we are now controlling software with the same rigor and management attention that we are devoting to hardware changes. Our Apollo Spacecraft Program Office has organized a number of Configuration Control Boards at MSC. These

include George Low's Apollo Spacecraft Configuration Control Board, Max Faget's Board for Government Furnished Equipment, Chris Kraft's Software Configuration Control Board, and Deke Slayton's Procedures Change Control Board. . . . Hardware changes . . . are directly under George Low's control. All computer program changes, both on board and on the ground, are controlled by Chris Kraft's Board. Changes to the Apollo Operations Handbook, flight crew procedures, crew checklists, trainers and simulators are controlled by Slayton. Changes in software or crew procedures that involve changes in schedule must additionally be approved by George Low's Board. The system I described is working well and, according to Sam Phillips, has resulted in a more disciplined change control than anywhere else in the Apollo Program. . . . We are not making discretionary software changes. We are only making those changes which our managers deem to be necessary in their effort to carry out the Apollo Program in the most effective manner."

Ltrs., Mueller to Gilruth, March 6, 1969; Gilruth to Mueller, March 11, 1969.

March 7

In a report to the Administrator, the Associate Administrator for Manned Space Flight summed up the feeling of accomplishment as well as the problem of the space program: "The phenomenal precision and practically flawless performance of the Apollo 9 lunar module descent and ascent engines on March 7 were major milestones in the progress toward our first manned landing on the moon, and tributes to the intensive contractor and government effort that brought these two complex systems to the point of safe and reliable manned space flight. The inevitable developmental problems that plagued the LM propulsion system were recurring items in our management reporting, and the fact that essentially all major test objectives were met during last Friday's flight operations is an outstanding achievement. The earth orbital simulations of the lunar descent, ascent, rendezvous, and docking maneuvers, taking Astronauts McDivitt and Schweickart 114 miles [183.4 km] away from the CSM piloted by Dave Scott and safely back, were a measure of the skill of the Apollo 9 crew and the quality of the hardware they were flying."

NASA OMSF, "Manned Space Flight Weekly Report - March 10, 1969."

March 7

A radiation survey of CSM 107 was planned to determine if the radiation produced by onboard sources would be of a sufficient level to impair the effectiveness of proposed experiments to measure the natural radiation emitted from the lunar surface. The survey would be conducted at KSC by personnel from the Goddard Space Flight Center.

Ltr., Kenneth S. Kleinknecht, MSC, to Rocco A. Petrone, KSC, "Background radiation survey of Apollo CSM," March 3, 1969.

March 10 and 31

A Flight Readiness Review Board convened at MSC to determine the readiness of Lunar Landing Training Vehicle No. 2 and the Flight Crew Operation Directorate for resuming flight test operations. During the briefing and discussion the board agreed that the operation test team was operationally ready. However, a release for resuming flight test operations was withheld until certain open items were resolved. The board reconvened on March 31 and after examination of the open items, agreed that flight testing of LLTV No. 2 should be resumed as soon as possible.

Minutes, Lunar Landing Training Vehicle Number Two (LLTV No. 2) Flight Readiness Review Board (FRRB), April 1, 1969.

March 11

Apollo 10 was transferred to Pad B, Launch Complex 39, at KSC - for first operational use of Pad B. Meanwhile, a revised work schedule providing for a Flight Readiness Test on April 9 and launch readiness on May 18 was being prepared for Apollo 10.

NASA OMSF, "Manned Space Flight Weekly Report - March 17, 1969."

March 11

The additional direct cost to the Apollo research and development program from the January 27, 1967, Apollo 204 fire was estimated at \$410 million, principally for spacecraft modifications, NASA Associate Administrator for Manned Space Flight George E. Mueller testified in congressional hearings. The accident delayed the first manned flight of the spacecraft by about 18 months. "During this period, however, there occurred a successful unmanned test of the Lunar Module and two unmanned tests of the Saturn V vehicle."

House Committee on Science and Astronautics, Subcommittee on Manned Space Flight. *1970 NASA Authorization: Hearings*, 91st Cong., 1st sess., pt. 2, Feb. 28, March 6, 7, 8, 11, 12, 14, and 25, 1969, pp. 183-85.

March 12

George M. Low discussed the status of a fire detection system for Apollo in a memorandum to Martin L. Raines, reminding him that such a system had been under consideration since the accident in January 1967. Low said: "Yesterday, Dr. [Maxime A.] Faget, you, and I participated in a meeting to review the current status of a flight fire detection system. It became quite clear that our state of knowledge about the physics and chemistry of fire in zero gravity is insufficient to permit the design and development of a flightworthy fire detection system at this time. For this reason, we agreed that we would not be able to incorporate a fire detection system in any of the Apollo spacecraft. We also agreed that it would be most worthwhile to continue the development of a detection system for future spacecraft." (See also entries of

March 27 and September 28, 1967, and April 17, 1968.)

Memo, Low to Raines, "Fire detection system for Apollo," March 12, 1969.

March 13

MSC requested that Apollo Program Directive No. 41 delivery dates for the LM be changed as follows: LM-6 from March 1 to March 26, LM-7 from April 16 to May 15, LM-8 from May 31 to July 15, and LMs 9 through 14 two months apart. The rescheduling was to permit incorporation of the redesigned ascent-stage fuel-tank torus ring, installation and testing of the liquid-cooled suit loop, replacement of the descent-stage tanks, and incorporation of structural fitting changes to prevent stress corrosion.

TWX, George M. Low to NASA Hq., Attn: S. C. Phillips, March 13, 1969.

March 14

MSC Director Robert R. Gilruth forwarded plans for the MSC Lunar Gravity Simulation device to Apollo Program Director Samuel C. Phillips. He informed Phillips that "we have moved out on the design and fabrication of the inclined plane 1/6 g simulator and our schedule shows that it will be completed and ready for checkout by May 1, 1969 [see February 5]. The vertical system approach is somewhat more sophisticated and our scheduled completion is February 1, 1970." Phillips replied March 28 that he was pleased to read that the simulator program was progressing so rapidly and "I feel very strongly that this device will greatly contribute to our capability to create useful lunar exploration missions."

Ltrs., George E. Mueller to Gilruth, Feb. 14, 1969; Gilruth to Phillips, March 14, 1969; Phillips to Gilruth, March 28, 1969.

March 20

ASPO Manager George Low wrote NASA Hq. - referring to a briefing of George Low at Downey on October 25, 1968 - that "MSC has reviewed the possibility of deleting the CSM boost protective cover. We have concluded that deletion . . . would require the following spacecraft modifications: a. A new thermal coating would have to be developed to withstand the boost environment. b. Protective covers would have to be developed for the windows, EVA handholds, vent lines, etc. . . . We have further concluded that a resulting overall weight reduction is questionable, and . . . have therefore decided that the cost of this change could not be justified and that the boost protective cover should be retained."

Ltr., Low to S. C. Phillips, "Deletion of the boost protective cover," March 20, 1969.

March 24

NASA announced that Apollo 10, scheduled for launch May 18, would be a lunar orbit mission during which two astronauts would descend to within 15,240 meters of the moon's surface. The decision followed reviews of technical and operational data from the *Apollo 9* earth-orbit mission. The prime crew would be astronauts Thomas P. Stafford, spacecraft commander; John W. Young, command module pilot; and Eugene A. Cernan, lunar module pilot. Backup crew members were L. Gordon Cooper, Jr., Donn F. Eisele, and Edgar D. Mitchell. With the exception of the actual landing, the mission plan was the same as for the lunar landing mission. Stafford and Cernan were to enter the LM, separate from the CSM, descend twice to within 16 kilometers of one of the preselected landing sites, and then rendezvous and dock with the CSM. Because of propellant limitations in the ascent stage, landing and subsequent liftoff from the moon would be impossible.

NASA News Release No: 69-46, "Apollo 10 Mission Scheduled," March 24, 1969.

March 25

The first flight-model ALSEP arrived at KSC, where it would undergo software integration tests and be prepared for installation in the LM.

NASA OMSF, "Manned Space Flight Weekly Report - April 1, 1969."

March 28

Following a report by the *Apollo 9* astronauts that they were thrown forward in their seats and had to grab their arm rests for support during the S-IC/S-II stage separation, an evaluation working group were studying the problem. Preliminary results indicated that the separation transients were a dynamic characteristic of the Saturn V vehicle; that the measured accelerations were within predicted range and below design limits; and that the separation sequences were normal. Conclusions were that similar separation dynamics could be anticipated on future Saturn V flights.

Memo, J. P. Lindberg, MSFC, to Addressees, "Special Bulletin on S-IC/S-II Stage Separation, AS-504," March 28, 1969.

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Part 3 (D)

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April 3

ASPO requested a plan for flight crew tests of sleeping pills and other drugs. The plan was to include number of tests to be performed by each crew member; time of the test with respect to the last sleep period; amount and kind of food and drink taken during a specified time before the test; general physical activity by the crew before taking a drug; and, for comparison purpose, any available statistical information on the effect of these pills after being taken.

Memo, George M. Low, ASPO Manager, to Charles A. Berry, Medical Research and Operations Directorate, MSC, "Use of sleeping pills," April 3, 1969.

April 5

ASPO Manager George Low, commented on control of Apollo spacecraft weight. Following the January 1967 spacecraft fire at Cape Kennedy, there had been substantial initial weight growth in the CSM. This was attributed to such items as the new CSM hatch, the flammability changes, and the additional flight safety changes. In mid-1967 the CSM weight stabilized and from then on showed a downward trend. The LM weight stabilized in mid-1968 and since that time had remained fairly constant. Conclusions were that the program redefinition had caused a larger weight increase than expected, but that once the

weight control system became fully effective, it was possible to maintain a weight that was essentially constant. Low told Caldwell C. Johnson, Jr., of the MSC Spacecraft Design Division that the weight control was in part due to Johnson's strong inputs in early 1968. Johnson responded, "Your control of Apollo weight growth has destroyed my reputation as a weight forecaster - but I'm rather glad."

Ltrs., Low to Apollo Program Director Samuel C. Phillips, April 5, 1969; Phillips to Low, May 5, 1969; memos, Low to Johnson, "Apollo weight growth," April 5, 1969; Johnson to Low, "Apollo weight growth," April 8, 1969.

April 7-11

Work on Apollo 10 continued on schedule for a May 18 launch readiness date. The flight readiness test began on April 7 and was completed on April 10. A lunar module mission-simulation run was completed on April 10, and a crew compartment fit and function test on April 11. Mission control simulations were proceeding on schedule without major problems. The Apollo 10 preflight readiness review was held at MSC on April 11.

NASA OMSF, "Manned Space Flight Weekly Report - April 14, 1969."

April 12

ASPO Manager George Low informed MSC Director of Science and Applications Wilmot N. Hess that he had signed paperwork increasing the weight allowance for the Apollo scientific payload from 136 to 156.4 kilograms. Low said he was able to do this for the LM-6 (Apollo 12) mission because of the favorable LM weight picture. He stated, however, "I believe that we should understand that this increase in weight allowance does not alter our basic agreement to provide for a scientific payload of 300 pounds [136 kilograms]. In the event that future difficulties with the Lunar Module require additional weight growth in the basic spacecraft system, we will have to once again reduce the scientific payload to 300 pounds [136 kilograms]. . . . I wanted to be sure that we agreed in advance that the added 45 pounds [20.4 kilograms] of scientific payload allowance would be the first weight to be deleted. . . ." Hess concurred with the memorandum.

Memo, Manager, ASPO, to Hess, "Increased weight allowance for Apollo scientific payload," April 12, 1969.

April 14-21

Twenty-two astronauts trained in the MSC Flight Acceleration Facility during the week, for lunar reentry. Closed-loop simulation permitted the crews to control the centrifuge during the lunar reentry deceleration profiles. Each astronaut flew four different reentry angles, which imposed acceleration loads of from 4.57 to 9.3 g.

NASA OMSF, "Manned Space Flight Weekly Activity Report - April 21, 1969."

April 18

ASPO announced changes in launch readiness dates for the Apollo 12 and Apollo 13 missions. Apollo 12 was moved up from September 18 to September 13, 1969; and Apollo 13 was moved up from December 1 to November 10.

Memo, George M. Low to distr., "Apollo launch readiness dates for Apollo 12 and 13 changes," April 18, 1969.

April 21

The Director of Apollo Test in the NASA Hq. Apollo Program Office, LeRoy E. Day, was detailed to head the MSF Space Shuttle Task Group. The group would provide NASA with material for a report on the Space Shuttle to the President's Space Task Group.

Memo, George E. Mueller, NASA OMSF, to distr., "Special Assignment of Mr. LeRoy E. Day, Director of Apollo Test," April 21, 1969.

April 25

Discovery of six new mascons (mass concentrations of dense material) beneath the moon's surface by William L. Sjogren, Paul M. Muller, and Peter Gottlieb of Jet Propulsion Laboratory was announced. The first six mascons had been discovered in 1968 by Sjogren and Muller. Each mascon was found to be centered below a ringed sea, or an ancient, obliterated circular sea on the side of the moon's surface facing the earth. Noticeable acceleration variations were seen as moon-orbiting spacecraft flew over the mascons. Information was not available concerning possible mascons on the far side of the moon, since orbiting spacecraft could not be tracked while the moon blocked them from the view of earth antennas.

NASA News Release 69-61, "New Lunar Mascons Discovered," April 25 1969.

April 25-26

In an exchange of correspondence, Samuel C. Phillips, NASA OMSF, and ASPO Manager George Low, MSC, discussed the possibility of carrying an aseptic sampler and a closeup stereo camera on the Apollo 11 flight. They decided the flight would carry the camera as an additional source of data; Apollo 11 crewmen would use it on targets of opportunity during lunar surface exploration. Because of the unrealistic schedule that would be required to certify the flight worthiness of the aseptic sampler, however, they decided not to fly it on Apollo 11.

TWX, Phillips to Low, "Assignment of Priority for Aseptic Sampler and Close-up Camera for Apollo G-

1 Mission," April 25, 1969; ltr., Low to Phillips, April 26, 1969.

April 28

A power outage, required to permit maintenance work at the KSC Launch Control Center, was relayed to the pneumatic controls of the S-IC stage of the Apollo 10 launch vehicle, causing the prevalves to open and allowing 5,280 liters of RP-1 fuel to drain from the vehicle. This, in turn, produced negative pressure in the RP-1 tank, which displaced the upper bulkhead.

After repressurization, the bulkhead apparently returned to its normal shape. An effort was under way to determine the nature of the damage to the bulkhead and the effect on the May 18 Apollo 10 launch readiness date.

NASA OMSF, "Manned Space Flight Weekly Report - April 28, 1969"; "Manned Space Flight Weekly Report - May 5, 1969."

April 29

The NASA Associate Administrator for Manned Space Flight concurred in a recommendation to carry an erectable antenna on the Apollo 11 mission. However, it would be deployed only if required to obtain satisfactory television, voice, telemetry, and biomedical data simultaneously from the lunar surface.

Ltr., George H. Hage, NASA OMSF, to George M. Low, MSC, "LM Steerable Antenna Versus Erectable Antenna," April 29, 1969.

May 2

A temporary fix to provide for an S-II-stage early center engine cutoff was made for Apollo 10 and 11. Purpose was to eliminate oscillations of the center engine and sympathetic structures. (See March 28, 1969, entry.) Meanwhile, plans were being made to incorporate a permanent fix into Apollo 12 and subsequent vehicles to eliminate the oscillations.

TWX, Samuel C. Phillips, NASA OMSF, to Lee B. James, MSFC, Roderick O. Middleton, KSC, and George M. Low, MSC, "Permanent Fix for S-II Stage Oscillations," May 2, 1969.

May 5

ASPO reported a recent manned-test abort of the portable life support system had been caused by a nonfunctional lithium hydroxide canister. Quality control procedures were in existence and if properly implemented would have precluded the abort incident. To prevent similar incidents from occurring, all manned-test and flight equipment would be accompanied by complete documentation, would be visually

inspected, and would be certified by quality assurance personnel before use.

Memo, ASPO Manager to Acting Manager for Flight Safety, MSC, "Incident involving an out-of-configuration LiOH canister in an MSC manned altitude test," May 5, 1969.

May 5

MSC asked North American Rockwell to propose a design modification in the CM to add a cold storage compartment for fresh and frozen foods. If the frozen food study appeared promising, then the addition of a small oven or heater, similar in concept to that used by the Air Force on long flights, would also be required.

Ltr., Kenneth S. Kleinknecht, MSC, to George W. Jeffs, North American Rockwell, May 5, 1969.

May 7-8

The fifth and final drop test of LM-2 was made on May 7. The first four drop tests had been made to establish the proper functioning of all LM systems after a lunar landing. The fifth test was made to qualify the functioning of the pyrotechnics after landing. On May 8, the final test, physically separating the ascent stage, was conducted.

NASA OMSF, "Manned Space Flight Weekly Report - May 12, 1969."

May 8

Apollo Program Director Samuel C. Phillips suggested to MSC Director Robert R. Gilruth that a meeting be held at MSC during the period of the Apollo 10 return flight to earth to review the status of experiment support facilities and the overall plans for science support operations during lunar missions and over an extended period of time. Phillips pointed out that the results from the Early Apollo Scientific Experiments Package, the Apollo Lunar Surface Experiments Packages, the Lunar Geology Experiment, and the analyses of the returned lunar samples would be of inestimable scientific value. However, NASA in the dissemination of the scientific results would require a science operations and data management plan which would spell out the operational, support, management, data-handling, and science relationships.

Ltr., Phillips to Gilruth, May 8, 1969.

May 8

The Apollo Back Contamination Documentation and Configuration Control Office was established at MSC to provide a documentation program for any possible contamination from the moon. The program was required by June 15, to meet deadlines for the launch of Apollo 11.

Memo, Richard S. Johnston, MSC, to distr., "Apollo Back Contamination Documentation Control Office," May 8, 1969.

May 9

NASA Hq. informed MSC that, for planning purposes and Change Control Board action, the following science sequence was being recommended for the Apollo 12 mission:

1. contingency sample;
2. ALSEP deployment; and
3. field geology investigations.

The message said, "It is important that ALSEP be deployed in the first EVA (extravehicular activity). Then the entire second EVA could be devoted to Field Geology Investigations."

TWX, Samuel C. Phillips, NASA OMSF, to George M. Low and Wilmot N. Hess, MSC, "Mission H-1 Recommended Science Sequence," May 9, 1969.

May 9

MSC forwarded a plan for the Apollo 15 Lunar Surface Science Project to NASA Hq. The plan provided for replacement of the ALSEP Array A-2 central station and lunar geological equipment, along with rework of the Passive Seismic Experiment. Total cost of the project was estimated at \$6.7 million excluding the cost of surveying instrument and instrument staff. With a May 15 go-ahead, delivery could be made by one year from that date. Apollo Program Director Samuel C. Phillips in a message to MSC Director Robert R. Gilruth approved the plan, saying that a June 1, 1970, delivery of the array would be acceptable and requesting procurement action leading to a definitive Bendix contract be submitted by June 20, 1969.

Ltr., Gilruth to George E. Mueller, NASA Hq., "Apollo 15 Lunar Surface Science," May 9, 1969; TWX, Phillips to Gilruth, June 12, 1969.

May 12

Because the first flight of the ALSEP was scheduled on Apollo 12, NASA Hq. asked MSFC to provide for installation at KSC of the prelaunch cooling system for the ALSEP radioisotopic thermoelectric generator (RTG) on instrument units 507 through 510.

TWX, Samuel C. Phillips, NASA Hq., to MSFC, May 12, 1969.

May 13

NASA policy on release of manned space flight communications was outlined. The policy was to release all air-to-ground conversations in real time. However, if circumstances arose in which crew or mission director requested a private conversation, the public information officer responsible for the mission commentary would be notified and would monitor the conversation with the mission director. A summary would be released at the discretion of the Office of Public Affairs. Tapes of the air-to-ground private conversations would not be released.

Memo, T. O. Paine, NASA Administrator, to S. C. Phillips, NASA OMSF, May 13, 1969; ltr., G. E. Mueller, OMSF, to R. R. Gilruth, MSC, May 15, 1969.

May 18-26

Apollo 10 (AS-505) - with crew members Thomas P. Stafford, Eugene A. Cernan, and John W. Young aboard - lifted off from Pad B, Launch Complex 39, KSC, at 12:49 p.m. EDT on the first lunar orbital mission with complete spacecraft. The Saturn V's S-IVB stage and the spacecraft were inserted into an earth parking orbit of 189.9 by 184.4 kilometers while the onboard systems were checked. The S-IVB engine was then ignited at 3:19 p.m. EDT to place the spacecraft in a trajectory toward the moon. One-half hour later the CSM separated from the S-IVB, transposed, and docked with the lunar module. At 4:29 p.m. the docked spacecraft were ejected, a separation maneuver was performed, and the S-IVB was placed in a solar orbit by venting residual propellants. TV coverage of docking procedures was transmitted to the Goldstone, Calif., tracking station for worldwide, commercial viewing.

On May 19 the crew elected not to make the first of a series of midcourse maneuvers. A second preplanned midcourse correction that adjusted the trajectory to coincide with a July lunar landing trajectory was executed at 3:19 p.m. The maneuver was so accurate that preplanned third and fourth midcourse corrections were canceled. During the translunar coast, five color TV transmissions totaling 72 minutes were made of the spacecraft and the earth.

At 4:49 p.m. EDT on May 21 the spacecraft was inserted into a lunar orbit of 110.4 by 315.5 kilometers. After two revolutions of tracking and ground updates, a maneuver circularized the orbit at 109.1 by 113.9 kilometers. Astronaut Cernan then entered the LM, checked all systems, and returned to the CM for the scheduled sleep period.

On May 22 activation of the lunar module systems began at 11:49 a.m. EDT. At 2:04 p.m. the spacecraft were undocked and at 4:34 p.m. the LM was inserted into a descent orbit. One hour later the LM made a low-level pass at an altitude of 15.4 kilometers over the planned site for the first lunar landing. The test included a test of the landing radar, visual observation of lunar lighting, stereo photography of the moon, and execution of a phasing maneuver using the descent engine. The lunar module returned to dock successfully with the CSM following the eight-hour separation, and the LM crew returned to the CSM.

The LM ascent stage was jettisoned, its batteries were burned to depletion, and it was placed in a solar orbit on May 23. The crew then prepared for the return trip to earth and after 61.5 hours in lunar orbit a service propulsion system TEI burn injected the CSM into a trajectory toward the earth. During the return trip the astronauts made star-lunar landmark sightings, star-earth horizon navigation sightings, and live television transmissions.

Apollo 10 splashed down in the Pacific at 12:52 p.m. EDT on May 26, 5.4 kilometers from the recovery ship. The crew was picked up and reached the recovery ship U.S.S. *Princeton* at 1:31 p.m. All primary mission objectives of evaluating performance and support and the detailed test objectives were achieved. (Objectives of all the Apollo flights are shown in Appendix 5.)

MSC, "Apollo 10 (AS-505) Flight Summary," undated; MSC, "Apollo 10 Mission Report" (MSC-00126), August 1969; NASA OMSF, "Manned Space Flight Weekly Reports," May 9, 26, 1969; memo, R. O. Middleton, KSC, to distr., "Apollo 10 (AS-505) Quick Look Assessment Report," May 22, 1969.

May 19

Recent serious incidents were reported at MSC, involving mercury and affecting ground support equipment or Apollo flight hardware. These incidents reflected the relaxation of safety disciplinary procedures required in handling mercury and mercury-filled instruments. To preclude further such incidents, stringent regulations were imposed governing the acquisition, use, and disposition of mercury at MSC.

Memo, Robert R. Gilruth, MSC, to distr., "Mercury Contamination Control," May 19, 1969.

May 19

Vision distortion was found when looking through the pressure garment assembly helmet during Water Immersion Facility training activities at MSC. Curvature of the helmet caused objects to appear distorted, hampering crew training. Studies were being made in an effort to correct the problem. Negotiations were also under way with the Department of the Navy to provide a modified indoctrination course in open-circuit SCUBA for a number of astronauts, to ensure their safety while training in the Water Immersion Facility.

Memo, Director of Flight Crew Operations to Director of Medical Research and Operations, "Vision distortion while training in the Water Immersion Facility (WIF)," May 19, 1969; ltr., D. K. Slayton, MSC, to B. J. Semmes, Jr., Department of the Navy, May 19, 1969.

May 19

In a telephone conference, MSC personnel and members of the Interagency Committee on Back Contamination agreed to eliminate the requirement for a postlanding ventilation filter for Apollo 12,

approve a plan for sterilization of the CM in the Lunar Receiving Laboratory (LRL), release the spacecraft at the same time as the crew release, and approve the LRL Bioprotocol Summary. The ICBC planned to meet on June 5 to complete planning and documentation for Apollo 11.

Memo, Richard S. Johnston, MSC, to distr., "ICBC Telephone Conference Summary and Action Items," May 21, 1969; NASA OMSF, "Manned Space Flight Report - May 26, 1969."

May 27

MSFC was authorized to proceed with development of a manned lunar roving vehicle for use on the Apollo missions beginning in mid-1971. A meeting was scheduled for June 6 in Washington to establish requirements for development of the vehicle.

TWX, Lee R. Scherer, NASA Hq., to Wernher von Braun and William R. Lucas, MSFC; Robert R. Gilruth and John D. Hodge, MSC; and Kurt H. Debus, KSC, May 27, 1969.

May 27

Apollo Program Director Sam C. Phillips wrote to MSC regarding a Flight Readiness Review action item on translunar injection (TLI: insertion into a trajectory toward the moon) dispersions after manual guidance for TLI on Apollo missions. He enclosed a memorandum prepared by W. G. Heffron of Bellcomm, Inc., on the subject. Phillips stated that fuel reserves on *Apollo 10* were such that dispersions seemed acceptable and he would have permitted use of manned guidance during TLI if it had been needed. He pointed out that margins would be much less for the Apollo 11 mission, and that it would be necessary either to reduce the dispersions or limit the use of the capability. ASPO Manager George M. Low replied to the letter on June 13 and submitted the following comments for consideration: ". . . I see little advantage to not attempting manual launch vehicle guidance for TLI. . . . If the dispersions are within the 120 feet [37 meters] per second budgeted for translunar midcourse corrections, the mission would be continued as planned. If the dispersions are within 270 feet [82 meters] per second, the mission would be completed utilizing a slower transearth trajectory. If the dispersions are very large, the mission would be limited to a circumlunar flight in which all of the service propulsion system and LM descent stage propellants could be used for midcourse corrections. . . ."

Ltrs., Phillips to Low, "Manual Launch Vehicle Guidance - TLI Dispersion," May 27, 1969; Low to Phillips, "Manual launch vehicle guidance - TLI dispersions," June 13, 1969.

June 3

Apollo Program Office Change Control Board (CCB) Directive No. 140 assigned Experiment S080, Solar Wind Composition, to the first lunar landing mission. CCB Directive No. 156 requested MSC to also include this experiment on the second lunar landing mission.

TWX, S. C. Phillips, NASA Hq., to G. M. Low, MSC, June 4, 1969.

June 3

The early engineering evaluation of the *Apollo 10* launch vehicle, Saturn V AS-505, indicated that the major flight objectives were accomplished. Indications were that all detailed test objectives were also accomplished.

The basic performance of the Saturn V was satisfactory, but the following problem areas were identified for more extensive investigation:

1. The S-IVB stage auxiliary hydraulic pump performance degraded during S-IVB second burn. The hydraulic system cycle after second burn also indicated degraded pump performance.
2. Astronauts reported low-frequency lateral and longitudinal oscillations throughout the S-IVB first and second burn, with high-frequency vibration superimposed beginning at 4 minutes 40 seconds into second burn and continuing until engine cutoff. While the associated amplitudes of both high and low frequency were well within structural and component vibration qualification levels, a priority effort to identify the source of these vibrations was under way.

Ltr., Lee B. James, MSFC, to Samuel C. Phillips, NASA Hq., June 3, 1969, with encl., "Saturn AS-505 M + 5 Day Report," June 3, 1969.

June 3

In a report to the ASPO Manager, the Chief of MSC's Systems Engineering Division described Apollo Site Selection Board (ASSB) action on proposed landing sites for the Apollo 12 mission. The MSC recommendation was to land at either the *Surveyor III* or *Surveyor I* site if Apollo 11 landed in either Apollo site 2 or site 3. Earlier, on January 10, Benjamin Milwitzky, NASA Hq., had said, "There appears to be much merit in landing close to one or more Surveyors." He pointed out that "reexamination of disturbances in the lunar surface created by Surveyor landings, the study of unique lunar features seen by Surveyors, and the return to Earth of objects identified by Surveyors as scientifically important can greatly enhance the scientific and technological value of subsequent Apollo landings. . . ."

MSC informed NASA Hq. on June 12 that it had analyzed landing terrain in Hipparchus and Fra Mauro and concluded that these areas were too rough to be given consideration for the Apollo 12 mission. At the same time, MSC recommended that ASSB reconsider the *Surveyor III* site as a prospective site for that mission. On June 16, Apollo Program Director Sam C. Phillips wrote that Fra Mauro and Hipparchus would not be considered as landing sites for the Apollo 12 mission and that he would entertain consideration of the *Surveyor III* site following analysis of its scientific desirability in a meeting of the Group for Lunar Exploration Planning at MSC on June 17 and subsequent recommendations by MSC and NASA Hq. OMSF staff members.

Memos, Benjamin Milwitzky, NASA Hq., to Apollo Lunar Exploration Office Director, NASA Hq., "Biasing Apollo Missions to Land Near Surveyor Spacecraft on the Moon," Jan. 10, 1969; Chief, Systems Engineering Div., MSC, to ASPO Manager, "Apollo Site Selection Board trip report - June 3, 1969," dated June 10, 1969; TWXs, G. M. Low, MSC, to S. C. Phillips, NASA Hq., "Lunar Landing Sites for H-1 Mission," June 12, 1969; Phillips to Low, "Lunar Landing Sites for H-1 Mission," June 16, 1969.

June 7

ASPO Manager George Low suggested to MSC Director of Flight Crew Operations Donald K. Slayton that beginning with Apollo 12 Velcro applications should be "in a spacecraft configuration and not vice versa." In the past, Velcro applications had presumably been made in the spacecraft to conform to the configurations used in training.

Memo, Low to Slayton, "Velcro Changes," June 7, 1969.

June 9

The CSM 107 (Apollo 11) Flight Readiness Review Board met at MSC. The board heard reviews of government-furnished equipment problems, a special report on camera equipment, scientific experiments and equipment to be used on Apollo 11, medical requirements, operations and procedures to preclude back contamination from the moon, and a structural assessment of the LM/SLA/CSM. CSM Manager Kenneth S. Kleinknecht summarized the status of CSM 107 and emphasized that Apollo Operations Handbook changes must be in by June 15. Board Chairman George S. Trimble, MSC, noted that there seemed to be a tendency to bring more items to the board at this review than before, since this mission was the goal toward which everyone had been working.

Trimble, MSC, to distr., "Minutes of Meeting, CSM 107, Flight Readiness Review Board," June 9, 1969.

June 9

Preparation of Apollo 11 was on schedule for a July 16 launch date. Lunar landmark and landing site mosaics were delivered for flight crew training. A flight readiness test, begun on June 4, had been completed June 6 despite an MSC Mission Control Center power outage that delayed the test for several hours.

NASA OMSF, "Manned Space Flight Weekly Report - June 9, 1969;" OMSF, "Apollo Program Weekly Status Report," June 12, 1969.

June 9-13

Studies were being conducted to determine the feasibility of intentionally impacting an S-IVB stage and an empty LM stage on the lunar surface after jettison, to gather geological data and enhance the scientific return of the seismology experiment. Data would be obtained with the ALSEP seismographic equipment placed on the lunar surface during the Apollo 11 or Apollo 12 flight. MSFC and Bellcomm were examining the possibility of the S-IVB jettison; MSC, the LM ascent stage jettison. Intentional impacting of the ascent stage for Apollo 11 was later determined not to be desirable.

TWXs, Samuel C. Phillips, NASA Hq., to George M. Low, MSC, "LM-5 Ascent Stage Disposition after Jettison," June 13, 1969; Phillips to Low, "Impact of the Ascent Stage on Apollo 11," June 25, 1969; Phillips to MSFC and MSC, "This Is APO CCB Directive No. 158," June 30, 1969; NASA OMSF, "Manned Space Flight Weekly Report - June 9, 1969."

June 11

In establishing a task force for hardware development, Apollo Program Director Samuel C. Phillips stated: "We have recently been given . . . approval on our plans for continuing the lunar missions through Apollo 20. We have given authority to the field centers to issue CCA's for the design and the procurement of long lead time items for modifications to the LM and CSM. We have also authorized the procurement of a wheeled vehicle for lunar surface transportation. We are in the process of evaluating over 50 proposals for lunar orbital experiments, and have given MSC authority to procure an already approved experiment group. In short, we are becoming very rapidly involved in the definition and management of the lunar exploration missions."

Ltr., Phillips to distr., "Task Force for Hardware Development," June 11, 1969; NASA OMSF, "Manned Space Flight Weekly Report - June 16, 1969."

June 13

Apollo Program Director Phillips wrote MSC ASPO Manager George Low, that "based on the excellent results of the color TV coverage on the Apollo 10 mission . . . I concur with your plan to carry and utilize a color TV camera in the Command Module for Apollo 11 and subsequent missions. . . ."

Ltr., Phillips to Low, "Apollo On-board Color TV," June 13, 1969.

June 13

NASA Hq. authorized MSC to modify its contract with Bendix to include a 60- to 90-day effort to define a modified ALSEP design. Additional cost was not to exceed \$300,000.

TWX, Samuel C. Phillips to Robert R. Gilruth, "Design Definition of Modified ALSEP," June 13, 1969.

June 13

The NASA Associate Administrator for Manned Space Flight, in a message to MSC, said he understood that, subsequent to the MSC Flight Readiness Review (FRR) and the NASA Headquarters Readiness Review of the LLTV, additional modifications had been made to that training vehicle. He requested a return wire indicating the date of the delta Flight Readiness Review and evaluation of the readiness for astronaut LLTV flight. In a reply, several hours later, MSC informed Mueller that a delta FRR had been conducted that date; that the changes in avionics had been extensively ground-checked and demonstrated on two separate test flights on June 9 and June 12; that the MSC board concluded the overall system was ready for astronaut training; and that the plan was to start the Apollo 11 Critical Design Review on the following day.

TWXs, George E. Mueller to Robert R. Gilruth, June 13, 1969; Gilruth to Mueller, June 13, 1969.

June 17

A seven-day simulation was successfully completed in the Lunar Receiving Laboratory at MSC. The test simulated processing of lunar samples, operation of the mobile quarantine facility and crew reception area, and biolab activities. Action was under way to overcome procedural and equipment difficulties encountered in the vacuum laboratory.

NASA OMSF, "Manned Space Flight Weekly Report - June 23, 1969."

June 20

Sigurd A. Sjoberg, MSC Deputy Director of Flight Operations, informed MSC management of a list of records that could be set in the Apollo 11 flight. Plans were made to file claims with the Fdration Aronautique Internationale for:

Class records for lunar missions

1. Duration of stay on the surface of the moon.
2. Duration of stay inside the spacecraft on the surface of the moon.
3. Duration of stay outside the spacecraft on the surface of the moon.
4. Greatest mass landed on the moon.
5. Greatest mass lifted to lunar orbit from the surface of the moon.
6. Duration of stay in lunar orbit (The *Apollo 10* record would be broken if the optional sleep period after rendezvous and before transearth injection were included.)

Absolute world record

1. EVA record-duration of stay outside spacecraft.

Memo, Sigurd A. Sjoberg to distr., "World Space Flight Records for the Apollo 11 Mission," June 30, 1969.

June 20

Christopher C. Kraft, Jr., MSC Director of Flight Operations, recommended that the following fundamental requirements be considered during the lunar roving vehicle (LRV) design approach: "a. A means of continuous voice communication with one crew member, on or off the LRV to the mother station (LM) and from the mother station to earth, must be provided. b. A simple dead reckoning system should be considered for determining the LRV and crew location at all times in order to provide a safe return of the astronauts to the LM. The accuracy should be sufficient to permit the astronauts to rendezvous with the LM from any point on a sortie. c. The vehicle should be designed so that a telemetry system is not required for operation. However, for crew safety and systems operations, instrumentation may be required."

Memo, Kraft to Manager, Advanced Missions Program, "FOD criteria for manned Lunar Roving Vehicle," June 20, 1969.

June 23

Preparations for the first manned lunar landing continued on schedule for a July 16 launch of Apollo 11. Dress rehearsal of the countdown was scheduled to begin on Friday, June 27, and to run for 113 hours, including a 6-hour built-in hold. Spacecraft hypergolic loading started on June 18 and was completed on June 23, despite delays caused by weather conditions. A lunar module landing-radar problem was resolved by repainting the base heatshield to reduce the reflectivity. In flight operations, the crew, the controllers, and the recovery operations team were moving ahead with training sessions on schedule. Two days of discussions were held with senior recovery officials on the U.S.S. *Hornet* and no major problems were identified. A second mobile quarantine facility was being deployed aboard the *Hornet* to provide backup support on the bioprotocol. A significant milestone was reached June 18 when the scientific investigators and the Apollo 11 astronauts went through a successful simulation of the EASEP (Early Apollo Surface Experiments Package) activities, ranging from the data plans and procedures to the use of the facilities.

NASA OMSF, "Manned Space Flight Weekly Report - June 23, 1969."

June 27

The status of the Apollo 11 crew training program as of June 15 was reported to NASA Headquarters by MSC. The summary indicated the crew had completed more than 70 percent of the briefing and reviews, had spent a total of 143 hours on procedures against a programmed 100 hours, had spent a total of 71 hours on spacecraft test and checkout procedures against a programmed 68 hours, had spent 167 hours in command module simulators against a requirement for 156, and had accomplished 96 percent of the

required 226 hours of training in the LM simulators and about 94 percent of the 180 hours of required special-purpose training. Overall, 92 percent of the training program had been accomplished. The special-purpose training included such items as lunar surface timeline walk-throughs, lunar surface operations preparation and post-walk-throughs, and bench checks. Astronaut Neil Armstrong had successfully completed his LLTV training program by flying a ground run and eight flights on June 14, 15, and 16.

Ltr., Robert R. Gilruth, MSC, to George E. Mueller, NASA Hq., "Flight crew training summaries," June 27, 1969, with encl., "Apollo 11 Crew Training Summary Status as of June 15, 1969."

June 27

How the decision was reached on who would be the first man to step out onto the moon was reported in a letter by ASPO Manager George M. Low: "Some time during the middle of the night, I had a call from Associated Press informing me that they had a story that Neil Armstrong had pulled rank on Buzz Aldrin to be the first man on the surface of the moon. They wanted to know whether it was true and how the decision was reached concerning who would get out of the LM first.

"To the best of my recollection, I gave the following information:

"a. There had been many informal plans developed during the past several years concerning the lunar timeline. These probably included all combinations of one man out versus two men out, who gets out first, etc.

"b. There was only one approved plan and that was established 2 to 4 weeks prior to our public announcement of this planning. I believe that this was in April 1969.

"c. The basic decision was made by my Configuration Control Board. It was based on a recommendation by the Flight Crew Operations Directorate. I am sure that Armstrong had made an input to this recommendation, but he, by no means, had the final say. The CCB decision was final."

Ltr., Low to B. M. Duff, MSC, "Press Inquiry," June 27, 1969.

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Part 3 (E)

Man Circles the Moon, the Eagle Lands, and Manned Lunar Exploration

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1969

July 1

Preparations continued on schedule for a July 16 launch of Apollo 11. Edwin Aldrin, Neil Armstrong, and Michael Collins were in good physical condition and on schedule for their training and mission preparations. Descent and landing simulations were successfully completed. The recovery ship U.S.S. *Hornet* was prepared for the recovery operation. The Goldstone 64-meter dish antenna was ready to support both the Apollo 11 and the Mariner requirements. [*Mariner VI* and *VII*, launched February 24 and March 27, were on their way to July 31 and August 4 flybys of the planet Mars]. Mission control and the worldwide network stations were completing final simulation and tracking preparations, and the flight plan was ready for distribution.

NASA OMSF, "Manned Space Flight Weekly Report - July 1, 1969."

July 2

The Interagency Committee on Back Contamination agreed to the designation of the MSC Director of Medical Research and Operations as the agent to impose a quarantine applicable to the crew, the spacecraft, and the returned lunar materials during any phase of the Apollo 11 mission. He was authorized to appoint persons at each location and phase of the mission who would have the

responsibility of exercising the quarantine authority if necessary.

Ltr., Apollo Mission Director George H. Hage to NASA General Counsel, "Back Contamination and Quarantine - Apollo 11," July 2, 1969.

July 8

In an effort to stem the increasing number of human errors found in flight hardware, the ASPO Manager appointed a spacecraft walk-down team to take a first-hand look at spacecraft as late as possible before delivery to KSC. Team members selected were highly experienced in their respective fields and thoroughly familiar with the spacecraft. While ASPO recognized that the team could not possibly discover all the possible discrepancies, it hoped that the inspections might help avoid some of the problems experienced in the past.

Ltr., G. M. Low, MSC, to R. A. Petrone, KSC, July 8, 1969.

July 9

The ASPO Manager for the command and service modules expressed belief that costs could be reduced and others avoided by the effective use of agency resources in many areas. However, he pointed out that the very nature of the program - that is, one operating in a research and development atmosphere - would result in higher costs than would a mass-production program.

Memo, Kenneth S. Kleinknecht to Manager, Apollo Spacecraft Program, "Cost of manned flight programs," July 9, 1969.

July 9

Microscopic examination of dust particles collected from the spacecraft after the Apollo 10 mission and of samples collected from the inside of nine garments worn by the Apollo 10 astronauts confirmed preliminary findings that the itching experienced by the astronauts was due to the insulation in the tunnel hatch of the command module. Investigation showed the fiberglass insulation had flaked off during LM pressurization. Review of thermal conditions indicated the insulation was not essential and it was eliminated from future vehicles.

Ltr., Kenneth S. Kleinknecht, MSC, to George W. Jeffs, North American Rockwell Corp., July 9, 1969.

July 16-24

Apollo 11 (AS-506) - with astronauts Neil A. Armstrong, Michael Collins, and Edwin E. Aldrin, Jr., aboard - was launched from Pad A, Launch Complex 39, KSC, at 9:32 a.m. EDT July 16. The activities during earth-orbit checkout, translunar injection, CSM transposition and docking, spacecraft ejection,

and translunar coast were similar to those of *Apollo 10*. (See entry for May 18-26, 1969.)



The Apollo 11 space vehicle thrusts upward from Kennedy Space Center July 16, 1969, on the flight that fulfilled President Kennedy's May 26, 1961, challenge to land man on the moon and return him safely to the earth by the end of the decade.

At 4:40 p.m. EDT July 18, the crew began a 96-minute color television transmission of the CSM and LM interiors, CSM exterior, the earth, probe and drogue removal, spacecraft tunnel hatch opening, food preparation, and LM housekeeping. One scheduled and two unscheduled television broadcasts had been made previously by the *Apollo 11* crew.

The spacecraft entered lunar orbit at 1:28 p.m. EDT on July 19. During the second lunar orbit a live color telecast of the lunar surface was made. A second service-propulsion-system burn placed the spacecraft in a circularized orbit, after which astronaut Aldrin entered the LM for two hours of housekeeping including a voice and telemetry test and an oxygen-purge-system check.

At 8:50 a.m. July 20, Armstrong and Aldrin reentered the LM and checked out all systems. They performed a maneuver at 1:11 p.m. to separate the LM from the CSM and began the descent to the moon. The LM touched down on the moon at 4:18 p.m. EDT July 20. Armstrong reported to mission control at MSC, "Houston, Tranquillity Base here - the *Eagle* has landed." (*Eagle* was the name given to the *Apollo 11* LM; the CSM was named *Columbia*.) Man's first step on the moon was taken by Armstrong at 10:56 p.m. EDT. As he stepped onto the surface of the moon, Armstrong described the feat as "one small step for a man - one giant leap for mankind."

Aldrin joined Armstrong on the surface of the moon at 11:15 p.m. July 20. The astronauts unveiled a plaque mounted on a strut of the LM and read to a worldwide TV audience, "Here men from the planet earth first set foot on the moon July 1969, A.D. We came in peace for all mankind." After raising the American flag and talking to President Nixon by radiotelephone, the two astronauts deployed the lunar surface experiments assigned to the mission and gathered 22 kilograms of samples of lunar soil and rocks. They then reentered the LM and closed the hatch at 1:11 a.m. July 21. All lunar extravehicular activities were televised in black-and-white. Meanwhile, Collins continued orbiting moon alone in CSM *Columbia*.

The *Eagle* lifted off from the moon at 1:54 p.m. EDT July 21, having spent 21 hours 36 minutes on the lunar surface. It docked with the CSM at 5:35 p.m. and the crew, with the lunar samples and film, transferred to the CSM. The LM ascent stage was jettisoned into lunar orbit. The crew then rested and prepared for the return trip to the earth.

The CSM was injected into a trajectory toward the earth at 12:55 a.m. EDT July 22. Following a midcourse correction at 4:01 p.m., an 18-minute color television transmission was made, in which the astronauts demonstrated the weightlessness of food and water and showed shots of the earth and the moon.

At 12:15 p.m. EDT July 24 the *Apollo 11's* command module *Columbia* splashed down in the mid-Pacific, about 24 kilometers from the recovery ship U.S.S. *Hornet*. Following decontamination procedures at the point of splashdown, the astronauts were carried by helicopter to the *Hornet* where they entered a mobile quarantine facility to begin a period of observation under strict quarantine

conditions. The CM was recovered and removed to the quarantine facility. Sample containers and film were flown to Houston.

All primary mission objectives and all detailed test objectives of *Apollo 11* were met, and all crew members remained in good health. (Objectives of all the Apollo flights are shown in Appendix 5.)

MSC, "Apollo 11 (AS-506) Flight Summary," undated; MSC, "Apollo 11 Mission Report" (MSC-00171), November 1969; "Apollo 11 Sequence of Events," July 30, 1969; KSC, "Apollo 11 (AS-506) Quick Look Assessment Report," July 23, 1969; NASA Hq., "Mission Director's Summary Report, Apollo 11," July 24, 1969; *Apollo 11 Mission Report* (NASA SP-238, 1971).

July 19

During the Apollo 11 mission, members of the Lunar International Observer Network (LION) made continuous observations of a lunar area where illuminations had been noted. At 18:45 GMT (2:45 p.m. EDT), the astronauts sighted an illumination in the Aristarchus region, the first time that a lunar transient event was sighted by an observer in space. The sighting was confirmed by a LION observer in West Germany.

NASA OMSF, "Manned Space Flight Weekly Report - August 11, 1969."

July 27-August 1

The scientific experiments planned for the Apollo 11 mission were reported successfully accomplished. The passive seismometry had recorded a series of minor events and withstood temperatures of up to 364 kelvins (195 degrees F). The average temperature in the central station reached 361 K (190 degrees F) at solar noon on July 27 and dropped to 243 K (157 degrees F) on July 31. MSC appointed a study group to investigate the causes of the higher than predicted temperature levels. Lick Observatory in California successfully acquired beams from the laser retroreflector on August 1 and was continuing ranging activities.

NASA OMSF, "Manned Space Flight Weekly Report - August 11, 1969."

July 28

To guard against cannibalization, misuse, or destruction of any part of the lunar mission support equipment, spacecraft, and recovered equipment (however insignificant it might seem) from the *Apollo 11* mission, NASA Hq. specified the following steps: All recovered items would be identified, recorded, and inventoried as soon as quarantine, decontamination, and deactivation activities permitted. All items would be placed in secure storage, under guard if necessary. No removal would be permitted that would deface exterior portions of the spacecraft or portions of the cabin visible through the hatch or windows. No destructive testing would be permitted. Items returned to contractors for testing would be under

bond. Preparation for public display would be expedited.

Ltr., Samuel C. Phillips, NASA Hq., to George M. Low, MSC, "Control and Disposition of Apollo 11 Hardware," July 28, 1969.

July 29

NASA issued a tentative planning schedule for the Apollo program:

Flight	Launch Plans	Tentative Landing Area
Apollo 12	November 1969	Oceanus Procellarum lunar lowlands
Apollo 13	March 1970	Fra Mauro highlands
Apollo 14	July 1970	Crater Censorinus highlands
Apollo 15	November 1970	Littrow volcanic area
Apollo 16	April 1971	Crater Tycho (Surveyor VII impact area)
Apollo 17	September 1971	Marius Hills volcanic domes
Apollo 18	February 1972	Schroter's Valley, riverlike channel-ways
Apollo 19	July 1972	Hyginus Rille region-Linear Rille, crater area
Apollo 20	December 1972	Crater Copernicus, large crater impact area

NASA OMSF, "Manned Space Flight Weekly Report - July 28, 1969."

July 31

The Secretary of Defense announced the assignment of Lt. Gen. Samuel C. Phillips (USAF), who had been serving as Apollo Program Director in the NASA Office of Manned Space Flight, to be Commander of the Air Force Space and Missile Systems Organization (SAMSO) in Los Angeles. He would assume his new responsibilities in the Air Force effective September 1.

NASA Announcement of Key Personnel Change, "DOD Announcement of General Phillips' Air Force Assignment," July 31, 1969.

August 1

During the *Apollo 11* management debriefing, the ASPO Manager noted a number of items requiring investigation. During separation from the S-IVB stage, the CSM autopilot apparently had difficulty determining direction of rotation. After the CSM hatch removal, there was a strong odor of burnt material in the tunnel. The leveling device on one of the experiment packages did not work. The closeup stereo camera was hard to operate and tended to fall over. The temperature in the lunar module was too

cold during sleep periods. The biological isolation garment was uncomfortably hot and its visor fogged. The crew observed flashes at the rate of about one per minute in the command module at night.

Memo, George M. Low, MSC, to Donald D. Arabian, MSC, "Apollo 11 management debriefing," Aug. 1, 1969.

August 7

George Low, James McDivitt, Neil Armstrong, and Edwin Aldrin discussed lunar exploration that could be carried out by astronauts walking in spacesuits or riding roving vehicles. The following conclusions were reached: "a. A possible mode of exploration would be to walk 1 hour (3 to 5 miles [5 to 8 kilometers]) to an exploration site; spend 1 to 2 hours at that site; and then return to the LM. b. It would be easy to carry anything that need be carried, provided that it did not require the hands for the purpose. c. A roving vehicle might work if it had extremely large wheels. There appeared to be no significant advantage of using the presently conceived roving vehicle instead of walking. d. All extravehicular excursions should be carried out by two men at a time. e. Excursions should not be carried out beyond the radius of ground communications."

ASPO Manager, Memo for the Record, "Lunar Exploration," Aug. 13, 1969.

August 7

MSFC-NASA Hq. correspondence emphasized the need to restrict the lunar roving vehicle to a 181-kilogram weight limit. If necessary, range and speed would be traded off to retain this weight limit.

Ltr., Saverio F. Morea, MSFC, to William E. Stoney, Jr., NASA Hq., Aug. 7, 1969.

August 10

The Interagency Committee on Back Contamination met in Atlanta, Ga. Basing its decision on medical and biological data obtained during a 21-day observation period, the committee lifted the quarantine on the *Apollo 11* crew and the personnel in quarantine with the crew. The CSM was also released from quarantine. However, all loose equipment removed from the spacecraft and held in the Lunar Receiving Laboratory would remain in quarantine until the lunar samples were released. The committee also agreed that a postlanding ventilation filter would not be required on Apollo 12.

Memo, Richard S. Johnston, MSC, to ASPO Manager, "Apollo Back Contamination Program," Aug. 11, 1969.

August 12

During lunar module checkout activities at KSC, the LM-6 (for Apollo 12) guidance computer was

removed and replaced because of an unexpected restart during panel revalidation.

NASA OMSF, "Manned Space Flight Weekly Report - August 18, 1969."

August 13

S. C. Phillips, NASA Hq., suggested that for communications on the lunar surface a long, deployable antenna might work. He suggested that an antenna about 30 meters long could be used. The antenna would be rolled up like a tape measure and would curl into a cylinder when deployed, somewhat like an antenna that had been used on the CSM.

Ltr., G. M. Low, MSC, to J. A. McDivitt, MSC, "Discussions with General Phillips," Aug. 13. 1969.

August 18

The Lunar Roving Vehicle Task Team, which had been established at MSFC on April 7, was reconstituted as the Lunar Mobility Task Team. Its function would be to direct and coordinate MSFC efforts to conceive, design, and develop various modes of lunar transportation systems.

MSFC Organization Announcement, "Lunar Roving Vehicle Task Team Reconstituted as the Lunar Mobility Task Team," Aug. 18, 1969.

August 19

The *Apollo 11* seismic experiment package on the moon was reactivated. Indications were that the unit was fully functional. The laser reflector was also operating well. Scientists at the McDonald Observatory, Fort Davis, Tex., conducted ranging operations that established the distance between the earth and the moon, to within an accuracy of 4 meters as 373,794.3333 kilometers.

NASA OMSF, "Manned Space Flight Weekly Report - August 25, 1969."

August 20

MSC rejected a Grumman proposal to use the LM as a lunar reconnaissance module. MSC pointed out that an MSC special task team had recently studied a number of proposals for lunar reconnaissance. These included use of a command module test vehicle, the AAP multiple docking adapter, the subsystem test bed, the ascent stage of the LM, and the entire LM vehicle.

Ltrs., Joseph G. Gavin, Jr., Grumman Aerospace Corp., to Robert R. Gilruth MSC, July 18, 1969; Gilruth to Gavin, Aug. 20, 1969.

August 22

NASA named Rocco A. Petrone, Director of Launch Operations at KSC, to succeed Samuel C. Phillips as Director of the Apollo Program effective September 1. (See also July 31, 1969, entry.)

NASA News Release 69-124, "Petrone Named Apollo Director," Aug. 22, 1969.

August 26

In response to a query from MSFC, MSC took the position that primary batteries as opposed to secondary (rechargeable batteries) should be used to power the lunar roving vehicle. Concern was expressed that a solar array recharge assembly would introduce an extra complexity into the LM payload packaging and the roving vehicle servicing requirements and would contribute to a loss in effective EVA time because astronauts would need time to deploy the solar array and connect it to the rover.

Ltrs. Saverio F. Morea, MSFC, to John D. Hodge, MSC, July 14, 1969; Hodge to Morea, "Power requirements for the Lunar Roving Vehicle (LRV)," August 26, 1969.

September 2

Analyses of the radioactive decay of Argon 40 and Neon 21 in two lunar samples indicated that the minimum age of the part of the Sea of Tranquillity from which the samples were obtained was about 3.1 billion years - plus or minus 200 million years.

NASA OMSF, "Manned Space Flight Weekly Report - September 2, 1969."

September 8

After the preliminary examination of *Apollo 11* lunar samples, the Department of the Interior made a number of recommendations for processing samples to be brought from the moon by the Apollo 12 mission.

Memo, E. C. T. Chao and R. L. Smith, Dept. of Interior, to W. Hess, A. J. Calio, and P. R. Bell, MSC, "Recommendations and suggestions for preliminary examination of Apollo 12 returned lunar samples," Sept. 6, 1969; ltr., R. S. Johnston, MSC, to Chao and Smith, Sept. 23, 1969.

September 16

The first reported weights of *Apollo 11* lunar samples were inaccurate because of a number of variables that could not be eliminated until after quarantine was lifted, MSC told NASA Hq. Because of the concern this inaccuracy had generated, procedures were being developed for future missions to permit

more accurate determination of sample weights early in the Lunar Receiving Laboratory processing cycle.

Memo, George M. Low, MSC, to Rocco A. Petrone, NASA Hq., "Apollo 11 Lunar Sample Weight," Sept. 16, 1969.

September 17

The Interagency Committee on Back Contamination recommended changes in Apollo mission recovery procedures, including:

- Elimination of the biological isolation garment and, instead, use of a mask and clean room garment for astronauts returning from lunar missions.
- Design changes to improve the spacecraft and mobile quarantine facility tunnel operation.

Memo for record, Richard S. Johnston, MSC, "Apollo 12 Back Contamination Program," Sept. 17, 1969; memo, Donald K. Slayton, MSC, to Special Assistant to Director, "Crew comments on the use of biological isolation garment (BIG)," Oct. 6, 1969.

September 19

MSC replied to a query that 136 flags of other nations, the U.N. flag, and flags from each state and territory of the United States had been flown on *Apollo 11*. The flags, measuring 10.16 cm x 15.24 cm and made of silkscreened rayon, were procured through available commercial sources. Vacuum packed and stowed in Beta cloth bags for flammability protection the flags were not removed from the containers during the flight. The American flag left on the surface of the moon would probably last for a considerable period, since the only deterioration expected would be from the solar wind.

Ltr., Donald K. Slayton, MSC, to Mrs. Seddon Sadtler, ca. Sept. 19, 1969.

September 23

In response to a query from *Guinness Superlatives*, London, as to the maximum distance from the earth reached by *Apollo 8* and *Apollo 11*, MSC said the maximum distance for *Apollo 8* was 377,348.704 kilometers, during the 10th lunar revolution. The maximum distance from the earth for *Apollo 11* was 389,921.3764 kilometers, during lunar orbit insertion. However, because of the requirement to exceed previously established space records by 10 percent, the altitude achieved on *Apollo 8* was still the recognized record.

Ltr., George M. Low, MSC, to Norris D. McWhirter, *Guinness Superlatives*, Sept. 23, 1969.

September 25

James A. McDivitt was appointed ASPO Manager at MSC. George M. Low, former ASPO Manager was temporarily on special assignment at MSC to plan future MSC programs and work on organizational matters.

MSC News Release, 69-66, Sept. 25, 1969.

September 25-26

A Manned Space Flight Awareness seminar was held at MSC. The seminar, attended by some 500 industry and government representatives, emphasized the need for maintaining the dedication and motivation that led to the success of *Apollo 11*.

NASA OMSF, "Manned Space Flight Weekly Report - September 29, 1969."

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Part 3 (F)

Man Circles the Moon, the Eagle Lands, and Manned Lunar Exploration

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October 3

An exchange of correspondence that had begun in April formalized the suggestion that a series of handbooks on the "lessons learned" from the Apollo program should be prepared as an aid to future programs.

Ltrs., Samuel C. Phillips, NASA Hq., to George M. Low, MSC, April 30, 1969; Low to Phillips, May 5, 1969; memos, Low to Director of Flight Operations, "Apollo experience reports," Sept. 23, 1969; Christopher C. Kraft, Jr., MSC, to distr., "Documentation of FOD Apollo experience," Oct. 3, 1969.

October 6

Program responsibility for the Saturn launch vehicles was divided, at the Headquarters level, between the Apollo Program Office and the Apollo Applications Program. Overall responsibility for the Saturn V remained with the Apollo Program Office, while overall responsibility for the Saturn IB vehicle was assigned to Apollo Applications.

Memorandum of Understanding between the Apollo and Apollo Applications Program Offices on Saturn Vehicle Management Interfaces, signed Rocco A. Petrone, APO, Oct. 6, 1969, and William C.

Schneider, AAP, Oct. 13, 1969.

October 10

Major milestones were reached for extending astronauts' staytime on the moon and increasing their mobility for the Apollo 16-20 missions. Modifications in the A7L spacesuit incorporating improved waist mobility were authorized, and letter contract authority for the portable life support system secondary life support system was approved.

Minutes of Manned Space Flight Management Council Meeting, Oct. 15, 1969.

October 12

A portion of the Apollo 12 mission would be devoted to an examination of *Surveyor III* and recovery of its TV camera and thermal-switch glass mirror fragments, MSC announced. Recovery of the glass fragments was important to Jet Propulsion Laboratory, to provide data for designing thermal switches for the Mercury-Venus Mariners to be flown in 1973. However, recovery of the splinters could easily cause cuts and leaks in the astronauts' gloves; extreme caution would be required. The following procedures were recommended: use of a line during the initial solo descent into the *Surveyor III* crater, to determine the footing and climbing situation before both crewmen descended into the crater, and recovery of thermal-switch glass fragments by a suitable tool such as tweezers, to prevent glove damage.

Memo, James A. McDivitt, MSC, to distr., "Apollo 12 Surveyor III safety review and recommendation," Oct. 18, 1969; Apollo 12 Surveyor III Safety Report, Oct. 10, 1969.

October 21

Apollo 12 film from the onboard cameras would be delivered in two batches to the Lunar Receiving Laboratory for decontamination within 24 to 36 hours after recovery, MSC reported. Decontamination was expected to take an additional 47 hours for each batch. Film would then be released for processing at the Photographic Technology Laboratory. Photography containing earth views would be prepared at once, but would not be released until authorized by the MSC Director. The flight crew logs would be photographically copied from outside the crew reception area of the LRL using procedures previously developed and agreed on. Original logs would be retained within the crew recovery area during the quarantine period, after which they would be picked up by the flight crew.

Memo, Donald D. Arabian, MSC, to Chief, Photographic Technology Laboratory, "Photographic processing and distribution requirements for Apollo 12 (AS-507) mission and scientific photography," Oct. 21, 1969.

October 22

The Flight Crew Operations Directorate expressed opposition to a major effort to develop a lunar flyer until after the Apollo 16 mission. Plans for Apollo flights 12 through 16 required that the LM be maneuvered to landings at various points of scientific interest on the lunar surface, and experience from *Apollo 11* and partial gravity simulators indicated the crews would be able to accomplish their surface EVA tasks for these missions without the aid of a mobility device.

Memo, Donald K. Slayton, MSC, to Director of Engineering and Development, "Lunar flyer studies," Oct. 22, 1969.

October 27

MSC Flight Operations informed the Apollo 12 commander that records could be set in a number of areas on the Apollo 12 mission. MSC planned to file claims with the Fédération Aéronautique Internationale for:

Class records for a lunar mission

1. Duration of a lunar mission.
2. Duration of stay in lunar orbit.
3. Duration of stay on lunar surface.
4. Duration of stay in spacecraft on lunar surface.
5. Duration of stay outside spacecraft on lunar surface.

Absolute world record

1. Duration of stay outside spacecraft on lunar surface.

Memo, Sigurd A. Sjöberg, MSC, to the Apollo 12 Commander, "World Space Flight Records for the Apollo 12 Mission," Oct. 27, 1969.

October 28

A lunar roving vehicle (LRV) cost-plus-incentive-fee contract was awarded to the Boeing Co. LRV-1 was scheduled for delivery on April 1, 1971, leaving only 17 months for vehicle development, production, and tests. The LRV project was managed at MSFC by Saverio F. Morea as a project within the Saturn Program Office. The Boeing Company would manage the LRV project in Huntsville, Ala., under Henry Kudish. General Motors Corp. AC Electronics Defense Research Laboratories in Santa Barbara, Calif., would furnish the mobility system (wheels, motors, and suspension). The Boeing Co. in Seattle, Wash., would furnish the electronics and navigation system. Vehicle testing would take place at the Boeing facility in Kent, Wash., and the chassis manufacturing and overall assembly would take place at the Boeing facility in Huntsville, Ala.

Memo, James A. McDivitt, MSC, to distr., "Lunar Roving Vehicle," Nov. 1, 1969; NASA OMSF, "Manned Space Flight Weekly Report - November 3, 1969."

October 30

The Interagency Committee on Back Contamination made the following decisions regarding Apollo 12. The biological isolation garment would not be used. A biological mask and flight suit would be used instead. (See entry of September 17, 1969.) Sterilization of flight film was eliminated. Data tapes would be sterilized if required before the release of samples. The command module would not be decontaminated unless access for postflight testing was required before the sample release date of January 7, 1970.

Memos, Richard C. Johnston, MSC, to distr., "Minutes of ICBC Meeting of October 30, 1969"; Johnston to Director of Medical Research and Operations and Director of Science and Applications, "ICBC Meeting," Oct. 7, 1969.

November 3

The spacecraft walk-down team, established by ASPO in July in an effort to stem the increased number of human errors found in flight hardware, made a walkaround inspection of CSM-110 (Apollo 14 hardware). (See entry of July 8, 1969.) Cooperation of North American Rockwell and the Resident Apollo Spacecraft Program Office was excellent during the preparation and implementation of the inspection. No significant discrepancies were found by the inspection team during the several hours of inspection.

Memo, Scott H. Simpkinson, MSC, to ASPO Command and Service Modules Manager, "Action items resulting from CSM-110 engineering walkaround inspection," Nov. 10, 1969.

November 3

Christopher C. Kraft, Jr., MSC Director of Flight Operations, suggested that an in-house review reevaluate the Apollo secondary life support system, because of its complexity and cost of development, and at the same time reexamine the possibilities of an expanded oxygen purge system using identical concepts.

Memo, Christopher C. Kraft, Jr., MSC, to James A McDivitt, MSC, "SLSS," Nov. 3, 1969.

November 4

Provision of a thermometer that could be attached to the ALSEP for the Apollo 13 mission, to take a reading of the lunar surface soil temperature, was being considered at MSC.

Memo, James A. McDivitt, MSC, to Robert A. Gardiner, MSC, "Lunar surface temperatures," Nov. 4, 1969.

November 4-7

Preparations for a November 14 launch of Apollo 12 continued on schedule. Final lunar surface simulations with the crew, network, and Mission Control Center were completed on November 4. The instrument-unit command system, with a replacement transponder and decoder, was successfully retested and in-place repair of four LM-6 circuit breakers was completed, also on November 4. The recovery quarantine equipment and mobile quarantine facility completed checkout for shipment to the recovery ship on November 7. The final consumable analysis showed positive margins for all phases of the mission. Also, on November 7, the countdown to launch began at KSC (T minus 98 hours). A 31-hour hold was scheduled for November 8 with the count resuming at 9:00 a.m. November 9 (T minus 84 hours). The hold was designed to avoid premium wage cost.

NASA OMSF, "Manned Space Flight Weekly Report - November 10, 1969."

November 6

In an exchange of correspondence between MSFC and MSC concern was expressed over the weight growth of the lunar roving vehicle (LRV) and its payload. As a result, a recommendation was made that MSFC manage the weight of the LRV and MSC the payload weight.

Ltrs., Saverio F. Morea, MSFC, to James A. McDivitt, MSC, "LRV Weight Growth," Nov. 6, 1969; McDivitt to Roy E. Godfrey, MSFC, Dec. 12, 1969.

November 10

At the request of the Apollo 12 crew, the internal primary guidance and navigational control system targeting for descent was being changed so that the automatic guidance would land LM-6 at *Surveyor III* rather than at a point offset 305 meters east and 153 meters north as originally planned.

Memo, James A. McDivitt, MSC, to distr., "Apollo 12 PGNCS descent targeting is being changed," Nov. 10, 1969; TWX, McDivitt to C. Lee and R. Sheridan, NASA Hq., Nov. 4, 1969.

November 10

NASA announced the resignation of Associate Administrator for Manned Space Flight George E. Mueller effective December 10. In December Charles W. Mathews was named Acting Associate Administrator for Manned Space Flight until a successor for Mueller was appointed.

Astronautics and Aeronautics, 1969 (NASA SP-4014, 1970), pp. 368, 405; NASA News Release 69-151; NASA Announcement, Dec. 11, 1969.

November 13

President Nixon nominated George M. Low, former Apollo Spacecraft Program Manager at MSC, as NASA Deputy Administrator. Low had been with the space program since 1949, when he joined NACA. The Senate confirmed the nomination on November 26. (See also entries of September 25 and December 3, 1969.)

Office of the Federal Register, National Archives and Records Service, *Weekly Compilation of Presidential Documents*, Nov. 17, 1969, p. 1597; *Congressional Record*, Nov. 26, 1969, pp. S15140, D1126.

November 14-24

Apollo 12 (AS-507)-with astronauts Charles Conrad, Jr., Richard F. Gordon, Jr., and Alan L. Bean as the crewmen-was launched from Pad A, Launch Complex 39, KSC, at 11:22 a.m. EST November 14. Lightning struck the space vehicle twice, at 36.5 seconds and 52 seconds into the mission. The first strike was visible to spectators at the launch site. No damage was done. Except for special attention given to verifying all spacecraft systems because of the lightning strikes, the activities during earth-orbit checkout, translunar injection, and translunar coast were similar to those of *Apollo 10* and *Apollo 11* (see entries of May 18-26 and July 16-24, 1969).

During the translunar coast astronauts Conrad and Bean transferred to the LM one-half hour earlier than planned in order to obtain full TV coverage through the Goldstone tracking station. The 56-minute TV transmission showed excellent color pictures of the CSM, the intravehicular transfer, the LM interior, the earth, and the moon.

At 10:47 p.m. EST, November 17, the spacecraft entered a lunar orbit of 312.6 x 115.9 kilometers. A second service propulsion system burn circularized the orbit with a 122.5-kilometer apolune and a 100.6-kilometer perilune. Conrad and Bean again transferred to the LM, where they performed housekeeping chores, a voice and telemetry test, and an oxygen purge system check. They then returned to the CM.

Conrad and Bean reentered the LM, checked out all systems, and at 10:17 p.m. EST on November 18 fired the reaction control system thrusters to separate the CSM 108 (the *Yankee Clipper*) from the LM-6 (the *Intrepid*). At 1:55 a.m. EST November 19, the *Intrepid* landed on the moon's Ocean of Storms, about 163 meters from the *Surveyor III* spacecraft that had landed April 19, 1967. Conrad, shorter than Neil Armstrong (first man on the moon, July 20), had a little difficulty negotiating the last step from the LM ladder to the lunar surface. When he touched the surface at 6:44 a.m. EST November 19, he exclaimed, "Whoopee! Man, that may have been a small step for Neil, but that's a long one for me."

Bean joined Conrad on the surface at 7:14 a.m. They collected a 1.9-kilogram contingency sample of lunar material and later a 14.8-kilogram selected sample. They also deployed an S-band antenna, solar wind composition experiment, and the American flag. An Apollo Lunar Surface Experiments Package with a SNAP-27 atomic generator was deployed about 182 meters from the LM. After 3 hours 56 minutes on the lunar surface, the two astronauts entered the *Intrepid* to rest and check plans for the next EVA.

The astronauts again left the LM at 10:55 p.m. EST November 19. During the second EVA, Conrad and Bean retrieved the lunar module TV camera for return to earth for a failure analysis, obtained photographic panoramas, core and trench samples, a lunar environment sample, and assorted rock, dirt, bedrock, and molten samples. The crew then examined and retrieved parts of *Surveyor III*, including the TV camera and soil scoop. After 3 hours 49 minutes on the lunar surface during the second EVA, the two crewmen entered the LM at 2:44 a.m. EST November 20. Meanwhile astronaut Gordon, orbiting the moon in the *Yankee Clipper*, had completed a lunar multispectral photography experiment and photographed proposed future landing sites.

At 9:26 a.m. EST November 20, after 31 hours 31 minutes on the moon, *Intrepid* successfully lifted off with 34.4 kilograms of lunar samples. Rendezvous maneuvers went as planned. The LM docked with the CSM at 12:58 p.m. November 20. The last 24 minutes of the rendezvous sequence was televised. After the crew transferred with the samples, equipment, and film to the *Yankee Clipper*, the *Intrepid* was jettisoned and intentionally crashed onto the lunar surface at 5:17 p.m. November 20, 72.2 kilometers southeast of *Surveyor III*. The crash produced reverberations that lasted about 30 minutes and were detected by the seismometer left on the moon.

At 3:49 p.m. EST November 21, the crew fired the service propulsion system engine, injecting the CSM into a transearth trajectory after 89 hours 2 minutes in lunar orbit. During the transearth coast, views of the receding moon and the interior of the spacecraft were televised, and a question and answer session with scientists and the press was conducted.

Parachute deployment and other reentry events occurred as planned. The CM splashed down in mid-Pacific at 3:58 p.m. EST November 24, 7.25 kilometers from the recovery ship, U.S.S. *Hornet*. The astronauts, wearing flight suits and biological face masks, were airlifted by helicopter from the CM to the recovery ship, where they entered the mobile quarantine facility. They would remain in this facility until arrival at the Lunar Receiving Laboratory, MSC. The *Apollo 12* mission objectives were achieved and the experiments successfully accomplished. [All Apollo experiments are listed in Appendix 5.]

MSC "Apollo 12 (AS-507) Flight Summary," undated; MSC, "Apollo 12 Mission Report" (MSC-01855), March 1970; MSC Apollo Program Summary Report," preliminary draft, p. 2-38, undated; TWX, F. A. Speer, MSFC, to C. M. Lee, NASA Hq., "Apollo 12 (AS-507) HOSC Report," Nov. 14, 1974; ltr., E. R. Mathews, KSC, to distr., "Apollo 12 (AS-507) Quick Look Assessment Report," Nov. 26, 1969; *Apollo 12 Preliminary Science Report* (NASA SP-235. 1970).

November 15

A review of North American Rockwell Space Division's in subcontract management indicated that its subcontractor schedule and cost performance had been excellent. The quality had been achieved, for the most part, by effective North American Rockwell subcontract management planning and execution of these plans.

Ltr., Kenneth S. Kleinknecht, MSC, to George W. Jeffs, North American Rockwell Corp., Nov. 15, 1969.

November 17

NASA selected an Apollo Orbital Science Photographic Team to provide scientific guidance in design, operation, and data use of photographic systems for the Apollo lunar orbital science program. Chairman was Frederick Doyle of the U.S. Geological Survey. The 14-man team comprised experts from industry, universities, and government.

NASA OMSF, "Manned Space Flight Weekly Report - November 17, 1969."

November 17

NASA discontinued the use of names such "LEO," "ALEM," and "Apollo Lunar Exploration Program" that had been used since *Apollo 11* to identify the lunar exploration phase of the Apollo program. Henceforth, the single word title "Apollo" would be used when referring to the program. However, additional descriptive language, such as "lunar exploration phase of Apollo" and "Apollo lunar exploration" would continue to be authorized for defining the Apollo program activity. The action was taken to establish uniformity and eliminate misunderstanding.

Ltr., George E. Mueller, NASA Hq., to Robert R. Gilruth, MSC, Nov. 17, 1969; memo, James A. McDivitt, MSC, to distr., "Identification of the current lunar exploration phase of the Apollo Program," Nov. 26, 1969.

November 26

Christopher C. Kraft, Jr., was appointed Deputy Director of MSC. Kraft, Director of Flight Operations at MSC since November 1963, succeeded George S. Trimble, Jr., who had resigned September 30.

NASA Announcement, Jan. 18, 1972; NASA News Release 72-11; MSC News Release 69-70.

December 1

The MSC Flight Crew Operations Directorate submitted its requirement for a simple lightweight Rover (lunar roving vehicle) guidance and navigation system that would provide the following displayed information to the crew: vehicle heading and heading to the LM, speed in kilometers per hour, total distance traveled in kilometers, and distance to the LM. Requirements were based on the assumptions that the landing area was as well known as for *Apollo 12*, all traverses were preplanned, accurate photo maps were available, and there was MSFN support through voice communications. The Directorate emphasized that it had no requirements for a display of pitch and roll, X and Y coordinates, or time.

Memo, Donald K. Slayton, MSC, to ASPO Manager, "Rover guidance and navigation system," Dec. 1, 1969.

December 2

The *Apollo 12* crew program/project debriefing was held. Some areas of concern included the lunar dust which obscured visibility during the landing, a dust problem in the suit connectors after completion of the first extravehicular activity, and wear on the suits after completion of the second EVA.

NASA OMSF, "Manned Space Flight Weekly Report - December 8, 1969."

December 3

MSFC Director Wernher von Braun forwarded to MSC Director Robert R. Gilruth an analysis of increasing space scientists' dissatisfaction with the space program. "Ultimate origin" of dissatisfaction was in "the very complex and difficult interfaces between science, engineering, and management" in NASA and governmental systems and "the need for a quick and flexible challenge-and-response capability."

Young scientists from an academic environment found changing from a research scientist to a science administrator difficult; they often preferred active research to desk-and-meetings career.

Many scientists were reluctant to accept the long times between conceptual design and data gathering in space experiments - often 6 to 10 years. The question was not only of patience, graduate student support, and funding continuity, but also of scientific obsolescence.

Scientists felt that science was not as well represented in upper NASA management as were engineering and project management and that high-level decisions were often made without consideration of scientific viewpoints. While recognizing that the space program also had other prime objectives - such as advancement of technology, national achievement, applications, earth resources, and "bringing the world closer together" - they felt that "science is still a stepchild in this family of program objectives."

The analysis said that a good portion of the problems could be relieved by actions taken by Centers and NASA Hq. over the next few months and years. NASA space projects should be structured to give more

scientists an opportunity to launch experiments. With the few present scientific flights, only a few scientists could hope to have their experiments flown in their lifetimes. The situation would improve when the Space Shuttle and Space Station were available, but that would not be before 1978 or 1979. With low emphasis on OAO, HEAO, Pioneer, ATM, and planetary flights suggested by the President's Space Task Group, "we will have almost no good flight experiments prepared, and almost no scientists left in the program, by the time the gates of the shuttle and the station open for science."

NASA should also find ways to reduce the time span between conception and flight of an experiment. "For Bill Kraushaar, who proposed a measurement of gamma rays with a simple (now almost obsolete) sensor on a Saturn launch vehicle, this time is now 8 years, with no end in sight." For the Apollo telescope mount principal investigators, "this time will be 8 years, provided that ATM-A is launched early in 1972."

The Shuttle promised great improvements, but "initiation or continuation of unmanned, relatively unsophisticated spacecraft projects for science payloads" was "highly desirable."

Procedures for proposal, screening, selection, acceptance, and final approval of experiments were "exceedingly cumbersome and time consuming." Streamlining requirements after approval - early definition, documentation, reporting, reviews, and administrative actions - as well as the maze of committees, boards, panels, and offices, was urgently recommended.

"Many scientists inside and outside NASA have suggested that NASA should establish, at a high level in the Administrator's Office, a 'Chief Scientist' position with no other functions than to act as a spokesman for . . . scientists who wish to participate in the space program."

Ltr., von Braun, MSFC, to Gilruth, MSC, Dec. 3, 1969, with encl., memo, Ernst Stuhlinger, MSFC, to von Braun, "Notes on 'Science in NASA,'" Nov. 7, 1969.

December 3

George M. Low was sworn in as NASA Deputy Administrator by Thomas O. Paine, NASA Administrator. (See November 13.)

NASA News Release 69-159, Dec. 3, 1969.

December 15

NASA was considering incorporation of a mobile equipment transporter on LM-8, LM-9, and LM-10, to help with problems such as the *Apollo 12* astronauts had in carrying hand tools, sample boxes and bags, a stereo camera, and other equipment on the lunar surface. The MET also could extend lunar surface activities to a greater distance from the lunar module. A prototype MET and training hardware were being fabricated and were expected to be available in late December.

Memo, James A. McDivitt, MSC, to Rocco A. Petrone, NASA Hq., "Mobile Equipment Transporter (MET)," Dec. 15, 1969.

December 16-18

A lunar roving vehicle preliminary requirements review was held at MSFC. MSC was asked to review the requirement for a roll bar which it had requested in the interest of astronaut safety. Navigation system requirements as defined by MSC would require changes in the design presented by Boeing (see entry of December 1, 1969). Full-length fenders and effects of dust on radiators, sealed joints, and vision needed to be considered and appropriate measures taken in the vehicle design, the review found.

Ltr., William E. Stoney, NASA Hq., to Roy E. Godfrey, MSFC, and James A. McDivitt, MSC, "Lunar Roving Vehicle Preliminary Requirements Review, December 16-18, 1969," Dec. 24, 1969; memo, Donald K. Slayton, MSC, to David B. Pendley, MSC, "Lunar Rover Vehicle (LRV) crew safety provisions," Dec. 12, 1969.

December 18

A configuration control panel for Apollo GFE scientific equipment was established at MSC, with Robert A. Gardiner as chairman. The panel would control proposed changes in Apollo spacecraft GFE science equipment.

Memo, James A. McDivitt, MSC, to distr., "Configuration control panel for GFE scientific equipment," Dec. 18, 1969.

December 22

Correlation of the *Apollo 12* descent film with the crew's comments during landing indicated that lunar dust first became apparent at about 30 meters from the surface and that from about 12 meters above to the actual touchdown the ground was almost completely obscured by the dust. Because of both *Apollo 11* and *Apollo 12* landing experiences, studies were begun and discussions held about various aspects of lunar dust. An MSC management review in the latter part of January 1970 would include discussions of the basic mechanism of erosion during landing, the possibility of alleviating the effects of erosion on visibility, and an estimate of what could be expected at future lunar landing sites.

Memo, James A. McDivitt, MSC, to distr., "Investigation of the effects of lunar dust during LM landing," Dec. 22, 1969; NASA OMSF, "Manned Space Flight Weekly Report - December 22, 1969"; ltr., Robert R. Gilruth, MSC, to Rocco A. Petrone, NASA Hq., "Landing site for Apollo 13," Dec. 18, 1969.

December 28

MSC announced the appointment of Sigurd A. Sjoberg as Director of Flight Operations, replacing Christopher C. Kraft, Jr., who had been appointed MSC Deputy Director Nov. 26. Sjoberg had been Deputy Director of Flight Operations since 1963.

MSC News Release 70-1, Jan. 1, 1969.

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Part 3 (G)

Man Circles the Moon, the Eagle Lands, and Manned Lunar Exploration

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January 4

NASA had canceled the Apollo 20 mission and stretched out the remaining seven missions to six-month intervals, Deputy Administrator George M. Low told the press in an interview after dedication of the Lunar Science Institute (next to MSC in Houston). Budget restrictions had brought the decision to suspend Saturn V launch vehicle production after vehicle 515 and to use the Apollo 20 Saturn V to

launch the first U.S. space station in 1972. (See also Jan. 7.)

UPI, "Apollo Missions Extended to '74," *New York Times*, Jan. 5, 1970, p. 10; NASA Administrator Thomas O. Paine in NASA News Release, "NASA Future Plans," press conference transcript, Jan. 13, 1970.

January 5-8

Detailed reports on the *Apollo 11* sample analyses were presented at the Lunar Science Conference at MSC. Principal investigators covered the fields of geology, mineralogy, petrology, radiogenic isotopes, inorganic and organic chemistry, solar wind and cosmic ray spallation products, magnetic and electrical properties, physical properties, impact metamorphism, and micropaleontology. The results added up to the greatest single advance in the understanding of a planetary-size body attained to date.

Abstract, N. W. Hinnners, Bellcomm, Case 340, "Significant Results Reported at the Apollo 11 Lunar Science Conference," Jan. 30, 1970.

January 6

An MSC Experiments Review Group was established to consider new or late experiments for the Apollo flights. The group would recommend MSC policy on changes in experiments and would serve as a management clearing house.

Memo, James A. McDivitt, MSC, to distr., "Apollo Experiments Review Group," Jan. 6, 1970.

January 6

North American Rockwell announced a reorganization to strengthen its operating divisions, streamline channels of communication, and place more direct responsibility for performance with top division management.

Ltr., J. Leland Atwood, North American Rockwell Corp., to Robert R. Gilruth, MSC, Jan. 6, 1970.

January 6

North American Rockwell declined to become a member of the Coordinated Aerospace Supplier Evaluation (CASE) organization. North American Rockwell stated that its Certified Special Processors system provided greater effectiveness, that there was no real assurance that a supplier listed in the CASE Register was capable of performing to all the requirements of the indicated specifications, and that participants in CASE were prohibited from any exchange of information concerning supplier inadequacies. Several processors discontinued by North American Rockwell because of poor performance were still enjoying the full benefit of listing in the CASE Register, with the implication of

system acceptability and certified-processor status that the listing provided.

Ltr., George W. Jeffs, North American Rockwell Corp., to Kenneth S. Kleinknecht, MSC, Jan. 6, 1970.

January 7

NASA issued instructions for deletion of the Apollo 20 mission from the program (see January 4). MSC was directed to take immediate action to:

- Stop work on LM-14 and determine its disposition.
- Delete requirements for the Apollo 20 spacesuits and portable and secondary life support systems.
- Determine disposition of CSM 115A pending a final decision as to its possible use in a second workshop mission.
- Reevaluate orbital science experiments and assignments and prepare proposed revisions.

TWX, Rocco A. Petrone, NASA Hq., to MSC, "Apollo 20 Deletion," Jan. 7, 1970.

January 12

Dale D. Myers' appointment as NASA Associate Administrator for Manned Space Flight was announced effective January 12, to succeed Dr. George E. Mueller, who had joined General Dynamics Corp. in New York City as a Vice President. Before this appointment, Myers was Vice President and General Manager of the Space Shuttle Program, North American Rockwell Corp.

NASA News Release 70-4, Jan. 8, 1970.

January 14

The scientific debriefing of the *Apollo 12* astronauts indicated there were areas of strong interest for which there was no data and that the data could have been provided by an Apollo lunar surface closeup stereo camera. These included three distinct kinds of soil noticed by the astronauts, strangely patterned surface in certain areas, glazings in craters, and fillets around certain rocks. To assist the Apollo 13 astronauts in making scientific judgment of targets to be documented, the following photography list was established: unexpected features, glassy features, rock-soil junction, undisturbed surface, surface patterns, rock surface, and craters.

Memos, Anthony J. Calio, MSC, to James A. McDivitt, MSC, "Experiment S184 on Apollo 13, Apollo Lunar Surface Close-up Photography," Jan. 14, 1970; Richard S. Johnston, MSC, to Lee R. Scherer, NASA Hq., "Close-up stereo camera utilization on Apollo 13," Jan. 27, 1970.

January 16

An MSC meeting to realign the Apollo 16-19 lunar orbital science experiments recommended that the Sounding Radar Experiment, S-167, be deleted and the Lunar Electromagnetic Sounder, S-168, should be developed and flown. Scientific-value for the experiments was ranked in the following descending priorities for the various scientific disciplines: geochemistry, particles and fields, imagery and geodesy, surface and subsurface profiles, and atmospheres.

Minutes, Lunar Orbital Experiments Review, Jan. 16, 1970; memo, James A. McDivitt, MSC, to Rocco A. Petrone, NASA Hq., "Lunar orbital science experiments," Jan. 21, 1970.

January 29

Ground rules for service module design and integration, established during recent changes in the lunar orbital science program (see January 16), were reported. The Apollo LM experiment hardware would be installed and tested at KSC. A single scientific instrument module configuration was being proposed for Apollo 16-19 with modification kits developed, as required, to install Apollo 18 and Apollo 19 experiments. An expanded Apollo LM data system would be available for Apollo 16 (spacecraft 112).

Memo, James A. McDivitt, MSC, to Rocco A. Petrone, NASA Hq., "Apollo lunar orbital science program," Jan. 29, 1970.

February 5

North American Rockwell completed an investigation, requested by NASA, of the *Apollo 12* flight anomalies associated with apparent vehicle electrostatic discharges at 36.5 and 52 seconds into the flight. The investigation indicated the most logical recommendation consistent with cost and schedule considerations to minimize or eliminate similar occurrences was for more restrictive launch rules. When atmospheric conditions exhibited electrostatic gradients in excess of several thousand volts with severe fluctuations or when heavy cloud conditions associated with frontal passages existed even in the absence of precipitation or reported spherics activities, delay of launch should be considered.

Ltr., George W. Jeffs, North American Rockwell Corp., to James A. McDivitt, MSC, Feb. 5, 1970.

February 6

A statement of agreements was reached between NASA Hq. and the Centers covering the requirements for a lunar roving vehicle (LRV). Appropriate portions of the agreements were being incorporated in a revised Apollo Program Specification and in Apollo Program Directive No. 4.

Memo, Rocco A. Petrone, NASA Hq., to MSFC, MSC, and KSC, "Lunar Roving Vehicle Requirements," Feb. 6, 1970.

February 17

MSC appointed a panel to investigate a February 13 accident at the Aerojet-General plant in Fullerton, Calif., that had damaged a lunar module descent tank beyond repair. Panel findings were reported to a review board later in the month, which recommended needed safety measures.

Ltr., O. G. Morris, MSC, to R. H. Tripp, Grumman, Feb. 17, 1970; memo for record, S. H. Simpkinson, MSC, "LM descent tank incident at Aerojet-General Corporation, California, on February 13, 1970," March 6, 1970.

March 7

In a White House release, President Nixon listed six specific objectives for the space program: continued exploration of the moon, exploration of the planets and the universe, substantial reductions in the cost of space operations, extension of man's capability to live and work in space, rapid expansion of the practical applications of space technology, and greater international cooperation in space.

Office of the Federal Register, National Archives and Records Service, *Weekly Compilation of Presidential Documents*, March 9, 1970, pp. 328-31.

March 13

Wernher von Braun was sworn in as NASA Deputy Associate Administrator for Planning. He left MSFC on March 1 and was succeeded as MSFC Director by Eberhard F. M. Rees.

Astronautics and Aeronautics, 1970 (NASA SP-4015, 1972), pp. 88-89.

April 6-10

Astronaut John L. Swigert, Jr., Apollo 13 backup command module pilot, began intensive training as a replacement for Thomas K. Mattingly II. The Apollo 13 prime crew had undergone a comprehensive medical examination after German measles had been contracted by Charles M. Duke, Jr., a member of the Apollo 13 backup crew. Mattingly had not shown immunity to the rubella virus and it was feared that he might become ill during the Apollo 13 flight.

MSC Apollo 13 Mission Report (MSC-02680), September 1970.

April 11-17

Apollo 13 (AS-508) was launched from Pad A, Launch Complex 39, KSC, at 2:13 p.m. EST April 11,

with astronauts James A. Lovell, Jr., John L. Swigert, Jr., and Fred W. Haise, Jr., aboard. The spacecraft and S-IVB stage entered a parking orbit with a 185.5-kilometer apogee and a 181.5-kilometer perigee. At 3:48 p.m., onboard TV was begun for five and one-half minutes. At 4:54 p.m., an S-IVB burn placed the spacecraft on a translunar trajectory, after which the CSM separated from the S-IVB and LM *Aquarius*. (The crew had named lunar module 7 *Aquarius* and CSM 109 *Odyssey*.) The CSM then hard-docked with the LM. The S-IVB auxiliary propulsion system made an evasive maneuver after CSM/LM ejection from the S-IVB at 6:14 p.m. The docking and ejection maneuvers were televised during a 72-minute period in which interior and exterior views of the spacecraft were also shown.

At 8:13 p.m. EST a 217-second S-IVB auxiliary propulsion system burn aimed the S-IVB for a lunar target point so accurately that another burn was not required. The S-IVB/IU impacted the lunar surface at 8:10 p.m. EST on April 14 at a speed of 259 meters per second. Impact was 137.1 kilometers from the *Apollo 12* seismometer. The seismic signal generated by the impact lasted 3 hours 20 minutes and was so strong that a ground command was necessary to reduce seismometer gain and keep the recording on the scale. The suprathreshold ion detector experiment, also deployed by the *Apollo 12* crew, recorded a jump in the number of ions from zero at the time of impact up to 2,500 shortly thereafter and then back to a zero count. Scientists theorized that ionization had been produced by 6,300 K to 10,300 K (6,000 degrees C to 10,000 degrees C) temperature generated by the impact or that particles had reached an altitude of 60 kilometers from the lunar surface and had been ionized by sunlight.

Meanwhile back in the CSM/LM, the crew had been performing the routine housekeeping duties associated with the period of the translunar coast. At 30:40 ground elapsed time a midcourse correction maneuver took the spacecraft off a free-return trajectory in order to control the arrival time at the moon. Ensuring proper lighting conditions at the landing site. The maneuver placed the spacecraft on the desired trajectory, on which the closest approach to the moon would be 114.9 kilometers.

At 10:08 p.m. EST April 13, the crew reported an undervoltage alarm on the CSM main bus B, rapid loss of pressure in SM oxygen tank No. 2, and dropping current in fuel cells 1 and 3 to a zero reading. The loss of oxygen and primary power in the service module required an immediate abort of the mission. The astronauts powered up the LM, powered down the CSM, and used the LM systems for power and life support. The first maneuver following the abort decision was made with the descent propulsion system to place the spacecraft back in a free-return trajectory around the moon. After the spacecraft swung around the moon, another maneuver reduced the coast time back to earth and moved the landing point from the Indian Ocean to the South Pacific.

About four hours before reentry on April 17, the service module was jettisoned and the crew took photographs and made visual observations of the damaged area. About one hour before splashdown the command module was powered up and the lunar module was jettisoned. Parachutes were deployed as planned, and the *Odyssey* landed in the mid-Pacific 6.4 kilometers from the recovery ship U.S.S. *Iwo Jima* at 1:07 p.m. EST April 17. The astronauts were picked up by helicopter and transported to the recovery ship less than an hour after splashdown.

MSC "Apollo 13 Mission Report" (MSC-02680), Sept. 1970; MSC "Apollo 13 (AS-508) Flight Summary," undated; memos, C. M. Lee, NASA Hq., to distr., "Mission Director's Summary Report, Apollo 13," April 17, 1970; E. R. Mathews, KSC, "Apollo 13 (AS-508) Post-Launch Report," April 24, 1970.

April 13

MSC informed NASA Hq. that the *Apollo 12* ALSEP left on the moon in November 1969 was continuing to transmit satisfactory data. Status of experiments feeding data into the station was as follows:

The operation of the solar wind experiment was satisfactory. During the lunar days, useful data were being received from the lunar surface magnetometer. However, during the lunar-night cycle data were not received.

Useful data were being received from the three long-period sensors of the passive seismometer experiment. The short period sensor was inoperative.

The cold cathode ion gauge power had failed.

Satisfactory data were being received from the suprathreshold ion detector.

Ltr., James A. McDivitt, MSC, to Rocco A. Petrone, NASA Hq., "Operational Status of Apollo 12 ALSEP," April 13, 1970.

April 13-June 15

"Hey, we've got a problem here." The message from the *Apollo 13* spacecraft to Houston ground controllers at 10:08 p.m. EDT on April 13, initiated an investigation to determine the cause of an oxygen tank failure that aborted the *Apollo 13* mission. The investigation terminated on June 15, when the Review Board accident report was released by NASA at a Headquarters press conference.

The Apollo 13 Review Board was established April 17 by George M. Low, NASA Deputy Administrator, and Thomas O. Paine, NASA Administrator, who appointed the Director of Langley Research Center, Edgar M. Cortright, as Review Board Chairman. On April 21 the members of the Board were named. In addition, by separate memos of April 20, the Aerospace Safety Advisory Panel was requested to review the procedures and findings of the Board and the Associate Administrator for Manned Space Flight was directed to provide records, data, and technical support as requested by the Board. The investigation indicated the accident was caused by a combination of mistakes and a somewhat deficient design. The following sequence of events led to the accident:

1. After assembly and acceptance testing, the oxygen tank no. 2 that flew on *Apollo 13* was shipped

- from Beech Aircraft Corp. to North American Rockwell (NR) in apparently satisfactory condition.
2. However, the tank contained two inadequate protective thermostatic switches on the heater assembly, and they subsequently failed during ground test operations at Kennedy Space Center (KSC).
 3. In addition, the tank probably contained a loosely fitting fill tube assembly. This assembly was probably displaced during subsequent handling, which included an incident at the prime contractor's plant in which the tank was jarred.
 4. In itself, the displaced fill tube assembly was not particularly serious, but it led to improvised detanking procedures at KSC, which "almost certainly set the stage for the accident."
 5. Although Beech had not met any problem in detanking during acceptance tests, it was not possible to detank oxygen tank no. 2 using normal procedures at KSC. Tests and analyses indicate that the problem was gas leakage through the displaced fill tube assembly.
 6. The special detanking procedures at KSC subjected the tank to an extended period of heater operation and pressure cycling. "These procedures had not been used before, and the tank had not been qualified by test for the conditions experienced. However, the procedures did not violate the specifications which governed the operation of the heaters at KSC."
 7. In reviewing these procedures before the flight, officials of NASA, NR, and Beech did not recognize the possibility of damage from overheating. Many were not aware of the extended heater operation. In any event, adequate thermostatic switches might have been expected to protect the tank.
 8. A number of factors contributed to the presence of inadequate thermostatic switches in the heater assembly. The original 1962 specifications from NR to Beech Aircraft Corp. for the tank and heater assembly specified the use of 28-volt, direct-current power, which was used in the spacecraft. In 1965, NR issued a revised specification that stated the heaters should use a 65-volt dc power supply for tank pressurization; this was the power supply used at KSC to reduce pressurization time. Beech ordered switches for the Block II tanks but did not change the switch specifications to be compatible with 65-volt dc.
 9. The thermostatic switch discrepancy was not detected by NASA, NR, or Beech in their review of documentation, nor did tests identify the incompatibility of the switches with the ground support equipment (GSE) at KSC, "since neither qualification nor acceptance testing required switch cycling under load as should have been done. It was a serious oversight in which all parties shared."
 10. The thermostatic switches could accommodate the 65-volt dc during tank pressurization because they normally remained cool and closed. However, they could not open without damage with 65 volt dc power applied. They were not required to open until the special detanking. During this procedure, as the switches started to open when they reached their upper temperature limit, they were welded permanently closed by the resulting arc and were rendered inoperative as protective thermostats.
 11. Failure of the thermostatic switches to open could have been detected at KSC if switch operation had been checked by observing heater current readings on the oxygen tank heater control panel. Although not recognized at the time, the tank temperature readings indicated that the heaters had reached their temperature limit "and switch opening should have been expected."

12. Subsequent tests showed that failure of the thermostatic switches probably permitted the temperature of the heater tube assembly to reach about 1,000 degrees F [810 K] in spots during the continuous eight-hour period of heater operation. Such heating had been shown by tests to damage severely the Teflon insulation on the fan motor wires near the heater assembly. "From that time on, including pad occupancy, the oxygen tank no. 2 was in a hazardous condition when filled with oxygen and electrically powered."
13. Nearly 56 hours into the mission, the fan motor wiring, possibly moved by the fan stirring, short-circuited and ignited its insulation. Combustion in the oxygen tank "probably overheated and failed the wiring conduit where it entered the tank, and possibly a portion of the tank itself."
14. The rapid expulsion of high-pressure oxygen which followed, "possibly augmented by combustion of insulation in the space surrounding the tank, blew off the outer panel to bay 4 of the SM, caused a leak in the high-pressure system of oxygen tank no. 1, damaged the high-gain antenna, caused other miscellaneous damage, and aborted the mission."

Based on the findings of the Board, a number of recommendations were made to preclude similar accidents in future space flights:

1. The cryogenic oxygen storage system in the service module should be modified to:
 1. Remove from contact with the oxygen all wiring and unsealed motors that could potentially short-circuit and ignite adjacent materials; or otherwise ensure against an electrically induced fire in the tank.
 2. Minimize the use of Teflon, aluminum, and other relatively combustible materials in the presence of the oxygen and potential ignition sources.
2. The modified cryogenic oxygen storage system should be subjected to a rigorous requalification program, including careful attention to potential operational problems.
3. The warning systems on the Apollo spacecraft and in the Mission Control Center should be carefully reviewed and modified where appropriate, with specific attention to:
 1. Increasing the differential between master alarm trip levels and expected normal operating ranges to avoid unnecessary alarms.
 2. Changing the caution and warning system logic to prevent an out-of-limits alarm from blocking another alarm if a second quantity in the same subsystem went out of limits.
 3. Establishing a second level of limit sensing in Mission Control on critical quantities, with a visual or audible alarm that could not be easily overlooked.
 4. Providing independent talk-back indicators for each of the six fuel cell reactant valves plus a master alarm when any valve closed.
4. Consumables and emergency equipment in the LM and the CM should be reviewed to determine whether steps should be taken to enhance their potential for use in a 'lifeboat' mode.
5. MSC should complete the special tests and analyses under way to understand more completely the details of the *Apollo 13* accident. In addition, the lunar module power system anomalies should receive careful attention. Other NASA Centers should continue support to MSC in the areas of analysis and test.
6. Whenever significant anomalies occurred in critical subsystems during final preparation for launch, standard procedures should require a presentation of all prior anomalies on that particular

piece of equipment, including those which have previously been corrected or explained. Critical decisions on flightworthiness should require the full participation of an expert "intimately familiar with the details of that subsystem."

7. NASA should thoroughly reexamine all its spacecraft, launch vehicle, and ground systems containing high-density oxygen or other strong oxidizers, to identify and evaluate potential combustion hazards in the light of information developed in this investigation.
8. NASA should conduct additional research on materials compatibility, ignition, and combustion in strong oxidizers at various gravity levels and on the characteristics of supercritical fluids. Where appropriate, new NASA design standards should be developed.
9. MSC should reassess all Apollo spacecraft subsystems, and the engineering organizations responsible for them at MSC and at its prime contractors, to ensure adequate understanding and control of the engineering and manufacturing details at the subcontractor and vendor level. "Where necessary, organizational elements should be strengthened and in-depth reviews conducted on selected subsystems with emphasis on soundness of design, quality of manufacturing, adequacy of test, and operational experience."

Memos, Low and Paine to Cortright, "Establishment of Apollo 13 Review Board," April 17, 1970; Low and Paine to Cortright, "Membership of Apollo 13 Review Board," April 21, 1970; Low and Paine to Chairman, Aerospace Safety Advisory Panel Charles D. Harrington, "Review of Procedures and Findings of Apollo 13 Review Board," April 20, 1970; Low and Paine to Dale D. Myers, NASA Hq., "Apollo 13 Review," April 20, 1970; ltr., Cortright to Paine, June 15, 1970; House Committee on Science and Astronautics, *The Apollo 13 Accident: Hearings*, 91st Cong., 2nd sess., June 16, 1970, pp. 234-36, 273-74.

April 19

To support the Apollo 13 Review Board, an MSC Apollo 13 Investigation Team, headed by Scott H. Simpkinson, was established with the following panels: spacecraft incident investigation, flight crew observations, flight operations and network; photograph handling, processing, and cataloging; corrective action study and implementation for the CSM, LM, and government-furnished equipment; related system evaluation; reaction processes in high-pressure fluid systems; high-pressure oxygen system survey; public affairs; and administration, communications, and procurement.

Memos, James A. McDivitt, MSC, to Apollo 13 Investigation Team, "Apollo 13 Investigation Team organization," April 19, 1970; Owen G. Morris, MSC, to Scott H. Simpkinson, "Apollo 13 Investigation Team organization," April 20, 1970.

June 26

NASA Hq. and Center actions were initiated on recommendations of the Apollo 13 Review Board. The Associate Administrator for Space Science and Applications would take specific action on recommendations 6, 7, and 9 of the report as they applied to spacecraft, launch vehicles, aircraft, ground

systems and laboratories under OSSA jurisdiction. Lewis Research Center was directed to conduct a comprehensive review of oxygen-handling practices in NASA programs. The Aerospace Safety Research and Data Institute was already conducting studies on oxygen handling in aerospace programs. Other Centers were taking action on Board recommendations as applicable. (See July 16 entry.)

Memos, George M. Low, NASA Hq., to Associate Administrator for Space Science and Applications, "Recommendations of the Apollo 13 Review Board," June 26, 1970; Low to Director, Lewis Research Center, "Expansion of ASRDI Oxygen Systems Review," June 26, 1970; T. O. Paine, NASA Hq., to Director, Lewis Research Center, "Review of Oxygen Handling in Aerospace Programs to be Conducted by the Aerospace Safety Research and Data Institute (ASRDI)," May 19, 1970; Bruce T. Lundin, Lewis Research Center to Deputy Administrator, "Proposed oxygen handling program," July 14, 1970; Deputy Associate Administrator for Space Science and Applications (Engineering) to distr., "Recommendations of the Apollo 13 Review Board," Aug. 5, 1970.

July 14

Efforts of MSC personnel that had been redirected to support the *Apollo 13* investigation would again be concentrated on the Apollo-experience-reporting project in an effort to attain a publication date of November 1, 1970.

Memo, Scott H. Simpkinson, MSC, to distr., "Apollo experience reporting," July 14, 1970.

July 16

MSC moved to reassess all Apollo spacecraft subsystems and the engineering organizations responsible for them at MSC and its prime contractors, in response to Apollo 13 Review Board recommendation 9 (see April 13-June 15).

Memo, James A. McDivitt, MSC, to distr., "Apollo 13 Review Board Report - Recommendation #9," July 16, 1970; extract from recommendation 9 of the Apollo 13 Review Board Report.

July 17

During the anniversary of *Apollo 11*, NASA Administrator Thomas O. Paine said: "The success of Apollo 11 marked the beginning of a new and important phase of mankind - not just the triumphant end of a mission. The mission was a voyage of discovery, and an important part of the discovery was the revelation of the infinite human potential for achievement as an endless new frontier was opened for future generations.

"Our remarkable progress in the first dozen years of the space age demonstrates that no dreams are impossible of realization, that the prospects for progress and human betterment here on earth as well as in space are limitless. And you may be sure that despite changing program directions, NASA will

continue to play an exciting and vigorous role in the avant-garde of human progress."

Paine, Message to NASA coworkers, July 17, 1970.

August 7

North American Rockwell announced that William B. Bergen, who had been serving as president of North American's Space Division, would become a corporate vice president with the title Group Vice President - Aerospace and Systems. This was one of a number of key organizational steps taken since January to improve and strengthen the North American management structure in response to significant changes that had occurred in the aerospace environment.

Ltr., Robert Anderson, North American Rockwell Corp., to Robert R. Gilruth, MSC, Aug. 11, 1970.

September 2

NASA was canceling Apollo missions 15 and 19 because of congressional cuts in FY 1971 NASA appropriations, Administrator Thomas O. Paine announced in a Washington news conference. Remaining missions would be designated Apollo 14 through 17. The Apollo budget would be reduced by \$42.1 million, to \$914.4 million - within total NASA \$3.27 billion.

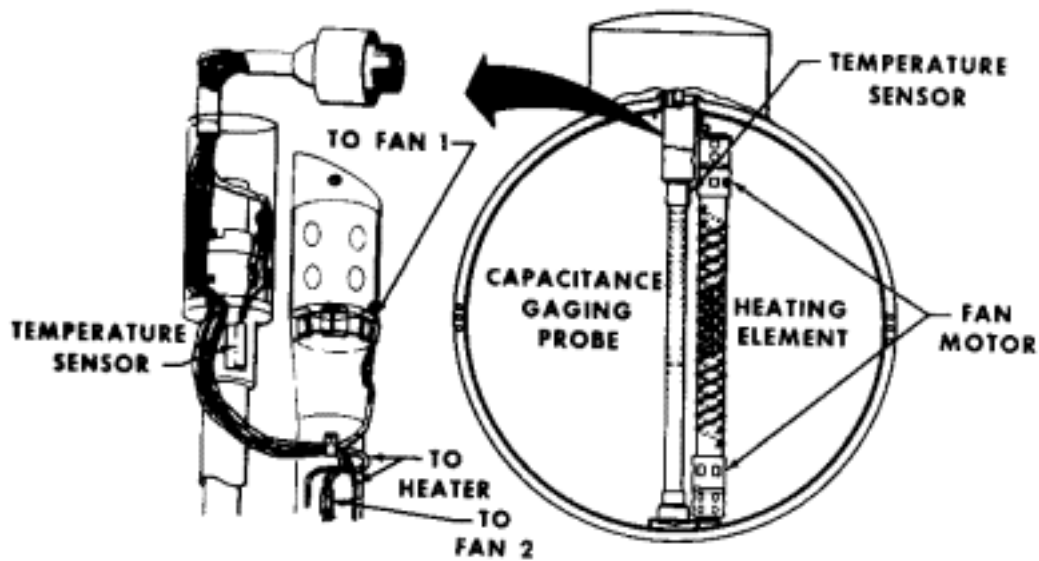
"Statement by Dr. Thomas O. Paine," Sept. 2, 1970; *Astronauts and Aeronautics, 1970* (NASA SP-4015, 1972), pp. 248, 257, 284-85.

September 11

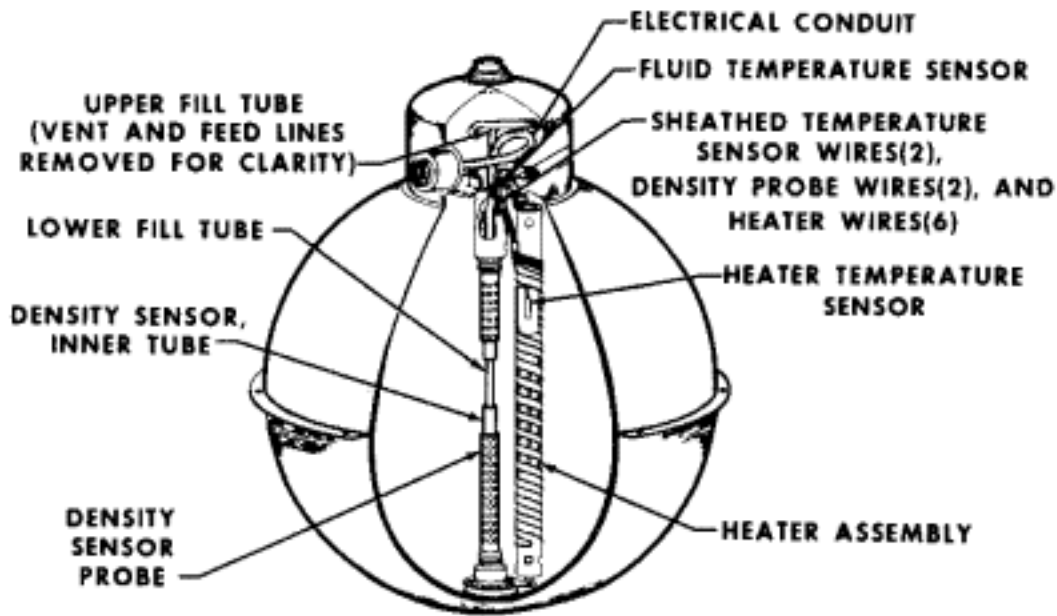
Modifications were made in MSFC's lunar roving vehicle simulator and the static mockup to eliminate extreme arm and hand fatigue felt by a flight crew member and other test subjects after driving 10 to 15 minutes in LRV simulator evaluation tests. A T-shaped handle was added to the pistol grip; a parking-brake release and a reduced brake-travel distance were incorporated; and a mechanical reverse lockout was added.

Memo, James A. McDivitt, MSC, to Richard G. Smith, MSFC, "Lunar roving vehicle hand controller," Sept. 11, 1970.

November 24



Apollo 13's service module oxygen tank.



Redesigned oxygen tank.

MSC Director Robert R. Gilruth reported MSC actions on the Apollo 13 Review Board recommendations (see April 13-June 15), including:

- Fan motors had been removed from oxygen storage tanks in the service modules; the electrical leads had been encased in stainless steel sheaths with hermetically sealed headers and had been shielded from contact with the remaining Teflon parts.
- The modified cryogenic oxygen storage system had been subjected to a comprehensive

recertification program developed in close coordination by North American Rockwell, Beech Aircraft Corp., and NASA. Requirements were founded on environmental as well as operational factors necessary to prove design capability.

- No major changes had been made in the caution and warning system.
- The LM and CSM consumables and emergency equipment had been reviewed to determine any design changes required to provide a safe return from lunar orbit in the event of a service module cryogenic-oxygen-supply loss. Three design changes were made in the CSM related to the oxygen tanks, an LM descent battery, and a water storage system in the CM.
- MSC had made special tests and analyses to understand the *Apollo 13* accident better. The testing had reaffirmed the conclusions reached by the Apollo 13 Review Board.
- Significant anomalies in critical subsystems during final preparation for launch would be analyzed and resolved with authorized and documented corrective action in much the same manner as employed during the missions. An Apollo Program Directive for identification and resolution of significant failures and anomalies had been issued.
- A thorough reexamination of all spacecraft, launch vehicle, and ground systems containing high-density oxygen and other strong oxidizers was being made to identify and evaluate potential combustion hazards.
- Additional research was being conducted on materials compatibility, ignition, and combustion in strong oxidizers at various gravity levels and on the characteristics of supercritical fluids. Arc-ignition tests of the Apollo 14 oxygen-storage-system materials in both normal and overstressed modes indicated a positive margin of safety.
- MSC had organized a system-by-system task team effort and made comprehensive reassessments of each subsystem. Design and qualification of each subsystem was reaffirmed as adequate for current ground test and mission requirements with the exception of a heatshield blowout plug for dumping reaction-control-subsystem propellant for launch aborts.

Ltr., Gilruth to Edgar M. Cortright, LaRC, Nov. 24, 1970.

November 25

George M. Low, Acting NASA Administrator, discussed the significance of unmanned lunar probes *Luna XVI* and *XVII* launched by the U.S.S.R. September 12 and November 10. *Luna XVI* had brought lunar samples back to earth and *Luna XVII* had landed an unmanned Lunokhod roving vehicle on the moon's surface. Low stated in a letter to Chairman Clinton P. Anderson of the Senate Committee on Aeronautical and Space Sciences that while the two launches were impressive their contributions to science and technology were relatively minor. Low suggested that the main lesson to be learned from the two launches specifically and the U.S. and U.S.S.R. space programs in general was that while the Soviet launch rate was increasing that of the United States was decreasing. These trends in the two countries' space programs should be a cause of concern if the United States was interested in maintaining a position of leadership in space.

Ltr., Dale D. Myers, NASA Hq., to Robert R. Gilruth, MSC, Dec. 16, 1970; *Congressional Record-Senate*, Nov. 30, 1970, pp. S19001-02.

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Part 3 (H)

Man Circles the Moon, the Eagle Lands, and Manned Lunar Exploration

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1971

January 18

NASA was considering several methods for providing real-time television coverage of lunar surface activities with scientific commentary to the news media during future Apollo flights. A recommended approach would place scientific personnel from within NASA, including Apollo Program principal investigators, in the MSC news center briefing room with a panel representing the news media. The

scientific personnel would supplement the normal air-to-ground communications, public affairs commentary, and TV transmissions from the moon with spontaneous commentary on surface activities in progress.

Memo, James A. McDivitt, MSC, to Rocco A. Petrone, NASA Hq., "Media coverage of Apollo 12 and 14 experiments," Jan. 18, 1971.

January 29

The space vehicle for the Apollo 14 mission was determined ready for launch on January 31. The Flight Readiness Review had been held at KSC on December 17, 1970; all required action and open work had been completed; and the Pre-Liftoff Readiness Review had been favorably completed January 29.

Memo, Rocco A. Petrone, NASA Hq., to Apollo 14 Flight Readiness Review Record, "Confirmation of Flight Readiness for the Apollo 14 Mission," Jan. 29, 1971.

January 31-February 9

The *Apollo 14* (AS-509) mission - manned by astronauts Alan B. Shepard, Jr., Stuart A. Roosa, and Edgar D. Mitchell - was launched from Pad A, Launch Complex 39, KSC, at 4:03 p.m. EST January 31 on a Saturn V launch vehicle. A 40-minute hold had been ordered 8 minutes before scheduled launch time because of unsatisfactory weather conditions, the first such delay in the Apollo program. Activities during earth orbit and translunar injection were similar to those of the previous lunar landing missions. However, during transposition and docking, CSM 110 *Kitty Hawk* had difficulty docking with LM-8 *Antares*. A hard dock was achieved on the sixth attempt at 9:00 p.m. EST, 1 hour 54 minutes later than planned. Other aspects of the translunar journey were normal and proceeded according to flight plan. A crew inspection of the probe and docking mechanism was televised during the coast toward the moon. The crew and ground personnel were unable to determine why the CSM and LM had failed to dock properly, but there was no indication that the systems would not work when used later in the flight.

Apollo 14 entered lunar orbit at 1:55 a.m. EST on February 4. At 2:41 a.m. the separated S-IVB stage and instrument unit struck the lunar surface 174 kilometers southeast of the planned impact point. The *Apollo 12* seismometer, left on the moon in November 1969, registered the impact and continued to record vibrations for two hours.

After rechecking the systems in the LM, astronauts Shepard and Mitchell separated the LM from the CSM and descended to the lunar surface. The *Antares* landed on Fra Mauro at 4:17 a.m. EST February 5, 9 to 18 meters short of the planned landing point. The first EVA began at 9:53 a.m., after intermittent communications problems in the portable life support system had caused a 49-minute delay. The two astronauts collected a 19.5-kilogram contingency sample; deployed the TV, S-band antenna, American flag, and Solar Wind Composition experiment; photographed the LM, lunar surface, and experiments; deployed the Apollo lunar surface experiments package 152 meters west of the LM and the laser-ranging

retroreflector 30 meters west of the ALSEP; and conducted an active seismic experiment, firing 13 thumper shots into the lunar surface.

A second EVA period began at 3:11 a.m. EST February 6. The two astronauts loaded the mobile equipment transporter (MET) - used for the first time - with photographic equipment, tools, and a lunar portable magnetometer. They made a geology traverse toward the rim of Cone Crater, collecting samples on the way. On their return, they adjusted the alignment of the ALSEP central station antenna in an effort to strengthen the signal received by the Manned Space Flight Network ground stations back on earth.

Just before reentering the LM, astronaut Shepard dropped a golf ball onto the lunar surface and on the third swing drove the ball 366 meters. The second EVA had lasted 4 hours 35 minutes, making a total EVA time for the mission of 9 hours 24 minutes. The *Antares* lifted off the moon with 43 kilograms of lunar samples at 1:48 p.m. EST February 6.

Meanwhile astronaut Roosa, orbiting the moon in the CSM, took astronomy and lunar photos, including photos of the proposed Descartes landing site for Apollo 16.

Ascent of the LM from the lunar surface, rendezvous, and docking with the CSM in orbit were performed as planned, with docking at 3:36 p.m. EST February 6. TV coverage of the rendezvous and docking maneuver was excellent. The two astronauts transferred from the LM to the CSM with samples, equipment, and film. The LM ascent stage was then jettisoned and intentionally crashed on the moon's surface at 7:46 p.m. The impact was recorded by the *Apollo 12* and *Apollo 14* ALSEPs.

The spacecraft was placed on its trajectory toward earth during the 34th lunar revolution. During transearth coast, four inflight technical demonstrations of equipment and processes in zero gravity were performed.

The CM and SM separated, the parachutes deployed, and other reentry events went as planned, and the *Kitty Hawk* splashed down in mid-Pacific at 4:05 p.m. EST February 9 about 7 kilometers from the recovery ship U.S.S. *New Orleans*. The *Apollo 14* crew returned to Houston on February 12, where they remained in quarantine until February 26.

All primary mission objectives had been met (see Appendix 5). The mission had lasted 216 hours 40 minutes and was marked by the following achievements:

- Third manned lunar landing mission and return.
- Use of mobile equipment transporter (MET).
- Payload of 32,500 kilograms placed in lunar orbit.
- Distance of 3.3 kilometers traversed on lunar surface.
- Payload of 43.5 kilograms returned from the lunar surface.
- Lunar surface stay time of 33 hours.

- Lunar surface EVA of 9 hours 47 minutes.
- Use of shortened rendezvous technique.
- Service propulsion system orbit insertion.
- Active seismic experiment.
- Inflight technical demonstrations.
- Extensive orbital science period during CSM solo operations.

MSC, "Apollo 14 (AS-509) Flight Summary," undated; MSC, "Apollo 14 Mission Report" (MSC-04112), April 1971; NASA OMSF, "Manned Space Flight Weekly Report - February 16, 1971"; TWX, F. A. Speer, MSFC, to C. M. Lee, NASA Hq., "Apollo 14 (AS-509) HOSC Report," Jan. 31, 1971; ltr., Chester M. Lee, NASA Hq., "Mission Director's Summary Report, Apollo 14," Feb. 9, 1971; NASA Hq., *Apollo 14 Preliminary Science Report* (NASA SP-272, 1971).

February 22

MSC requested removal of sharp corners from the lunar roving vehicle (LRV) seat. During a recent series of LRV/EMU (extravehicular mobility unit) tests, a nicking or tearing of the portable life support system thermal cover had been discovered. Observation revealed that the thermal cover was contacting sharp corners on the LRV seats, when the test subject entered and left the vehicle.

Ltr., James A. McDivitt, MSC, to Richard G. Smith, MSFC, "Sharp corners on current lunar roving vehicle design," Feb. 22, 1971.

March 1

Because of difficulties during the past several months in developing and qualifying an automatic deployment system for the lunar roving vehicle, the automatic system was abandoned in favor of a manual system. Boeing was directed to stop all further effort on the automatic system.

Ltr., Richard G. Smith, MSFC, to Rocco A. Petrone, NASA Hq., "LRV Manual Deployment System," March 1, 1971.

March 10

Action was initiated to determine the feasibility of providing photographic coverage of a lunar eclipse from the lunar surface or the CSM during the Apollo 15 mission. The eclipse would occur on August 6, three or four days after the scheduled Apollo 15 mission lunar surface liftoff.

TWX, Rocco A. Petrone, NASA Hq., to James A. McDivitt, MSC, "Lunar eclipse during Apollo 15 mission," March 10, 1971.

April 26

Acting NASA Administrator George M. Low discontinued the quarantine for future Apollo flights to the moon beginning with the Apollo 15 mission. The decision was based on a recommendation of the Interagency Committee on Back Contamination (ICBC). The ICBC would continue as an active body, however, at least until the results of the last Apollo lunar mission were reviewed. Biomedical characterization of returned lunar samples would also be continued.

Low announcement, "Decision to Terminate Quarantine under NMI 1052.90 (Attachment A, Change 1, 2)," April 26, 1971; ltr., Dale D. Myers, NASA Hq., to MSC Director, "Decision to Terminate Quarantine," May 10, 1971; TWX, J. W. Humphreys, NASA Hq., "Discontinuance of Lunar Quarantine," April 28, 1971.

April 27

James C. Fletcher was sworn in as NASA Administrator at a White House ceremony. President Nixon had nominated him for the position on March 1, and the Senate had confirmed the nomination on March 11. George M. Low, NASA Deputy Administrator, had been Acting Administrator since the resignation of Administrator Thomas O. Paine on September 15, 1970.

Astronautics and Aeronautics, 1971 (NASA SP-4018, 1972), pp. 56-57, 59, 68, 69, 72, 114.

April 30

Lee B. James, Director of Program Management at MSFC, would leave for a position in the academic community effective May 31, MSFC announced. On June 1, J. T. Shepherd would assume the duties as Acting Director, Program Management. James had been active in the space program since 1947.

MSFC Key Personnel Announcement, April 30, 1971; ltr., Eberhard F. M. Rees, MSFC, to Robert R. Gilruth, MSC, May 3, 1971.

May 5

The Apollo Site Selection Board selected Descartes as the Apollo 16 site. However, after the selection, a discussion began as to whether the Kant or Descartes region would be the better choice. NASA finally decided to go with the original selection of the Board: Descartes would be the prime Apollo 16 Site.

Ltr., Lee R. Scherer, NASA Hq., to distr., "Apollo 16 and 17 Site Selection Discussions," May 5, 1971; TWX, Rocco A. Petrone, NASA Hq., to James A. McDivitt, MSC, et al., "Apollo 16 Landing Site," June 11, 1971.

May 13

NASA was considering a plan for obtaining contamination measurements on the remaining Apollo flights for use in Skylab planning. The plan required photography on Apollo 15 of liquid dumps, limited magnitude starfield, and window deposition photography. Apollo 16 and 17 would carry instrumentation to measure cloud intensity and effects, deposits and their effects, critical surfaces, particle count, surface charge potential, and pressure.

TWX, Leland F. Belew, MSFC, to William C. Schneider and John H. Disher, NASA Hq., Kenneth S. Kleinknecht, James A. McDivitt, and Ronald W. Kubicki, MSC, "Contamination Measurements on Apollo," May 13, 1971; memo, Leland F. Belew, MSFC, to ASPO and Skylab Managers, MSC, "Background and Justification for Apollo 16 Skylab Data Request," Sept. 10, 1971.

July 26-August 7

Apollo 15 (AS-510) with astronauts David R. Scott, Alfred M. Worden, and James B. Irwin aboard was launched from Pad A, Launch Complex 39, KSC, at 9:34 a.m. EDT July 26. The spacecraft and S-IVB combination was placed in an earth parking orbit 11 minutes 44 seconds after liftoff. Activities during earth orbit and translunar injection (insertion into the trajectory for the moon) were similar to those of previous lunar landing missions. Translunar injection was at about 12:30 p.m., with separation of the CSM from the LM/S-IVB/IU at 12:56 p.m. At 1:08 p.m., onboard color TV showed the docking of the CSM with the LM.

S-IVB auxiliary propulsion system burns sent the S-IVB/IU stages toward the moon, where they impacted the lunar surface at 4:59 p.m. EDT July 29. The point of impact was 188 kilometers northeast of the *Apollo 14* landing site and 355 kilometers northeast of the *Apollo 12* site. The impact was detected by both the *Apollo 12* and *Apollo 14* seismometers, left on the moon in November 1969 and February 1971.

After the translunar coast, during which TV pictures of the CSM and LM interiors were shown and the LM communications and other systems were checked, *Apollo 15* entered lunar orbit at 4:06 p.m. EDT July 29.

The LM-10 *Falcon*, with astronauts Scott and Irwin aboard, undocked and separated from the *Endeavor* (CSM 112) with astronaut Worden aboard. At 6:16 p.m. EDT July 30, the *Falcon* landed in the Hadley-Apennine region of the moon 600 meters north-northwest of the proposed target. About two hours later, following cabin depressurization, Scott performed a 33-minute standup EVA in the upper hatch of the LM, during which he described and photographed the landing site.

The first crew EVA on the lunar surface began at 9:04 a.m. July 31. The crew collected and stowed a contingency sample, unpacked the ALSEP and other experiments, and prepared the lunar roving vehicle (LRV) for operations. Some problems were encountered in the deployment and checkout of the LRV, used for the first time, but they were quickly resolved. The first EVA traverse was to the Apennine mountain front, after which the ALSEP was deployed and activated, and one probe of a Heat Flow

experiment was emplaced. A second probe was not emplaced until EVA-2 because of drilling difficulties. The first EVA lasted 6 hours 33 minutes.

At 7:49 a.m. EDT August 1, the second EVA began. The astronauts made a maintenance check on the LRV and then began the second planned traverse of the mission. On completion of the traverse, Scott and Irwin completed the placement of heat flow experiment probes, collected a core sample, and deployed the American flag. They then stowed the sample container and the film in the LM, completing a second EVA of 7 hours 12 minutes.

The third EVA began at 4:52 a.m. August 2, included another traverse, and ended 4 hours 50 minutes later, for a total *Apollo 15* lunar surface EVA time of 18 hours 35 minutes.

While the lunar module was on the moon, astronaut Worden completed 34 lunar orbits in the CSM operating scientific instrument module experiments and cameras to obtain data concerning the lunar surface and environment. X-ray spectrometer data indicated richer abundance of aluminum in the highlands, especially on the far side, but greater concentrations of magnesium in the maria.

Liftoff of the ascent stage of the LM, the first one to be televised, occurred at 1:11 p.m. EDT August 2. About two hours later the LM and CSM rendezvoused and docked, and film, equipment, and 77 kilograms of lunar samples were transferred from the LM to the CSM. The ascent stage was jettisoned and hit the lunar surface at 11:04 p.m. EDT August 2. Its impact was recorded by the *Apollo 12*, *Apollo 14*, and *Apollo 15* seismometers, left on the moon during those missions. Before leaving the lunar orbit, the spacecraft deployed a subsatellite, at 4:13 p.m. August 4, in an orbit of 141.3 by 102 kilometers. The satellite would measure interplanetary and earth magnetic fields near the moon. It also carried charged-particle sensors and equipment to detect variations in lunar gravity caused by mascons (mass concentrations).

A transearth injection maneuver at 5:23 p.m. August 4 put the CSM on an earth trajectory. During the transearth coast, astronaut Worden performed an inflight EVA beginning at 11:32 a.m. August 5 and lasting for 38 minutes 12 seconds. He made three trips to the scientific instrument module (SIM) bay of the SM, twice to retrieve cassettes and once to observe the condition of the instruments in the SIM bay.

CM and SM separation, parachute deployment, and other reentry events went as planned, but one of the three main parachutes failed, causing a hard but safe landing. Splashdown - at 4:47 p.m. EDT August 7, after 12 days 7 hours 12 minutes from launch - was 530 kilometers north of Hawaii and 10 kilometers from the recovery ship U.S.S. *Okinawa*. The astronauts were carried to the ship by helicopter, and the CM was retrieved and placed on board. All primary mission objectives had been achieved (see Appendix 5).

MSC, "Apollo 15 Mission Report" (MSC-05161), December 1971; MSC, "Apollo 15 (AS-510) Flight Summary," undated; TWX, H. F. Kurtz, MSFC, to C. M. Lee, NASA Hq., "Apollo 15 (AS-510) HOSC Report," July 26, 1971; MSFC, "Saturn Evaluation Bulletin," No. 1, 2, and 3, Aug. 3, 13, 27, 1971; ltr.,

Lee, "Mission Director's Summary Report, Apollo 15," Aug. 7, 1971: KSC, "Apollo 15 Post-Launch Report," Aug. 12, 1971.

October 6-7

Major items of discussion during the Manned Space Flight Management Council meeting in Washington were the *Apollo 15* anomalies. These included parachute collapse during landing, lunar module descent battery, lunar surface drill, and steering mechanism on the LRV. Also discussed were the Apollo 16 preparations and the feasibility of TV coverage of the lunar rover during traverse.

The most likely cause of the parachute collapse was damage from burning raw RCS fuel (monomethyl hydrazine) being expelled during depletion firing. Corrective action included landing with reaction control system propellants on board for a normal landing and biasing the propellant load to a slight excess of oxidizer and increasing the time delay inhibiting the rapid propellant dump, to avoid fuel contacting the parachute riser and suspension lines during low-altitude-abort landings.

Highlights of Manned Space Management Council Meeting," Oct. 18, 1971.

October 21

Some members of the Lunar Sample Review Board expressed concern that, unless provisions were made to retain vital parts of the Apollo science program for a number of years after the lunar landings were completed, tangible returns from the lunar landings would be greatly diminished. Three main areas of concern were the lunar sample analysis program, the curatorial staff and facilities for care of the sample collection, and the lunar geophysical stations and Apollo orbital science.

Ltr., William W. Rubey and Robert A. Phinney, Cochairmen, Lunar Sample Review Board, to John E. Naugle, NASA Hq., Oct. 21, 1971.

November 18

A detailed objective assessment of the lunar roving vehicle (LRV) used on the *Apollo 15* mission indicated:

- The LRV was successfully deployed, with minor problems. Deployment took 26.5 minutes instead of the allotted time of 17 minutes.
- LRV systems were successfully prepared for traverse. Forward steering was inoperative during EVA-1, but functioned normally on EVA-2 and EVA-3.
- Average speed during traverse was 9.3 kilometers per hour; maximum speed 13 kilometers per hour. Maximum slopes negotiated were up to 12 degrees. Braking distance was 4.6 meters from 10 kilometers per hour.
- The navigation system was extremely accurate.

- Forward visibility was generally excellent.

Ltr., Richard G. Smith, MSFC, to ASPO Manager, "Apollo 15 Objective Assessment Report," Nov. 18, 1971, with encl., "LRV Detailed Objective Assessment."

December 7

A meeting was held at NASA Hq. to formulate a plan to provide the National Space Science Data Center (NSSDC) with the material required to serve the scientific community. As a result of the meeting, MSC was requested to:

- Prepare index map overlays and frame indexes for all lunar photos from command module and scientific instrument module cameras.
- Evaluate the photos in terms of the correctness of the exposure settings and the visible effects of any camera malfunctions.
- Manage the preparation of the photo support data and camera calibration data to ensure their suitability for the photogrammetric reduction and subsequent analysis of the photographs.
- Manage the preparation of microfiche imagery of all command module photographs and every third mapping camera photograph, supplying masters and/or copies of the fiches to NSSDC.
- Provide paper prints to NSSDC for the preparation of microfilm imagery of the panoramic camera photographs.

Ltr., Rocco A. Petrone, NASA Hq., to James A. McDivitt, MSC, "Revised Apollo Photo Data Package," Jan. 7, 1972.

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Part 3 (I)

Man Circles the Moon, the Eagle Lands, and Manned Lunar Exploration

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1972

January 14

Manned Spacecraft Center Robert R. Gilruth was appointed to the newly created position of NASA Director of Key Personnel Development. He would integrate NASA planning to fill key positions, identify actual and potential candidates, and guide them through appropriate work experience.

Christopher C. Kraft, Jr., MSC Deputy Director, was named Director of MSC. Both Kraft and Gilruth were original members of the NASA Space Task Group established in 1958 to manage Project Mercury.

NASA News Release 72-11, Jan. 14, 1972; MSC News Release 72-15, Jan. 14, 1972.

January 18

Sigurd A. Sjoberg was named Deputy Director of Manned Spacecraft Center. Sjoberg succeeded Christopher C. Kraft, Jr., who was named Director of MSC January 14.

MSC News Release 72-16, "Sjoberg Named Deputy Director of MSC," Jan. 18, 1972.

January 19

A directive establishing policy and procedure and assigning responsibilities governing articles to be included in astronaut preference kits flown on board Apollo spacecraft was promulgated.

Memo, Dale D. Myers, NASA Hq., to Apollo Program Director, "Astronaut Preference Kits - Apollo Missions," Jan. 19, 1972.

March 8

An Olympic Games flag 1.2 by 1.8 meters would be packed in a fireproof container and carried in the command module during the Apollo 16 mission. Weight and storage limitations would preclude carrying the flag in the lunar module. However, an additional Olympic Games flag, 1.2 by 1.8 centimeters, would be carried in the LM flag kit to the lunar surface. Small flags of members of the United Nations, other international organizations, and national states generally accepted as independent in the world community would be carried on the mission in the LM flag kit.

Memo, Rocco A. Petrone, NASA Hq., to Associate Deputy Administrator, "Flags to Be Carried on Apollo 16," March 8, 1972.

April 16-27

The *Apollo 16* (AS-511) space vehicle was launched from Pad A, Launch Complex 39, KSC, at 12:54 p. m. EST April 16, with a crew of astronauts John W. Young, Thomas K. Mattingly II, and Charles M. Duke, Jr. After insertion into an earth parking orbit for spacecraft system checks, the spacecraft and the S-IVB stage were placed on a trajectory to the moon at 3:28 p.m. CSM transposition and docking with the LM were achieved, although a number of minor anomalies were noted.

One anomaly, an auxiliary propulsion system leak on the S-IVB stage, produced an unpredictable thrust and prevented a final S-IVB targeting maneuver after separation from the CSM. Tracking of the S-IVB ended at 4:04 p.m. EST April 17, when the instrument unit's signal was lost. The stage hit the lunar surface at 4:02 p.m. April 19, 260 kilometers northeast of the target point. The impact was detected by the seismometers left on the moon by the *Apollo 12*, *14*, and *15* missions.

Spacecraft operations were near normal during the coast to the moon. Unexplained light-colored particles from the LM were investigated and identified as shredded thermal paint. Other activities during

the translunar coast included a cislunar navigation exercise, ultraviolet photography of the earth and moon, an electrophoresis demonstration, and an investigation of the visual light-flash phenomenon noted on previous flights. Astronaut Duke counted 70 white, instantaneous light flashes that left no after-glow.

Apollo 16 entered a lunar orbit of 314 by 107.7 kilometers at 3:22 p.m. April 19. After separation of LM-11 *Orion* from CSM 112 *Casper*, a CSM active rendezvous kept the two vehicles close together while an anomaly discovered on the service propulsion system was evaluated. Tests and analyses showed the redundant system to be still safe and usable if required. The vehicles were again separated and the mission continued on a revised timeline because of the 5 3/4-hour delay.

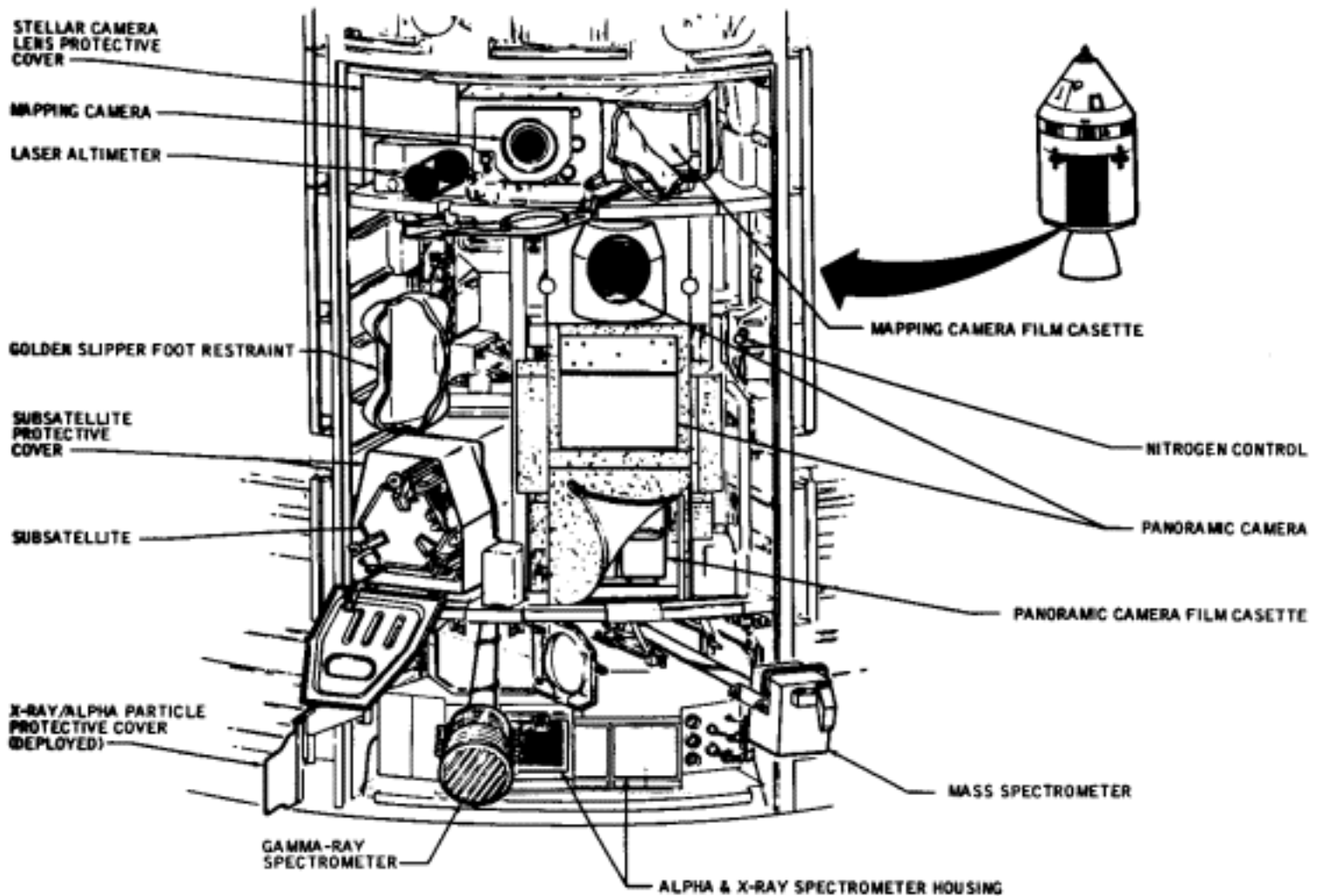
The lunar module landed with Duke and Young in the moon's Descartes region, about 230 meters northwest of the planned target area at 9:23 p.m. EST April 20. A sleep period was scheduled before EVA.

The first extravehicular activity began at 11:59 a.m. April 21, after the eight-hour rest period. Television coverage of surface activity was delayed until the lunar roving vehicle systems were activated, because the steerable antenna on the lunar module could not be used. The lunar surface experiments packages were deployed, but accidental breaking of the electronics cable rendered the heat flow experiment inoperable. After completing activities at the experiments site, the crew drove the lunar roving vehicle west to Flag Crater, where they performed the planned tasks. The inbound traverse route was just slightly south of the outbound route, and the next stop was Spook Crater. The crew then returned via the experiment station to the lunar module and deployed the solar wind composition experiment. The duration of the extravehicular activity was 7 hours 11 minutes. The distance traveled by the lunar roving vehicle was 4.2 kilometers. The crew collected 20 kilograms of samples.

The second extravehicular traverse, which began at 11:33 a.m. April 22, was south-southeast to a mare-sampling area near the Cinco Craters on Stone Mountain. The crew then drove in a northwesterly direction, making stops near Stubby and Wreck Craters. The last leg of the traverse was north to the experiments station and the lunar module. The second extravehicular activity lasted 7 hours 23 minutes. The distance traveled by the lunar roving vehicle was 11.1 kilometers.

Four stations were deleted from the third extravehicular traverse, which began 30 minutes early at 10:27 a.m. April 23 to allow extra time. The first stop was North Ray Crater, where "House Rock" on the rim of the crater was sampled. The crew then drove southeast to "Shadow Rock." The return route to the LM retraced the outbound route. The third extravehicular activity lasted 5 hours 40 minutes, and the lunar roving vehicle traveled 11.4 kilometers.

Lunar surface activities outside the LM totaled 20 hours 15 minutes for the mission. The total distance traveled in the lunar roving vehicle was 26.7 kilometers. The crew remained on the lunar surface 71 hours 14 minutes and collected 96.6 kilograms of lunar samples.



The SIM bay of the Apollo 16 scientific instrument module housed sensors and experiments to gather data on the moon's atmosphere and surface, as well as a subsatellite to be launched in lunar orbit. Gamma ray and mass spectrometer sensors extended on a boom when in use.

While the lunar module crew was on the surface, Mattingly, orbiting the moon in the CSM, was obtaining photographs, measuring physical properties of the moon and deep space, and making visual observations. Essentially the same complement of instruments was used to gather data as was used on the *Apollo 15* mission, but different areas of the lunar surface were flown over and more comprehensive deep space measurements were made, providing scientific data that could be used to validate findings from *Apollo 15* as well as add to the total store of knowledge of the moon and its atmosphere, the solar system, and galactic space.

The LM lifted off from the moon at 8:26 p.m. EST April 23, rendezvoused with the CSM, and docked with it in orbit. Young and Duke transferred to the CSM with samples, film, and equipment, and the LM was jettisoned the next day. LM attitude control was lost at jettison; therefore a deorbit maneuver was not possible and the LM remained in lunar orbit, with an estimated orbital lifetime of about one year.

The particles and fields subsatellite was launched into lunar orbit and normal system operation was noted. However, the spacecraft orbital shaping maneuver was not performed before ejection and the subsatellite was placed in a non-optimum orbit that resulted in a much shorter lifetime than the planned year. Loss of all subsatellite tracking and telemetry data on the 425th revolution (May 29) indicated that the subsatellite had hit the lunar surface.

The mass spectrometer deployment boom stalled during a retract cycle and was jettisoned before transearth injection. The second plane-change maneuver and some orbital science photography were deleted so that transearth injection could be performed about 24 hours earlier than originally planned.

Activities during the transearth coast phase of the mission included photography for a contamination study for the Skylab program and completion of the visual light-flash-phenomenon investigation that had been partially accomplished during translunar coast. A 1-hour 24-minute transearth extravehicular activity was conducted by command module pilot Mattingly to retrieve the film cassettes from the scientific instrument module cameras, inspect the equipment, and expose a microbial-response experiment to the space environment. Two midcourse corrections were made on the return flight to achieve the desired entry interface conditions.

Entry and landing were normal, completing a 265-hour 51-minute mission. The command module was viewed on television while dropping on the drogue parachutes, and continuous coverage was provided through crew recovery. Splashdown was at 2:44 p.m. EST April 27 in mid-Pacific, 5 kilometers from the recovery ship U.S.S. *Ticonderoga*. All primary mission objectives had been achieved (see Appendix 5).

MSC, "Apollo 16 Mission Report" (MSC-07230), August 1972; MSC "Apollo 16 (AS-511) Flight Summary," undated; C. M. Lee, NASA Hq., "Mission Director's Summary Report, Apollo 16," April 28, 1972; R. C. Hock, KSC, "Apollo 16 (AS-511) Post-Launch Report," May 2, 1972.

April 28

Owen G. Morris was appointed Manager, Apollo Spacecraft Program Office, at MSC. Morris, who had been Manager for the Lunar Module, succeeded James A. McDivitt, who was appointed Special Assistant to the Center Director for Organizational Affairs. Both appointments were effective immediately.

MSC Announcement 72-70, "Key Personnel Assignment," April 28, 1972; MSC Announcement 72-71, "Key Personnel Assignment," April 28, 1972.

May 7

A tank cart at the San Diego Naval Air Station, defueling the Apollo 16 command module after its April 27 return from its mission to the moon, exploded because of overpressurization. Forty-six persons

suspected of inhaling of toxic fumes, were hospitalized, but examination revealed no symptoms of inhalation. An Apollo 16 Deactivation Investigation Board completed its report on the accident June 30. The ratio of neutralizer to oxidizer being detanked had been too low because of the extra oxidizer retained in the CM tanks as a result of the *Apollo 15* parachute anomaly. Changes were made in ground support equipment and detanking procedure to prevent future overpressurization.

Ltr., Scott H. Simpkinson, MSC, to Thomas J. Walker III, Commander, Naval Air Force, U.S. Pacific Fleet, June 30, 1972; "Apollo 16 Mission Anomaly Report No. 1, Oxidizer Deservicing Tank Failure" (MSC-07032), June 1972.

June 26

NASA Deputy Administrator George M. Low and Associate Administrator for Manned Space Flight Dale D. Myers met and decided there was no foreseeable mission for CSMs 115 and 115a; funds would not be authorized for any work on these spacecraft; and skills would not be retained specifically to work on them.

Memos, Harry H. Gorman, NASA Hq., to Directors, Apollo Program and Skylab Program, July 6, 1972; Myers to Christopher C. Kraft, Jr., MSC, "Storage and Utilization of Apollo Command and Service Modules," Oct. 30, 1972; ltr., Kraft to Myers, NASA Hq., Sept. 27, 1972.

July 13

A meeting at NASA Hq. reviewed the proposed photographic and visual observation tasks of the command module pilot during the Apollo 17 mission scheduled for December. Feasibility of the tasks and potential flight planning impact were discussed.

Memo, George F. Esenwein, NASA Hq., to distr., "Apollo 17 CM Photographic and Visual Observation Tasks," July 26, 1972.

July 15

The Lunar Science Institute's summer study on post-Apollo lunar science arrived at a number of conclusions and recommendations. Some conclusions were: Lunar science would evolve through three rather distinct phases. For two years immediately following Apollo 17, high priority would be given to collection, organization, and preliminary analysis of the wealth of information acquired from the exploration of the moon. In the next two years (1975 and 1976), emphasis would shift to a careful first look at all the data. In the next years, investigations would be concentrated on key problems.

Some recommendations were: The tasks being carried out by NASA to preserve and describe the samples, data, and photographs, and to make them available to the scientific community would need to continue for the next few years. The lunar sample curatorial facility at MSC was absolutely essential to

lunar science objectives. The ALSEP network and the subsatellite should be operated continuously as long as significant new findings derived from their operation.

Ltr., Joseph W. Chamberlin, Lunar Science Institute, to John Naugle, NASA Hq., July 15, 1972.

September 26

During the Apollo 17 mission, MSC would be responsible for the medical briefing at the mission reviews, would provide the medical staffing of the mission operations control room, would assume the medical line responsibilities in the operations team, and would provide mission surgeons to take part in the change-of-shift press briefings.

Ltr., Christopher C. Kraft, Jr., MSC, to Dale D. Myers, NASA Hq., Sept. 26, 1972.

December 7-19

Apollo 17 (AS-512), the final Apollo manned lunar landing mission, was launched from Pad A, Launch Complex 39, KSC, at 12:33 a.m. EST December 7. Crew members were astronauts Eugene A. Cernan, Ronald E. Evans, and Harrison H. Schmitt. The launch had been delayed 2 hours 40 minutes by a countdown sequencer failure, the only such delay in the Apollo program caused by a hardware failure.

All launch vehicle systems performed normally in achieving an earth parking orbit of 170 by 168 kilometers. After checkout, insertion into a lunar trajectory was begun at 3:46 a.m.; translunar coast time was shortened to compensate for the launch delay. CSM 114 transposition, docking with LM-12, and LM ejection from the launch vehicle stage were normal. The S-IVB stage was maneuvered for lunar impact, striking the surface about 13.5 kilometers from the preplanned point at 3:27 p.m. EST December 10. The impact was recorded by the passive seismometers left on the moon by *Apollo 12, 14, 15, and 16*.

The crew performed a heat flow and convection demonstration and an Apollo light-flash experiment during the translunar coast. The scientific instrument module door on the SM was jettisoned at 10:17 a.m. EST December 10. The lunar orbit insertion maneuver was begun at 2:47 p.m. and the *Apollo 17* spacecraft entered a lunar orbit of 315 by 97 kilometers. After separation of the LM *Challenger* from the CSM *America* and a readjustment of orbits, the LM began its powered descent and landed on the lunar surface in the Taurus-Littrow region at 2:55 p.m. EST on December 11, with Cernan and Schmitt.

The first EVA began about 4 hours later (6:55 p.m.). Offloading of the lunar roving vehicle and equipment proceeded as scheduled. The Apollo Lunar Surface Experiment Package was deployed approximately 185 meters west northwest of the *Challenger*. Astronaut Cernan drove the lunar roving vehicle to the experiments deployment site, drilled the heat flow and deep core holes, and emplaced the neutron probe experiment. Two geological units were sampled, two explosive packages deployed, and seven traverse gravimeter measurements were taken. During the 7-hour 12-minute EVA, 14 kilograms of samples were collected.

The second extravehicular activity began at 6:28 p.m. EST December 12. Because of geological interest, station stop times were modified. Orange soil was discovered and became the subject of considerable geological discussion. Five surface samples and a double core sample were taken in the area of the orange soil. Three explosive packages were deployed, seven traverse gravimeter measurements were taken, and observations were photographed. Samples collected totaled 34 kilograms during the 7 hours and 37 minutes of the second EVA.

The third and final EVA began at 5:26 p.m. EST December 13. Specific sampling objectives were accomplished. Samples - including blue-gray breccias, fine-grained vesicular basalts, crushed anorthositic rocks, and soils - weighed 66 kilograms. Nine traverse gravimeter measurements were made. The surface electrical properties experiment was terminated. Before reentering the LM, the crew selected a breccia rock to dedicate to the nations represented by students visiting the Mission Control Center. A plaque on the landing gear of the lunar module, commemorating all of the Apollo lunar landings, was then unveiled. After 7 hours 15 minutes, the last Apollo EVA on the lunar surface ended. Total time of the three EVAs was approximately 22 hours; the lunar roving vehicle was driven 35 kilometers, and about 115 kilograms of lunar sample material was acquired.

While Cernan and Schmitt were exploring the lunar surface, Evans was conducting numerous scientific activities in the CSM in lunar orbit. In addition to the panoramic camera, the mapping camera, and the laser altimeter, three new scientific instrument module experiments were included in the *Apollo 17* orbital science equipment. An ultraviolet spectrometer measured lunar atmospheric density and composition; an infrared radiometer mapped the thermal characteristics of the moon; and a lunar sounder acquired data on the subsurface structure.

Challenger lifted off the moon at 5:55 p.m. EST December 14. Rendezvous with the orbiting CSM and docking were normal. The two astronauts transferred to the CM with samples and equipment and the LM ascent stage was jettisoned at 1:31 a.m. December 15. Its impact on the lunar surface about 1.6 kilometers from the planned target was recorded by four *Apollo 17* geophones and the *Apollo 12, 14, 15,* and *16* seismometers emplaced on the surface. The seismic experiment explosive packages that had been deployed on the moon were detonated as planned and recorded on the geophones.

During the coast back to earth, Evans left the CSM at 3:27 p.m. EST December 17 for a 1-hour 7-minute inflight EVA and retrieved lunar sounder film and panoramic and mapping camera cassettes from the scientific instrument module bay. The crew conducted the Apollo light- flash experiment and operated the infrared radiometer and ultraviolet spectrometer.

Reentry, landing, and recovery were normal. The command module parachuted into the mid-Pacific at 2:25 p.m. EST December 19, 6.4 kilometers from the prime recovery ship, U.S.S. *Ticonderoga*. The crew was picked up by helicopter and was on board the U.S.S. *Ticonderoga* 52 minutes after the CM landed. All primary mission objectives had been achieved (see Appendix 5).

MSC "Apollo 17 Mission Report," March 1973; MSC "Apollo 17 (AS-512) Flight Summary," undated; KSC, "Apollo 17 Post-Launch Report" (RCS-76-0000-0048), Dec. 19, 1972.

December 8

"Apollo, of course, was an absolutely unprecedented event in human history, one whose ultimate importance is impossible to fully comprehend at such close range," NASA Associate Administrator for Manned Space Flight Dale D. Myers wrote the Administrator. "In addition, its scientific contributions have far exceeded the expectations not only of the skeptics, but even of its proponents. It has virtually created a new branch of science as well as added a brilliant new chapter in the annals of exploration."

Myers, NASA Hq., to the NASA Administrator, "Scope of the Skylab Experiment Program," Dec. 8, 1972.

1973

January 22

Former President Lyndon B. Johnson - who as Senator had drafted the National Aeronautical and Space Act of 1958 establishing NASA and as Vice President had chaired the National Aeronautics and Space Council at the time of the U.S. decision to land a man on the moon - died of a heart attack in Austin, Tex., at the age of 64.

A letter Johnson had sent was read at the National Space Club's "Salute to Apollo" in Washington, D.C., in the evening. Johnson commended the "space pioneers who have made the Apollo miracle a living reality." He said: "It has been more, so much more than an amazing adventure into the unexplored and the unknown. The Apollo Program . . . will endure as a monument to many things, to the personal courage of some of the finest men our nation has ever produced, to the technological and managerial capability which is the genius of our system and to a successful cooperation among nations which has proved to us all what can be done when we work together with our eyes on a glorious goal.

"I rate Apollo as one of the real wonders of the world and I am proud that my country, through the exercise of great ability and daring leadership, has given it as a legacy to mankind."

Washington Post, Jan. 23, 1973, p. A1; *Congressional Record-Senate*, Jan.29, 1973, p. S1467; transcript of proceedings, "Salute to Apollo," Jan. 22, 1973.

January 26

Ames Research Center requested that six R4D rocket engines designed for use in the Apollo program be transferred from MSC to Ames. Possibly the engines would be suitable for the retro-injection function in the Pioneer Venus series of atmospheric probe and orbiter missions. First launch was planned for early 1977.

Ltr., R. R. Nunamaker, Ames Research Center, to M. A. Faget, MSC, "Apollo surplus R4D rocket engines for Pioneer Venus," Jan. 26, 1973.

February 17

The Manned Spacecraft Center was renamed the Lyndon B. Johnson Space Center by Public Law 93-8. The late President's interest and support of the space program began while he was Chairman of the Senate Committee on Aeronautical and Space Sciences and continued during his tenure as Vice President and President (see January 22).

MSC Announcement 73-34, "Renaming of the Manned Spacecraft Center," Feb. 27, 1973.

March 6

The Apollo Spacecraft Program Office, with Glynn S. Lunney as Manager, was reorganized. Lunney was also Manager for ASTP (Apollo/Soyuz Test Project), an assignment to which he had been appointed in June of 1972.

JSC Announcement 73-37, "Reorganization of the Apollo Spacecraft Program Office," March 6, 1973; MSC Announcement 72-98, "Key Personnel Assignments," June 26, 1972; ltr., Christopher C. Kraft, Jr., JSC, to Dale D. Myers, NASA Hq., March 2, 1973.

March 15

A Lunar Programs Office, under which the Lunar Data Analysis and Synthesis Program would be conducted, was established in the Office of Space Science, NASA Hq. The office was responsible for continued operation and collection of data from the Apollo lunar surface experiment packages and the *Apollo 15* subsatellite; Apollo surface and orbital science data analysis by principal investigators; development of selenodetic, cartographic, and photographic products; continued lunar laser ranging experiment; continued lunar sample analysis; lunar supporting research and technology; and advanced program studies.

Ltr., John E. Naugle, NASA Hq., to Colleagues, March 15, 1973.

August 7

National Air and Space Museum Director Michael Collins advised JSC that NASM had established a

center for research and study with responsibility for a complete library of lunar photos to document scientific results of the Apollo missions. The library would be used for original research and for planning and updating scientific parts of exhibits.

Ltr., Collins to Christopher C. Kraft, Jr., Director, JSC, Aug. 7, 1973.

August 27

Apollo Soyuz Test Project Program Director Chester M. Lee, Office of Manned Space Flight, NASA Hq., was assigned as the management official to take actions necessary for the final phaseout of the Apollo program. All Apollo program inquiries, activities, and actions not covered by specific delegations of authority would be referred to Lee for appropriate decision and disposition.

NASA Notice 8020, "Apollo Program Phaseout Activities," Aug. 27, 1973.

November 2

With the support of the trustees of the Washington Cathedral, Francis B. Sayre and Thomas O. Paine commissioned a large stained glass Space Window to be installed in the south wall of the nave, the main auditorium of the Cathedral. The window would be 5.4 meters high by 2.7 meters wide. The center of the window would contain an *Apollo 11* lunar sample 2 centimeters in diameter.

Ltrs., Paine, former NASA Administrator, to President Nixon, Nov. 2, 1973; Paine to J. C. Fletcher, NASA Hq., Nov. 2, 1973; Nixon to Paine, Jan. 14, 1974; G. P. Chandler, NASA Hq., to E. A. Cernan, MSC, Jan. 23, 1974; Fletcher to C. C. Kraft, Jr., MSC, Feb. 5, 1974.

1974

January

During the Month

Universal Studios filmed a program for the ABC TV Network entitled, "Houston, We've Got a Problem." Although fictitious, the show revolved around mission control and the flight controllers during the *Apollo 13* mission. The production was televised March 2, 1974.

Memo, John P. Donnelly, NASA Hq., to Deputy Administrator, Feb. 21, 1974.

January 4

Of the 134 *Apollo 17* lunar plaques, 93 were presented by American embassies to the countries in which the embassies were located.

Memo, John P. Donnelly, NASA Hq., to the Administrator and Deputy Administrator, "Status Report on Presentation of Apollo 17 Lunar Plaques," March 4, 1974.

July 13

In recognition of the fifth anniversary of the *Apollo 11* flight, which landed the first men on the moon, President Nixon proclaimed the period July 16 through July 24 as United States Space Week, stating: "The knowledge to be gained from space will lead to scientific, technological, medical and industrial advances which cannot be fully perceived today. In time man may take for granted in the heavens such wonders as we cannot imagine - just as superhighways across America would amaze the Puritans of 1620 or transatlantic flights would astound those who passed on the legend of Icarus. But we know that a beginning has been made that will affect the course of human life forever."

Presidential Proclamation 4303, "United States Space Week, 1974," July 13, 1974.

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Appendix 1

Glossary of Abbreviations

AAP - Apollo Applications Program

ACBWG - Apollo Reentry Communications Blackout Working Group

ACE - acceptance checkout equipment; also automatic checkout equipment

ACE - acceptance checkout equipment

S/C - spacecraft

ACED - AC Electronics Division, General Motors Corporation

AEC - Atomic Energy Commission

AEDC - Arnold Engineering Development Center, Air Force

AES - Apollo Extension System, forerunner of Apollo Applications Program

AFETR - Air Force Eastern Test Range

AFRM - airframe

AFSC - Air Force Systems Command

ALEP - Apollo lunar exploration program

ALSEP - Apollo Lunar Surface Experiments Package

ALSD - Apollo lunar surface drill

AMS - Apollo mission simulator

AOH - Apollo operations handbook

AP - Associated Press

ARC - Ames Research Center

AS - Apollo-Saturn

ASPO - Apollo Spacecraft Program Office, MSC

ASSB - Apollo Site Selection Board

ASTT - Apollo Special Task Team

ATM - Apollo telescope mount

BAC - Bell Aerospace Company or, before January 1970, Bell Aerosystems Company

BeV - billion electron volts

BIG - biological isolation garment

BTU - British thermal unit

degrees C - degrees Celsius (centigrade)

CARIDS - customer acceptance review item dispositions

CARR - Customer Acceptance Readiness Review

CASE - Coordinated Aerospace Supplier Evaluation

cc - cubic centimeter(s)

CCB - Configuration Control Board

CDR - commander

cm - centimeter(s)

CM - command module

CMP - command module pilot

cps - cycles per second (see Hz)

CSM - command and service modules

cu m - cubic meter(s)

DCR - Design Certification Review

DFI - development flight instrumentation

DOD - Department of Defense

DPS - descent propulsion system

EASEP - Early Apollo Science Experiments Package

ECP - engineering change proposal

ECS - environmental control system

EDCP - engineering design change proposal

EDS - emergency detection system

ELS - earth landing system

EMS - entry monitor system

EMU - extravehicular mobility unit

EO - engineering order

eV - electron volts(s)

EVA - extravehicular activity

degrees F - degrees Fahrenheit

FCOD - Flight Crew Operations Directorate

FCSM - flight combustion stability monitor

FAI - Fédération Aéronautique International (International Aeronautical Federation)

FOD - Flight Operations Directorate

FRR - Flight Readiness Review

G - specific gravity

g - gram, gravity

GAEC - Grumman Aircraft Engineering Corporation

GAO - Government Accounting Office

GE - General Electric Company

GET - ground elapsed time

GFE - government-furnished equipment

GLEP - Group for Lunar Exploration Planning

GMT - Greenwich mean time

GSE - ground support equipment

GSFC - Goddard Space Flight Center

HEAO - High Energy Astronomy Observatory (satellite)

HF - high frequency

Hz - hertz (unit of frequency: 1 cycle per second)

IBM - International Business Machines Corporation

ICBC - Interagency Committee on Back Contamination

IMU - inertial measurement unit

ITT - International Telephone and Telegraph Corporation

J - joule

JPL - Jet Propulsion Laboratory

JSC - Johnson Space Center (Manned Spacecraft Center before February 1973)

K - kelvin(s)

kg - kilogram(s)

km - kilometer(s)

km/hrs - kilometers per hour

KSC - Kennedy Space Center

LaRC - Langley Research Center

LC - Launch Complex

LEM - lunar excursion module

LeRC - Lewis Research Center

LES - launch escape system

LGI - lunar geology investigation

LION - Lunar International Observer Network

LLRF - Lunar Landing Research Facility

LLRV - lunar landing research vehicle

LLTV - lunar landing training vehicle

LM - lunar module

LMP - lunar module pilot

LMS - lunar module simulator

LMSS - lunar mapping and survey system

LOI - lunar orbit insertion

LOLA - lunar orbit and landing approach

LOX - liquid oxygen

LRL - Lunar Receiving Laboratory

LRV - lunar roving vehicle

LSI - Lunar Science Institute

LTA - lunar module test article

m - meter(s)

mascons - mass concentrations of dense material on lunar surface

MC - megacycles

MCC (H) (K) - Mission Control Center (Houston) (Kennedy)

MCP - mission control programmer

MCR - master change record

MDF - mild detonating fuse

MDOP - maximum design operating pressure

MET - mobile equipment transporter

MeV - million electron volts

MHz - megahertz (million cycles per second)

min - minute(s)

MIT - Massachusetts Institute of Technology

mm - millimeter

MMH - monomethylhydrazine

MOL - Manned Orbiting Laboratory

MRB - Material Review Board

MSC - Manned Spacecraft Center (became Johnson Space Center February 1973)

MSFC - Marshall Space Flight Center

MSFN - Manned Space Flight Network

MSOB - Manned Spacecraft Operations Building

M&SS - Mapping and survey system

Mw - megawatt(s)

NAA - North American Aviation, Inc. (until Sept. 22, 1967)

NAR (NR) - North American Rockwell Corporation (Sept. 22, 1967-Feb. 16, 1973; then Rockwell International Corporation)

NAS - National Academy of Sciences

NASA - National Aeronautics and Space Administration

NASM - National Air and Space Museum, Smithsonian Institution

nm - nautical mile(s)

NR - North American Rockwell Corporation (North American Aviation, Inc., before Sept. 22, 1967; Rockwell International Corporation Feb. 16, 1973)

NSSDC - National Space Science Data Center

OAQ - Orbiting Astronomical Observatory (satellite)

OART - Office of Advanced Research and Technology, NASA Headquarters

OAS - optical alignment sights

OCP - Operational Checkout Procedure

OMSF - Office of Manned Space Flight, NASA Headquarters

OPS - oxygen purge system

ORDEAL - orbital rate drive electronics for Apollo and LM

ORI - Operational readiness inspection

OSO - Orbiting Solar Observatory (satellite)

OSSA - Office of Space Science and Applications, NASA Headquarters

OTDA - Office of Tracking and Data Acquisition, NASA Headquarters

PAD - project approval document

PDR - Preliminary Design Review

PGA - pressure garment assembly

PHS - Public Health Service

PI - principal investigator

PIB - Pyrotechnic Installation Building

PLSS - portable life support system

pogo - launch vehicle induced oscillations (not an acronym; derived from "pogo stick" analogy)

PSAC - President's Scientific Advisory Committee

psi - pounds per square inch

psia - pounds per square inch absolute

PTV - parachute test vehicle

RASPO - Resident Apollo Spacecraft Program Office

RCA - Radio Corporation of America

RCS - reaction control system

RF - radio frequency

RTCC - Real Time Computer Complex

RTG - radioisotope thermoelectric generator

RTV - room temperature vulcanizing

SAMSO - Space and Missiles Organization, Air Force

S/C - spacecraft

SEB - Source Evaluation Board

sec - second(s)

SEQ - scientific equipment

SESL - Space Environmental Simulation Laboratory

SEVA - Stand-up extravehicular activity

S-IB - Saturn IB launch vehicle first stage

S-IC - Saturn V launch vehicle first stage

S-II - Saturn second stage

S-IVB - Saturn IB second stage; Saturn V third stage

SID - Space and Information Systems Division, NAA

SIM - scientific instrument module

SLA - spacecraft-lunar module adapter

SLSS - supplementary life support system

SM - service module

SPF - single point failure

SPS - service propulsion system

sq cm - square centimeter(s)

sq m - square meter(s)

SSC - spacesuit communications

STAG - Scientific and Technical Advisory Committee, university-NASA

STG - Space Task Group, NASA (forerunner of Manned Spacecraft Center); Space Task Group, President's (1969)

SWIP - Super Weight Improvement Program

TCP - test and checkout procedures

TEI - transearth injection (insertion into trajectory to earth)

TLI - translunar injection (insertion into trajectory to moon)

TM - test model

TV - thermal vacuum-test article; also television

V - volt(s)

VHF - very high frequency

W - Watt(s)

WIF - Water Immersion Facility

WSMR - White Sands Missile Range, Army

WSTF - White Sands Test Facility, MSC, NASA

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APPENDIX 2

Major Spacecraft Component Manufacturers

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Appendix 3

Official U.S. International Aeronautical Federation World Records

[Prepared by Carl R. Huss, Data Systems and Analysis Directorate, JSC.]

Mercury flights

MR-3, May 5, 1961

Alan B. Shepard, Jr.

Altitude without earth orbit - 186.6 km (116 mi)

Gemini flights

Gemini V, Aug. 21-29, 1965

L. Gordon Cooper, Jr., Charles Conrad, Jr.

1. Distance with earth orbit, 2-4 astronauts - 5,326,133.6 km (3,309,506 mi)
2. Duration with earth orbit, 2-4 astronauts - 190 hrs 56 min

Gemini VII, Dec. 4-18, 1965

Frank Borman, James A. Lovell, Jr.

1. Distance with earth orbit, 2-4 astronauts - 9,204,573.8 km (5,719,457 mi)
2. Duration with earth orbit, 2-4 astronauts - 330 hrs 35 min

Gemini X, July 18-21, 1966

John W. Young, Michael Collins

Greatest altitude with earth orbit. 2-4 astronauts - 766 km (476 mi)

Gemini XI, Sept. 12-15, 1966

Charles Conrad, Jr., Richard F. Gordon, Jr.

Greatest altitude with earth orbit, 2-4 astronauts - 1,368.98 km (850.65 mi)

Apollo flights

Apollo 7, Oct. 11-22, 1968

Walter M. Schirra, Jr., R. Walter Cunningham, Donn F. Eisele

1. Greatest mass lifted to altitude - 14,771.6 kg (32,566 lbs)
2. World class - greatest mass lifted to orbit, 2-4 astronauts - 14,771.6 kg (32,566 lbs)

Apollo 8, Dec. 21-27, 1968

Frank Borman, James A. Lovell, Jr., William A. Anders

1. Greatest mass lifted to altitude - 128,002.4 kg (282,197 lbs)
2. Highest altitude - 377,349.38 km (203,752.37 nm)
3. World class-greatest mass lifted to orbit, 2-4 astronauts - 128,002.4 kg (282,197 lbs)
4. World class-highest altitude, 2-4 astronauts - 377,349.38 km (203,752.37 nm)
5. Duration of a lunar mission - 147 hrs 42 min
6. Duration in lunar orbit, 2-4 astronauts - 20 hrs 6 min 49 sec (10 orbits)
7. Total time in space, 1 astronaut - 572 hrs 10 min 16 sec

Apollo 9, March 3-13, 1969

James A. McDivitt, David R. Scott, Russell L. Schweickart

1. Longest duration outside spacecraft (EVA) - 47 min 1 sec
2. Longest duration in group flight, linked - 21 hrs 36 min 31 sec
3. Greatest mass in group flight, linked - 28,428.9 kg (62,675 lbs)

4. Greatest distance in group flight, linked - 602,488.9km (325,318 nm)
5. Longest duration in group flight - 26 hrs 32 min 59 sec

Apollo 10, May 18-26, 1969

Thomas P. Stafford, John W. Young, Eugene A. Cernan

1. Duration of a lunar mission - 192 hrs 3 min 23 sec
2. Duration in lunar orbit - 31 orbits

Apollo 11, July 16-24, 1969

Neil A. Armstrong, Michael Collins, Edwin E. Aldrin, Jr.

1. Duration of stay on the surface of the moon - 21 hrs 36 min 21 sec
2. Greatest mass landed on the moon - 7,326.9 kg (16,153.2 lbs)
3. Duration of stay inside spacecraft on lunar surface - 19 hrs 49 min 28 sec
4. Duration of stay outside spacecraft on lunar surface - 2 hrs 31 min 40 sec
5. Greatest mass lifted to lunar orbit from lunar surface - 2,689.1 kg (5,928.6 lbs)
6. Duration of stay outside spacecraft (world absolute) - 2 hrs 31 min 40 sec

Apollo 12, Nov. 14-24, 1969

Charles Conrad, Jr., Richard F. Gordon, Jr., Alan L. Bean

1. Duration of a lunar mission - 244 hrs 36 min 25 sec
2. Duration of stay on lunar orbit - 88 hrs 56 min 1 sec
3. Duration of stay on lunar surface - 31 hrs 31 min 12 sec
4. Duration of stay outside the spacecraft - 25 hrs 6 min 49 sec (This item seems to be erroneous. W. D.W.)
5. Duration of stay on lunar surface for crewmen - 14 hrs 2 min 25 sec
6. Total continuous time outside the spacecraft for one crewman - 3 hrs 52 min 6 sec
7. Total accumulated time outside the spacecraft for one crewman - 7 hrs 37 min 37 sec

Apollo 13, April 11-17, 1970

James A. Lovell, Jr., Fred W. Haise, Jr., John L. Swigert, Jr.

Total accumulated time in space for one crewman - 715 hrs 4 min 57 sec

Apollo 14, Jan. 31-Feb. 9, 1971

Alan B. Shepard, Jr., Edgar D. Mitchell, Stuart A. Roosa

1. Total duration of stay outside spacecraft (EVA) by one astronaut for a single mission - 9 hrs 12 min 27 sec
2. Total duration of stay outside spacecraft on lunar surface for single mission (total accumulation for all crewmen) (world class for lunar mission) - 17 hrs 33 min 29 sec
3. Maximum distance traveled on lunar surface away from spacecraft (world class for lunar mission) - 1453.8 m (4,770 ft)

Apollo 15, July 26-Aug. 7, 1971

David R. Scott, Alfred M. Worden, James B. Irwin

1. Total time outside spacecraft on lunar surface for one crewman during one mission - 18 hrs 18 min 26 sec
2. Maximum radial distance traveled away from spacecraft on lunar surface - 5,020 m (16,470 ft)
3. Greatest mass to lunar orbit from earth - 34,599.1 kg (76,278 lbs)

Apollo 16, April 16-27, 1972

John W. Young, Thomas K. Mattingly II, Charles M. Duke, Jr.

1. Duration of stay in lunar orbit - 125 hrs 46 min 50 sec
2. Duration of stay on lunar surface - 71 hrs 2 min 13 sec
3. Duration of stay outside spacecraft for all crewmen on a single mission - 39 hrs 4 min 3 sec
4. Greatest mass landed on surface of moon - 8,259kg (18,208 lbs)
5. Greatest mass lifted from lunar surface - 4,966.3 kg (10,949 lbs)

Apollo 17, Dec. 7-19, 1972

Eugene A. Cernan, Ronald E. Evans, Harrison H. Schmitt

1. Total time outside spacecraft for one crewman on a single mission (world absolute) - 21 hrs 31 min 44 sec
2. Total time outside spacecraft for one crewman on a single lunar mission (world class - lunar mission) - 21 hrs 31 min 44 sec
3. Total time in lunar orbit (world class - lunar mission) - 147 hrs 41 min 13sec
4. Maximum distance traveled radially away from spacecraft on the lunar surface - 7,628.8 m (25,029 ft)
5. Duration of a lunar mission - 301 hrs 51 min 57 sec

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Appendix 4

FLIGHT SUMMARY

[January 21, 1966, through December 19, 1972]

ETR = Eastern Test Range

WS = Wallops Station

KSC = Kennedy Space Center

Source: *Astronautics and Aeronautics: Chronology of Science, Technology, and Policy*, annual volumes 1966 through 1972 (NASA SP-4007, 1967; SP-4008, 1968; SP-4010, 1969; SP-4014, 1970; SP-4015, 1972; SP-4016, 1972; SP-4017, 1975), Appendixes A, B, and C, and 1973 (NASA SP-4018), p. 282.

1966

January 31

Luna 9 (USSR)

Launch details not available

Soft-land on moon; take TV photos of lunar surface and measurements of cosmic radiation and transmit to earth.

Performance:-

Soft-landed on moon Feb. 3.

February 26

Apollo-Saturn 201 (AS-201)

Saturn IB (ETR)

Unmanned suborbital launch vehicle development test. First flight of Saturn IB and of Apollo spacecraft (CSM 009).

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

March 16

Gemini VIII GATV

Atlas-GATV (ETR)

Gemini-Agena Target Vehicle for *Gemini VIII* rendezvous and docking exercise.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

March 16

Gemini VIII

Titan II (ETR)

Neil A. Armstrong and David R. Scott in orbital space flight to rendezvous with GATV and make first docking in space.

Performance:-

Vehicle - Successful

Payload - Partially successful

Mission Results - Successful

March 31

Luna 10 (USSR)

Launch details not available

Maneuver spacecraft into vicinity of moon; test systems for putting satellite in orbit around moon.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

May 17

Gemini IX GATV

Atlas-GATV (ETR)

Gemini-Agena Target Vehicle for planned rendezvous and docking mission; failed to orbit after launch. Launch of manned Gemini IX was canceled.

Performance:-

Vehicle - Unsuccessful

Payload - Unknown

Mission Results - Unsuccessful

May 30

Surveyor 1 (Surveyor A)

Atlas-Centaur (ETR)

First U.S. attempt at soft-landing on moon. Spacecraft landed June 2. TV photos were excellent.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

June 1

Gemini IX-A ATDA

Atlas-ATDA (ETR)

Augmented Target Docking Adapter launched into orbit as target vehicle for manned *Gemini IX-A* rendezvous and docking.

Performance:-

Vehicle - Successful

Payload - Partially successful

Mission Results - Unsuccessful

June 3

Gemini IX-A

Titan II (ETR)

Thomas P. Stafford and Eugene A. Cernan, launched into orbit, rendezvoused with ATDA during 3rd orbit but docking was not possible because ATDA's shroud had not separated. Cernan performed 2hr EVA.

Performance:-

Vehicle - Successful

Payload - Partially successful

Mission Results - Unsuccessful

July 5

Apollo-Saturn 203 (AS-203)

Upgraded Saturn I (ETR)

Launch vehicle development test. Orbited Saturn's S-IVB stage for new U.S. weight record-26,535kg.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

July 18

Gemini X GATV

Atlas-GATV (ETR)

Gemini-Agena Target Vehicle for manned *Gemini X* rendezvous and docking.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

July 18

Gemini X

Titan II (ETR)

John W. Young and Michael Collins made first manned space rendezvous with 2 spacecraft - *Gemini X GATV* and *Gemini VIII GATV*. First use of another spacecraft to provide primary and secondary power for docked manned spacecraft. Two EVAs.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

August 10

Lunar Orbiter 1 (Lunar Orbiter A)

Atlas-Agena D (ETR)

Lunar orbital probe. Went into lunar orbit Aug. 14; medium resolution camera took good photos of Apollo landing sites, back of moon, and first view of earth from moon.

Performance:-

Vehicle - Successful

Payload - Partially successful

Mission Results - Successful

August 24

Luna 11 (USSR)

launch details not available

Orbit the moon, measure lunar radiation. Made observations and transmitted 137 times before batteries failed Oct. 1.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

August 25

Apollo-Saturn 202 (AS-202)

Upgraded Saturn I (ETR)

Third test, suborbital, of Uprated Saturn I (Saturn IB) and second test of Apollo heatshield. Service module was fired 4 times; command module was propelled into reentry at 32,000 km per hr.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

September 12

Gemini XI GATV (Gemini XI)

Atlas-GATV (ETR)

Gemini-Agena Target Vehicle for manned *Gemini XI* spacecraft.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

September 12

Gemini XI (Gemini XI)

Titan II (ETR)

Orbital manned space flight. Charles Conrad, Jr., and Richard F. Gordon, Jr., achieved rendezvous and docking on first revolution; set new manned space flight altitude record, 1,370 kilometers.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

September 20

Surveyor 2 (Surveyor B)

Atlas-Centaur (ETR)

Launched on good trajectory for lunar landing. Failure of 1 of 3 vernier engines to fire during midcourse maneuver caused spacecraft to spin. Crash-landed on the moon Sep. 22.

Performance:-

Vehicle - Successful

Payload - Unsuccessful

Mission Results - Unsuccessful

October 22

Luna 12 (USSR)

Launch details not available

Orbited the moon, took TV photos of moon and scientific measurements of lunar radiation, meteoroids.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

November 6

Lunar Orbiter 2 (Lunar Orbiter B)

Atlas-Agena D (ETR)

Lunar probe, orbital. By Nov. 25 had taken all planned medium-and high-resolution photos of 13 possible Apollo landing sites.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

November 11

Gemini XII GATV (Gemini XII)

Atlas-GATV (ETR)

Gemini-Agena Target Vehicle for final manned orbital Gemini space flight.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

November 11

Gemini XII (Gemini XII)

Titan II (ETR)

James A. Lovell, Jr., and Edwin E. Aldrin, Jr., rendezvoused and docked with target vehicle. Aldrin performed 2 standup and 1 tethered EVA and work tasks in space.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

December 21

Luna 13 (USSR)

Not available

Made 2nd successful USSR soft-landing on moon, photographed lunar surface characteristics, measured lunar radiation.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

1967

February 4

Lunar Orbiter 3 (Lunar Orbiter C)

Atlas-Agena B (ETR)

Lunar probe, orbital. Entered orbit Feb. 8, then close lunar orbit. Took 211 medium- and high-resolution photos of Apollo landing sites and lunar features.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

April 17

Surveyor 3 (Surveyor C)

Atlas-Centaur (ETR)

Scientific lunar landing probe. Soft-landed on moon after 3 bounces. Transmitted 6,315 detailed photos of lunar surface.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

April 23

Soyuz 1 (USSR)

Launch details not available

First Soviet manned space flight since Mar.1966. Cosmonaut Vladimir M. Komarov was killed in crash landing after tumbling caused premature spacecraft reentry and parachute straps twisted on opening. First man to die in space flight.

Performance:-

Vehicle - Successful

Payload - Unsuccessful

Mission Results - Unsuccessful

May 4

Lunar Orbiter 4 (Lunar Orbiter D)

Atlas-Agena D (ETR)

Lunar photographic probe. Transmitted 163 high- and medium-resolution photos of lunar surface, including coverage of 99 percent of moon's front face and much of back face.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

July 14

Surveyor 4 (Surveyor D)

Atlas-Centaur (ETR)

Scientific lunar landing probe. Trajectory was excellent but all communications were lost seconds before attempt at soft landing.

Performance:-

Vehicle - Successful

Payload - Unsuccessful

Mission Results - Unsuccessful

July 19

Explorer 35 (IMP-E)

Thrust Augmented Thor-Delta (ETR)

Traveled to moon on direct trajectory; on July 21 retrorockets slowed spacecraft enough to permit lunar capture; went into elliptical lunar orbit, 7,693 by 800 km; returned data on radiation at lunar distance.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

August 1

Lunar Orbiter 5 (Lunar Orbiter E)

Atlas-Agena D (ETR)

Lunar orbital probe, took 424 photos of lunar surface, filling gaps in lunar coverage; provided detailed coverage of 36 scientific-interest sites and 5 Apollo sites.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

September 8

Surveyor 5 (Surveyor E)

Atlas-Centaur (ETR)

Scientific lunar landing probe. Soft-landed in lunar Sea of Tranquillity. Transmitted 18,006 photos during first lunar day; soil test confirmed basaltic character of lunar soil, similar to earth's.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

November 7

Surveyor 6 (Surveyor F)

Atlas-Centaur (ETR)

Scientific lunar landing probe. Soft-landed in Sinus Medii area, transmitted 30,065 TV photos during first lunar day. On Nov. 17 vernier engines were restarted and spacecraft lifted off lunar surface and landed 2.4 m away.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

November 9

Apollo 4 (AS-501)

Saturn V (ETR)

Launch vehicle and spacecraft development. Launched into earth orbit; S-IVB stage fired again and lifted CSM to apogee of 18,089 km. Service propulsion system powered command module to reentry speed of 11,136 m per sec.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

1968

January 7

Surveyor 7 (Surveyor G)

Atlas-Centaur (ETR)

Scientific lunar landing probe. Soft-landed on moon Jan. 9. During first lunar day, transmitted 21,274 TV photos and operated 3 scientific experiments.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

January 22

Apollo 5 (AS-204)

Saturn IB (ETR)

Launch vehicle and spacecraft development. *Apollo 5* was launched into earth orbit; lunar module, in first flight test, separated and fired its ascent and descent engines several times.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

April 4

Apollo 6 (AS-502)

Saturn V (ETR)

Launch vehicle and spacecraft development. Apollo 6 was launched into earth orbit. Three of primary objectives were met but mission was not a success. CM was recovered.

Performance:-

Vehicle - Unsuccessful

Payload - Unknown

Mission Results - Unsuccessful

April 7

Luna 14 (USSR)

Launch details not available

Study near-lunar space.

Performance:-

Entered lunar orbit April 10

April 27

Reentry F

Scout (WS)

Suborbital 6,069-m-per-sec reentry test. Reentry F reentered at 6,020 m-per-sec.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

August 22

RAM C-II

Scout (WS)

Suborbital reentry probe. RAM C-II reentered at 27,400 km per hr, measured electrons and ions built up around spacecraft.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

October 11

Apollo 7 (AS-205)

Saturn IB (ETR)

First manned Apollo flight, manned by Walter M. Schirra, Jr., Donn F. Eisele, and R. Walter Cunningham; confirmed operation of all major systems except lunar module. First live commercial TV from space. Earth-orbital mission landed during 164th revolution on October 22.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

October 25

Soyuz2 (USSR)

Launch details not available

Target for joint experiments with manned spacecraft.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

October 26

Soyuz 3 (USSR)

Launch details not available

Perfect rendezvous techniques in orbit and perform joint experiments with target vehicle. Automatic maneuvering brought spacecraft within 200 m of *Soyuz 2* on first orbit. Cosmonaut Georgy T. Beregovoy later made manual maneuvers. No docking. Soft-landed October 30 after 64 orbits.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

December 21

Apollo 8 (AS-503)

Saturn V (ETR)

After 2 revolutions in earth orbit, *Apollo 8*'s 3rd-stage was fired to attain escape velocity and insert spacecraft on lunar trajectory. Manned Spacecraft with Frank Borman, James A. Lovell, Jr., and William A. Anders, entered lunar orbit December 24, stayed for 10 orbits; transmitted live TV of lunar surface to earth; fired spacecraft motor to lunar escape speed December 25; reentered earth's atmosphere December 27. First manned Saturn V flight, first men to escape earth's gravity, first men to orbit moon.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

1969

January 4

Soyuz 4 (USSR)

Launch details not available

Perform tests between 2 manned orbiting spacecraft. Cosmonaut Vladimir A. Shatalov switched to manual control and rendezvoused and docked with Soyuz 5 (launched January 15). Link-up covered on live TV. Landed safely January 17 with 3-man crew.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

January 15

Soyuz 5 (USSR)

Launch details not available

Launched 1 day after Soyuz 4 with cosmonauts Yevgeny V. Khrunov, Boris V. Volynov, and Aleksey

S. Yeliseyev aboard. Rendezvoused with *Soyuz 4* and docked during 18th orbit. Khrunov and Yeliseyev completed first manned transfer (to *Soyuz 4*) after 1-hour EVA. *Soyuz 5*, with Volynov aboard, landed safely January 18.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

March 3

Apollo 9 (AS-504)

Saturn V (KSC)

Earth-orbital manned Apollo flight by James A. McDivitt, David R. Scott, and Russell L. Schweickart. First manned testing of complete Apollo Spacecraft; first manned testing of LM, including rendezvous with CSM; 37-min. EVA by Schweickart; simulated LM landing and takeoff from lunar surface. Landed and recovered March 13.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

May 18

Apollo 10 (AS-505)

Saturn V (KSC)

Lunar-orbital manned Apollo flight by Thomas P. Stafford, Eugene A. Cernan, and John W. Young. After insertion into lunar orbit, crew transposed CSM and docked with LM. SPS fired 76 hrs into mission to insert spacecraft into lunar orbit; second firing circularized orbit at about 100-hrs. Stafford and Cernan entered LM, undocked from CSM and briefly flew station-keeping exercise. LM flew over Apollo 11 landing site 2, and simulated lunar landing by descending to within 14,300 meters of lunar surface. After 8-hr separation, LM docked with CSM, crew transferred, and LM ascent stage was

jettisoned. After 61 hrs in lunar orbit, spacecraft was injected into transearth trajectory. One midcourse correction was required; CM landed in Pacific on May 26 and crew and spacecraft were safely recovered.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

July 13

Luna 15 (USSR)

Launch details not available

Make further scientific exploration of moon and near lunar space.

Performance:-

Impacted on moon July 16

July 16

Apollo 11 (AS-506)

Saturn V (KSC)

First manned lunar landing mission, crewed by astronauts Neil A. Armstrong, Edwin E. Aldrin, Jr., and Michael Collins. After LM checkout in lunar orbit, Armstrong and Aldrin undocked LM from CSM and descended to land on Sea of Tranquillity at 4:18p.m. EDT July 20. Armstrong took man's first step on moon's surface at 10:56 p.m. and Aldrin followed at 11:15 p.m. Samples were collected, several experiments deployed, and LM lifted off from moon at 1:54 p.m. EDT July 21. Command module and crew landed in Pacific July 24.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

October 11

Soyuz 6 (USSR)

Launch details not available

Launched carrying cosmonauts Georgy S. Shonin and Valery Kubasov. Tested welding techniques in a depressurized spacecraft chamber. Hovered nearby as *Soyuz 7* and *Soyuz 8* made rendezvous maneuvers. Soft-landed in U.S.S.R. October 16.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

October 12

Soyuz 7 (USSR)

Launch details not available

Launched with cosmonauts Vladislav N. Volkov, Anatoly V. Filipchenko, and Viktor V. Gorbatko aboard. Performed rendezvous maneuvers with *Soyuz 8*, approaching within 460 m of spacecraft. Soft-landed in U.S.S.R. October 17.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

October 13

Soyuz 8 (USSR)

Launch details not available

Third Soviet manned spacecraft launched in 3 days, with cosmonaut crew of Vladimir A. Shatalov and

Aleksey S. Yeliseyev. Rendezvoused with *Soyuz 7* and together with *Soyuz 6* tested complex system of controlling simultaneous group flight of 3 spacecraft and maneuvering to solve number of problems in developing piloted space system. Soft-landed safely in U.S.S.R. October 18.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

November 14

Apollo 12 (AS-507)

Saturn V (KSC)

Second manned lunar landing mission with crew, Charles Conrad, Jr., Richard F. Gordon, Jr., and Alan L. Bean. Experienced momentary power loss 36 secs after liftoff, after electrical potential discharge from clouds passed through space vehicle to ground. Power was quickly restored. Conrad and Bean undocked LM, descended. and touched down in Ocean of Storms November 19 at 1:55 a.m. EST, 180 meters from *Surveyor 3* spacecraft. They performed two EVAs, obtained samples, erected experiments, and deployed ALSEP. Retrieved soil scoop from *Surveyor 3*. Total lunar stay time 31 hrs 31 min. LM liftoff from moon at 9:26 a.m. EST November 20. Command module and crew landed safely in Pacific November 24.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

1970

April 11

Apollo 13 (AS-508)

Saturn V (KSC)

Third planned lunar landing mission was launched successfully with James A. Lovell, Jr., John L. Swigert, Jr., and Fred W. Haise, Jr., aboard. Mission was aborted 56 hrs into flight toward moon because of SM oxygen tank rupture. LM "Lifeboat" emergency plan was put into effect; LM descent propulsion system placed spacecraft in free-return trajectory around moon. Command module and crew safely landed in Pacific April 17.

Performance:-

Vehicle - Successful

Payload - Partially successful

Mission Results - Unsuccessful

June 2

Soyuz 9 (USSR)

Launch details not available

Soyuz 9 with crew of cosmonauts Andrian G. Nikolayev and Vitaly I. Sevastyanov set new world endurance record for longest manned space flight - 17 days 16 hrs 59 min. Soft-landed in U.S.S.R. on June 19.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

September 12

Luna 16 (USSR)

Launch details not available

First unmanned spacecraft to land on moon and return to earth with lunar samples. Analyses of Sea of Fertility samples indicated same relative abundance of major elements as *Apollo 12* Ocean of Storms samples. Returned to earth September 24.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

September 30

RAM C-III

Scout (WS)

Suborbital reentry probe. Reentered at 7.6 km per sec to compare effectiveness of liquid electrophilic (Freon) with water in alleviating radio blackout during reentry.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

November 10

Luna 17 (USSR)

Launch details not available

Soft-landed in moon's Sea of Rains November 16 and released *Lunokhod 1*, self-propelled vehicle resembling large potbellied tub, about size of small auto, with 8 spoked wheels, powered by solar energy and batteries. Automatic lunar explorer - equipped with scientific apparatus, instruments, control system, radio, and TV - operated during lunar days and hibernated during lunar nights. By May 22, 1971, it had logged 8,458 m and explored 400,000 sq m.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

1971

January 31

Apollo 14 (AS-509)

Saturn V (KSC)

Third successful manned lunar landing mission. Alan B. Shepard, Jr., Stuart A. Roosa, and Edgar D. Mitchell composed crew. Shepard and Mitchell landed LM at Fra Mauro site February 5. Conducted two EVAs, deployed ALSEP, and used mobile equipment transporter to obtain 43 kg of lunar samples. LM lifted off February 6 and command module and crew splashed down in Pacific February 9.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

April 19

Salyut 1 (USSR)

Launch details not available

World's first manned space laboratory. Placed in orbit as working area for 2 Soviet cosmonaut crews. Reentered October 11 after nearly 6 months in orbit.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

April 23

Soyuz 10 (USSR)

Launch details not available

Cosmonauts Vladimir A. Shatalov, Aleksey S. Yeliseyev, and Nikolay N. Rukavishnikov docked April 24 with unmanned *Salyut 1* for 5 1/2 hours. No crew transfer. After separation, circled *Salyut 1* for 1 hr; taking pictures. Safely landed April 25 in U.S.S.R.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

June 6

Soyuz 11 (USSR)

Launch details not available

Spacecraft carried cosmonauts Georgy T. Dobrovolsky, Vladislav N. Volkov, and Viktor I. Patsayev docked with unmanned *Salyut 1* June 7. Crew transferred and *Salyut-Soyuz* station became first manned orbiting laboratory in space. Crew conducted experiments, made astronomical observations, transmitted live TV, reared tadpoles, grew vegetables and took photos. Crew transferred to *Soyuz 10* and undocked June 29. At 1:35 a.m. June 30 Moscow time, spacecraft's braking engine fired. At end of firing, communication with crew ceased. After normal automatic landing rescue helicopter team found *Soyuz 11* crew dead in spacecraft. Crew had died when accidental triggering of exhaust valve decompressed work compartment.

Performance:-

Vehicle - Successful

Payload - Unsuccessful

Mission Results - Unsuccessful

July 26

Apollo 15 (AS-510)

Saturn V (KSC)

Launched with crew of David R. Scott, Alfred M. Worden, and James B. Irwin. Scott and Irwin landed LM on lunar surface in Hadley-Apennine region July 30. Performed 3 EVAs, deployed ALSEP, obtained 77 kg of lunar samples, took photos, explored Hadley Rille, and drove lunar roving vehicle first time. LM lifted off from moon Aug.2. After LM-CSM docking, subsatellite was launched into lunar orbit from CSM. CM landed in Pacific August 7.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

Apollo 15 Subsatellite

First subsatellite launched from lunar orbit was spring-ejected from service module's scientific instrument module bay and began scientific studies of moon.

Performance:-

Payload - Successful

Mission Results - Successful

September 2

Luna 18 (USSR)

Launch details not available

Unmanned lunar probe entered lunar orbit September 7. Made 54 revolutions of moon before landing attempted near Sea of Fertility. Communication ceased upon landing. Believed to have crash-landed.

Performance:-

Vehicle - Successful

Payload - Unsuccessful

Mission Results - Unsuccessful

September 28

Luna 19 (USSR)

Launch details not available

Unmanned lunar probe entered lunar orbit October 3. All systems operating normally; conducted geophysical research of moon's gravitational field and relayed photos of lunar surface.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

1972

February 14

Luna 20 (USSR)

Launch details not available

Unmanned spacecraft entered lunar orbit February 18 and landed between moon's Sea of Fertility and Sea of Crises February 21. Earth-operated drilling rig penetrated lunar surface to 35 cm; samples were obtained and transferred to container in return capsule and hermetically sealed. Luna 20 remained on moon 21 hrs 39 min, lifted off February 22, and returned to earth February 24. Total time of mission, 11 days and 16 hrs. Analysis of lunar samples indicated area consisted primarily of anorthosite. Findings contrasted with *Luna 16* Sea of Fertility samples, which were primarily basaltic rock.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

April 16

Apollo 16 (AS-511)

Saturn V (KSC)

Sixth manned lunar landing mission was launched with John W. Young, Thomas L. Mattingly II, and Charles M. Duke, Jr., as crew. Spacecraft entered lunar orbit April 19. LM undocked and landed in the Descartes region of moon at 9:23 p.m. EST the following day. During lunar stay time of 71 hrs 14 min, Young and Duke completed EVA periods; drove lunar roving vehicle (LRV); deployed ALSEP (accidentally breaking heat flow experiment); explored Survey Ridge, Stone Mountain, South Ray Crater, North Ray Crater, and 2 other sites. Live color TV was transmitted during all EVAs. Ascent stage of the LM lifted off from moon April 24 with 96.6 kg of samples and with live TV coverage from LRV camera.

After docking with CSM and crew and cargo transfer, LM ascent stage was jettisoned, began tumbling, and went into lunar orbit rather than impacting lunar surface. Scientific subsatellite was launched into lunar orbit and CSM was inserted into trajectory for earth. During return trip Mattingly performed 1-hr 24-min EVA to retrieve film from SM camera. CM landed in Pacific Apr. 27 and was recovered by U.S. S. *Ticonderoga*.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

Apollo 16 Subsatellite

Scientific subsatellite was spring-ejected from the SM's scientific instrument module bay on April 24. Shaping burn to optimize its orbit was not performed, because of CSM engine problems. Subsatellite's orbit decreased and spacecraft impacted moon May 29 after 425 revolutions.

Performance:-

Payload - Successful

Mission Results - Partially Successful

December 7

Apollo 17 (AS-512)

Saturn V (KSC)

Final Apollo mission was launched with crew of Eugene A. Cernan, Ronald E. Evans, and Harrison H. Schmitt. CSM/LM entered lunar orbit December 10. LM undocked December 11 and touched down in Taurus-Littrow area of moon at 2:55 p.m. During stay time of 74 hrs 59 min 39 secs, Cernan and Schmitt performed 3 EVAs. They drove lunar roving vehicle to Steno Crater; deployed ALSEP; explored additional stations. Live color TV was transmitted during all 3 EVAs and liftoff from moon December 14.

During stay astronauts collected 115 kg of lunar samples and drove LRV about 35 km. After CSM/LM docking and crew and cargo transfer, ascent stage was jettisoned to impact moon. Impact was recorded by four *Apollo 17* geophones and *Apollo 12, 14, 15, and 16* ALSEPs. During coast to earth, Evans performed 1-hr 7-min EVA to retrieve film from SM camera. Spacecraft splashed down in mid-Pacific at 2:25 p.m. EST Dec. 19 and was recovered by U.S.S. *Ticonderoga*. Splashdown ended Apollo manned space flight program.

Performance:-

Vehicle - Successful

Payload - Successful

Mission Results - Successful

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Appendix 5

PRIMARY APOLLO FLIGHT OBJECTIVES

[Apollo-Saturn 201 through Apollo 17]

Apollo-Saturn 201

(February 26, 1966)

Primary Objectives (all achieved)

1. Obtain flight information on the structural integrity and compatibility of the launch vehicle and spacecraft and confirm launch loads.
2. Test the separation of:
 1. S-IVB stage, instrument unit (IU) and spacecraft from S-IB stage.
 2. Launch escape systems (LES) and boost protective cover from command and service modules (CSM) and launch vehicle.
 3. CSM from S-IVB stage, IU, and service module LEM adapter (SLA).
 4. Command module (CM) from service module (SM).
3. Obtain flight operation information on the following subsystems:
 1. Launch vehicle - propulsion, guidance and control, and electrical systems.
 2. Spacecraft - CM heatshield (adequacy for entry from low earth orbit); service propulsion system (SPS) (including restart); Environmental control system (ECS) (pressure and temperature control); communications (partial); CM reaction control system (RCS); SM RCS; stabilization control system (SCS); earth landing system (ELS); electrical power system (EPS), partial.
4. Evaluate performance of the space vehicle emergency detection system (EDS) in an open-loop configuration.
5. Evaluate the CM heatshield at a heating rate of approximately 200 BTU/ft-squared/sec during entry at approximately 9 km/sec.
6. Demonstrate the mission support facilities and operations required for launch, mission conduct, and CM recovery.
7. Recover the CM.

Apollo-Saturn 203

(July 5, 1966)

Primary Objectives (all achieved)

1. Evaluate performance of the S-IVB/IU stage under orbital conditions to obtain flight information on:
 1. Venting and chill-down systems.
 2. Fluid dynamics and heat transfer to propellant tanks.
 3. Attitude and thermal control systems.
 4. Launch vehicle guidance.
 5. Checkout in orbit.

Apollo-Saturn 202

(August 25, 1966)

Primary Objectives (all achieved)

1. Evaluate the CM heatshield at a high heating load.
2. Obtain further launch vehicle and spacecraft information on:
 1. Structural integrity and compatibility.
 2. Flight loads.
 3. Stage separation.
 4. Subsystem operations.
 5. Emergency detection system operation.

Apollo 4 (AS-501)

(November 9, 1967)

Primary objectives (all achieved)

Launch vehicle:

1. Demonstrate the S-IVB-stage restart capability.
2. Demonstrate the adequacy of the S-IVB continuous vent system while in earth orbit.
3. Demonstrate the capability of the S-IVB auxiliary propulsion system during S-IVB powered flight and orbital coast periods to maintain attitude control and perform required maneuvers.
4. Demonstrate the S-IVB-stage propulsion system, including the propellant management systems,

- and determine inflight system performance parameters.
5. Demonstrate the S-II-stage propulsion system, including programmed mixture ratio shift and the propellant management system, and determine inflight performance parameters.
 6. Demonstrate the S-IC-stage propulsion system, and determine inflight system performance parameters.
 7. Demonstrate the S-IC/S-II dual-plane separation.
 8. Demonstrate the S-II/S-IVB separation.
 9. Demonstrate the mission support capability required for launch and mission operations to high post-injection altitudes.
 10. Demonstrate structural and thermal integrity of the launch vehicle throughout powered and coasting flight and determine inflight structural loads and dynamic characteristics.
 11. Determine inflight launch vehicle internal environment.
 12. Demonstrate the launch vehicle guidance and control system during S- IC, S-II, and S-IVB powered flight, achieve guidance cutoff, and evaluate system accuracy.
 13. Demonstrate launch vehicle sequencing system.
 14. Evaluate the performance of the emergency detection system in an open-loop configuration.
 15. Demonstrate compatibility of the launch vehicle and spacecraft.
 16. Verify prelaunch and launch support equipment compatibility with launch vehicle and spacecraft systems.

Spacecraft:

1. Demonstrate CSM/SLA/LTA/Saturn V structural compatibility and determine spacecraft loads in a Saturn V launch environment.
2. Determine the dynamic and thermal responses of the SLA/CSM structure in the Saturn V launch environment.
3. Determine the force inputs to the simulated LM from the SLA at the spacecraft attachment structure in a Saturn V launch environment.
4. Obtain data on the acoustic and thermal environment of the SLA/ simulated LM interface during a Saturn V launch.
5. Determine vibration response of LM descent-stage engine and propellant tanks in a Saturn V launch environment.
6. Evaluate the thermal and structural performance of the Block II thermal protection system, including effects of cold soak and maximum thermal gradient when subjected to the combination of a high heat load and a high heating rate representative of lunar return entry.
7. Demonstrate an SPS no-ullage start.
8. Determine performance of the SPS during a long-duration burn.
9. Verify the performance of the SM/RCS thermal control subsystem and engine thermal response in the deep space environment.
10. Verify the thermal design adequacy of the CM/RCS thrusters and extensions during simulated lunar return entry.
11. Evaluate the thermal performance of a gap and seal configuration simulating the unified crew hatch design for heating conditions anticipated during lunar return entry.

12. Verify operation of the heat rejection system throughout the mission.
13. Evaluate the performance of the spacecraft emergency detection subsystem (EDS) in the open-loop configuration.
14. Demonstrate the performance of CSM/MSFN S-band communications.
15. Measure the integrated skin and depth radiation dose within the command module up to an altitude of at least 3,700 km.

Apollo 5 (AS-204/LM-1)

(January 22, 1968)

Primary Objectives (all achieved)

1. Verify operation of the following LM subsystems: ascent propulsion system and descent propulsion system (including restart), and structure.
2. Evaluate LM staging.
3. Evaluate the S-IVB/IU orbital performance.

Apollo 6 (AS-502)

(April 4, 1968)

Primary Objectives

1. Demonstrate the structural and thermal integrity and compatibility of the launch vehicle and spacecraft, confirm launch loads and dynamic characteristics (partially accomplished).
2. Demonstrate separation of:
 1. S-II from S-IC (dual plane).
 2. S-IVB from S-II.

(both accomplished)
3. Verify operation of the following launch vehicle subsystems: propulsion (including S-IVB restart), guidance and control (optimum injection), and electrical system (partially accomplished).
4. Evaluate performance of the space vehicle EDS in a closed-loop configuration (accomplished).
5. Demonstrate mission support facilities and operations required for launch, mission conduct, and CM recovery (accomplished).

Apollo 7 (AS-205)

(October 11, 1968)

Primary Objectives (all achieved)

1. Demonstrate CSM/crew performance.
2. Demonstrate crew-space vehicle-mission support facilities performance during a manned CSM mission.
3. Demonstrate CSM rendezvous capability.

Apollo 8 (AS-503)

(December 21, 1968)

Primary Objectives (all achieved)

1. Demonstrate crew-space vehicle-mission support facilities performance during a manned Saturn V mission with CSM.
2. Demonstrate performance of nominal and selected backup lunar orbit rendezvous (LOR) mission activities, including:
 1. Translunar injection.
 2. CSM navigation, communications, and midcourse corrections.
 3. CSM consumables assessment and passive thermal control.

Apollo 9 (AS-504)

(March 3, 1969)

Primary Objectives (all achieved)

1. Demonstrate crew-space vehicle-mission support facilities performance during a manned Saturn V mission with CSM and LM.
2. Demonstrate LM/crew performance.
3. Demonstrate performance of nominal and selected backup LOR mission activities, including:
 1. Transposition, docking, LM withdrawal.
 2. Interverhicular crew transfer.
 3. Extravehicular capability.
 4. SPS and DPS burns.
 5. LM-active rendezvous and docking.
4. CSM/LM consumables assessment.

Apollo 10 (AS-505)

(May 18, 1969)

Primary Objectives (all achieved)

1. Demonstrate crew-space vehicle-mission support facilities performance during a manned lunar mission with CSM and LM.
2. Evaluate LM performance in the cislunar and lunar environment.

Apollo 11 (AS-506)

(July 16, 1969)

Primary Objective (accomplished)

Perform a manned lunar landing and return.

Detailed Objectives and Experiments

1. Collect a contingency, sample (accomplished).
2. Egress from the LM to the lunar surface, perform lunar surface EVA operations, and ingress into the LM from the lunar surface (accomplished).
3. Perform lunar surface operations with the EMU (accomplished).
4. Obtain data on effects of DPS and RCS plume impingement on the LM and obtain data on the performance of the LM landing gear and descent engine skirt after touchdown (accomplished).
5. Obtain data on the lunar surface characteristics from the effects of the LM landing (accomplished).
6. Collect lunar bulk samples (accomplished).
7. Determine the position of the LM on the lunar surface (accomplished).
8. Obtain data on the effects of illumination and contrast conditions on crew visual perception (accomplished).
9. Demonstrate procedures and hardware used to prevent back contamination of the earth's biosphere (accomplished).
10. Deploy the Early Apollo Scientific Experiments Package (EASEP), which included:
 1. S031, Passive Seismic Experiment (accomplished).
 2. S078, Laser Ranging Retro-Reflector (accomplished).
11. Deploy and retrieve the Solar Wind Composition Experiment, S080 (accomplished).
12. Perform Cosmic Ray Detector Experiment (helmet portion), S151 (accomplished).
13. Perform Lunar Field Geology, S059 (partially accomplished).
14. Obtain television coverage during the lunar stay period (accomplished).
15. Obtain photographic coverage during the lunar stay period (accomplished).

Apollo 12 (AS-507)

(November 14, 1969)

Primary Objectives (all achieved)

1. Perform selenological inspection, survey, and sampling in a mare area.
2. Deploy and activate the Apollo Lunar Surface Experiments Package (ALSEP).
3. Develop techniques for a point landing capability.
4. Develop man's capability to work in the lunar environment.
5. Obtain photographs of candidate exploration sites.

Detailed Principal Objectives and Experiments (all achieved)

1. Collect a contingency sample.
2. Perform lunar surface EVA operations.
3. Deploy ALSEP I, which included:
 1. S031, Passive Seismic Experiment.
 2. S034, Lunar Surface Magnetometer Experiment.
 3. S035, Solar Wind Spectrometer Experiment.
 4. S036, Suprathermal Ion Detector Experiment.
 5. S058, Cold Cathode Ionization Gauge Experiment.
 6. M515, Lunar Dust Detector.
4. Collect selected samples.
5. Recharge the portable life support systems.
6. Perform Lunar Field Geology, S059.
7. Obtain photographic coverage of candidate exploration sites.

Apollo 13 (AS-508)

(April 11, 1970)

Primary Objectives (none achieved)

1. Perform selenological inspection, survey, and sampling of materials in a preselected region of the Fra Mauro formation.
2. Deploy and activate an Apollo Lunar Surface Experiments Package (ALSEP).
3. Develop man's capability to work in the lunar environment.
4. Obtain photographs of candidate exploration sites.

Apollo 14 (AS-509)

(January 31, 1971)

Primary Objectives (all achieved)

1. Perform selenological inspection, survey, and sampling of materials in a preselected region of the Fra Mauro formation.
2. Deploy and activate ALSEP.
3. Develop man's capability to work in the lunar environment.
4. Obtain photographs of candidate exploration sites.

Apollo 15 (AS-510)

(July 26, 1971)

Primary Objectives (all achieved)

1. Perform selenological inspection, survey, and sampling of materials and surface features in a preselected area of the Hadley-Apennine region.
2. Emplace and activate surface experiments.
3. Evaluate the capability of the Apollo equipment to provide extended lunar surface stay time, increased EVA operations, and surface mobility.
4. Conduct inflight experiments and photographic tasks from lunar orbit.

Apollo 16 (AS-511)

(April 16, 1972)

Primary Objectives (all achieved)

1. Perform selenological inspection, survey, and sampling of material and surface features in a preselected area of the Descartes region.
2. Emplace and activate surface experiments.
3. Conduct inflight experiments and photographic tasks.

Apollo 17 (AS-512)

(December 7, 1972)

Primary Objectives (all achieved)

1. Perform selenological inspection, survey, and sampling of material and surface features in a preselected area of the Taurus-Littrow region.
2. Emplace and activate surface experiments.

3. Conduct inflight experiments and photographic tasks.

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Appendix 6

CREWS AND SUPPORT FOR MANNED APOLLO FLIGHTS

[Compiled by Sally D. Gates, History Office, JSC, with Cyril E. Baker, Astronaut Office, JSC.]

Apollo 7:

Primecrew:

Schirra, Eisele, Cunningham

Backup:

Stafford, Young, Cernan

Support:

Evans, Swigert, Pogue

CapComs:

Stafford, Evans, Pogue, Swigert, Young, Cernan

Apollo 8:

Primecrew:

Borman, Lovell, Anders

Backup:

Armstrong, Aldrin, Haise

Support:

Brand, Mattingly, Carr

CapComs:

Collins, Mattingly, Carr, Armstrong, Aldrin, Brand, Haise

Apollo 9:

Primecrew:

McDivitt, Scott, Schweickart

Backup:

Bean, Conrad, Gordon

Support:

Lousma, Mitchell, Worden

CapComs:

Roosa, Evans, Worden, Conrad, Gordon, Bean

Apollo 10:

Prime crew:

Stafford, Young, Cernan

Backup:

Cooper, Eisele, Mitchell

Support:

Engle, Irwin, Duke

CapComs:

Duke, Engle, Lousma, McCandless

Apollo 11:

Primecrew:

Armstrong, Collins, Aldrin

Backup:

Lovell, Anders, Haise

Support:

Mattingly, Evans, Pogue, Swigert

CapComs:

Duke, Evans, McCandless, Lovell, Anders, Mattingly, Haise, Lind, Garriott, Schmitt

Apollo 12:

Prime crew:

Conrad, Gordon, Bean

Backup:

Scott, Irwin, Worden

Support:

Carr, Weitz, Gibson

Capcoms:

Carr, Gibson, Weitz, Lind, Scott, Worden, Irwin, Wash*, Warren*, Rippey*, Lewis*

*On this four-shift flight, Dickie K. Warren, James O. Rippey, James L. Lewis, and Michael R. Wash were backup CapComs. This was the first time in the American manned space flight program that this position was filled by non-astronaut personnel.

Apollo 13:

Prime crew:

Lovell, Swigert**, Haise

Backup:

Young, Swigert, Duke

Support:

Lousma, Brand, Pogue

Capcoms:

Kerwin, Brand, Lousma, Young, Mattingly

**Swigert moved from the backup to the prime crew at the last minute, when command module pilot Mattingly was exposed to a contagious disease. SOURCE: Mission reports, news releases, NASA Astronauts (NASA EP-34, Washington, 1967), and manning documents issued before each mission by the JSC Flight Operations Directorate and written, for the most part, by Cecil E. Dorsey.

Apollo 14:

Prime crew:

Shepard, Roosa, Mitchell

Backup:

Cernan, Evans, Engle

Support:

McCandless, Pogue, Fullerton, Chapman

Capcoms:

Fullerton, McCandless, Haise, Evans

Apollo 15:

Prime crew:

Scott, Worden, Irwin

Backup:

Gordon, Brand, Schmitt

Support:

Henize, Allen, Parker

Capcoms:

Allen, Fullerton, Henize, Mitchell, Parker, Schmitt, Shepard, Gordon, Brand

Apollo 16:

Prime crew:

Young, Mattingly, Duke

Backup:

Haise, Roosa, Mitchell

Support:

Peterson, England, Hartsfield, Chapman

Capcoms:

Peterson, Fullerton, Irwin, Haise, Roosa, Mitchell, Hartsfield, England, Overmyer

Apollo 17:

Prime crew:

Cernan, Evans, Schmitt

Backup:

Young, Roosa, Duke

Support:

Overmyer, Parker, Fullerton

CapComs:

Fullerton, Overmyer, Parker, Allen, Shepard, Mattingly, Duke, Roosa, Young

NOTE:

Capcom (capsule communicator) assignments are listed as they appeared in the manning documents (by shift), not as they might have been heard in chronological sequence during flight.

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Appendix 7

FUNDING

[Compiled by F. B. Hopson, Administrative and Program Support Directorate, NASA]

Funding Breakdown

Fiscal Year 1966

Original budget request - no supplemental for prior fiscal year

NASA: \$4,575,900,000

Apollo: \$2,997,385,000

Fiscal budget appropriation - no supplemental for prior fiscal year

NASA: \$4,511,644,000

Apollo: \$2,967,385,000

- Command and service modules: \$615,000,000
 - Lunar excursion module: \$310,800,000
 - Guidance and navigation: \$115,000,000
 - Integration, reliability, and checkout: \$34,400,000
 - Spacecraft support: \$95,400,000
 - Saturn I: \$800,000
 - Saturn IB: \$274,185,000
 - Saturn V: \$1,177,320,000
 - Engine development: \$134,095,000
 - Apollo mission support: \$210,385,000
-

1967

Original budget request

NASA: \$4,246,600,000

Apollo: \$2,974,200,000

Fiscal budget appropriation

NASA: \$4,175,100,000

Apollo: \$2,916,200,000

- Command and service modules: \$560,400,000
 - Lunar excursion module: \$472,500,000
 - Guidance and navigation: \$76,654,000
 - Integration, reliability, and checkout: \$29,975,000
 - Spacecraft support: \$110,771,000
 - Saturn IB: \$236,600,000
 - Saturn V: \$1,135,600,000
 - Engine development: \$49,800,000
 - Apollo mission support: \$243,900,000
-

1968

Original budget request including Fiscal Year 1967 supplemental

NASA: \$4,324,500,000

Apollo: \$2,606,500,000

Fiscal budget appropriation including Fiscal Year 1967 supplemental

NASA: \$3,970,600,000

Apollo: \$2,556,000,000

- Command and service modules: \$455,300,000

- Lunar excursion module: \$329,600,000
 - Guidance and navigation: \$113,000,000
 - Integration, reliability, and checkout: \$66,600,000
 - Spacecraft support: \$60,500,000
 - Saturn IB: \$146,600,000
 - Saturn V: \$998,900,000
 - Engine development: \$18,700,000
 - Apollo mission support: \$296,800,000
-

1969

Original budget request

NASA: \$3,677,200,000

Apollo: \$2,038,800,000

Fiscal budget appropriation

NASA: \$3,193,559,000

Apollo: \$2,025,000,000

- Command and service modules: \$346,000,000
 - Lunar excursion module: \$326,000,000
 - Guidance and navigation: \$43,900,000
 - Integration, reliability, and checkout: \$65,100,000
 - Spacecraft support: \$121,800,000
 - Saturn IB: \$41,347,000
 - Saturn V: \$534,453,000
 - Manned Space Flight Operations: \$546,400,000
-

1970

Original budget request including Fiscal Year 1969 reserve

NASA: \$3,168,900,000

Apollo: \$1,651,100,000

Fiscal budget appropriation including Fiscal Year 1969 reserve

NASA: \$3,113,765,000

Apollo: \$1,686,145,000

- Command and service modules: \$282,821,000
 - Lunar excursion module: \$231,433,000
 - Guidance and navigation: \$33,866,000
 - Science payloads: \$60,094,000
 - Spacecraft support: \$170,764,000
 - Saturn V: \$484,439,000
 - Manned Space Flight Operations: \$422,728,000
-

1971

Original budget request

NASA: \$2,606,100,000

Apollo: \$956,500,000

Fiscal budget appropriation

NASA: \$2,555,000,000

Apollo: \$913,669,000

- Flight modules: \$245,542,000
 - Science payloads: \$106,194,000
 - Ground support: \$46,411,000
 - Saturn V: \$189,059,000
 - Manned Space Flight Operations: \$314,963,000
 - Advance development: \$11,500,000
-

1972

Original budget request

NASA: \$2,517,700,000

Apollo: \$612,200,000

Fiscal budget appropriation

NASA: \$2,507,700,000

Apollo: \$601,200,000

- Flight modules: \$55,033,000
 - Science payloads: \$52,100,000
 - Ground support: \$31,659,000
 - Saturn V: \$142,458,000
 - Manned Space Flight Operations: \$307,450,000
 - Advance development: \$12,500,000
-

1973

Original budget request

NASA: \$2,600,900,000

Apollo: \$128,700,000

Fiscal budget appropriation

NASA: \$2,509,900,000

Apollo: \$76,700,000

- Spacecraft: \$50,400,000
 - Saturn V: \$26,300,000
-

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Appendix 8

Block II vs. Block I Apollo Spacecraft;

Hardware, Changes, Tests

[From "Manned Space Flight Report: Block II Spacecraft" in House Committee on Science and Astronautics, Subcommittee on NASA Oversight, Investigation into Apollo 204 Accident: Hearings, 90th Cong., 1st sess, 3, no. 4, May 10, 1967, 223-35.]

Subsystems and Units Unchanged for Block II CSM

- Launch escape system
- Command module reaction control system
- Service module reaction control system engine cluster
- Fuel cell power plants and entry batteries
- Cryogenic oxygen and hydrogen storage system
- Sequential events control system
- Emergency detection system
- Spacecraft LM adapter
- Atmosphere supply system
- Primary equipment cooling loop
- Waste management system
- Crew couches
- C-band radar transponder
- Ordnance devices
- Parachutes and recovery aids

New Subsystems and Units in Block II CSM

Docking system

 Docking tunnel and probe

 Umbilical and pressurization

 Rendezvous radar transponder

Sequence controllers

- LM docking and separation events

S-band antennas

- Flush omnidirectional

- High gain

Subsystems and Units Changed in Block II CSM

Structure:

Command module

- Docking provisions, mechanism, and hatch

- Extravehicular capability

- CM/SM mechanical connection

- Scientific airlock available

Service module

- Propellant tanks

- Empty bay

- Internal rearrangement

- Structural redesign

- Radiator areas

- RCS mounting panels

Propulsion:

Service module propulsion system

- Mixture ratio

- Thrust chamber

- Gimbal actuator

Service module reaction control

Propellant capacity

Monomethylhydrazine fuel

Crew support:

Environmental control system

Redundant cooling loop

Radiator design and area

Spacesuit

Apollo suit

Extravehicular capability

Displays and controls

Panel structure

Electroluminescent lighting

Entry monitor system

Power and communication:

Electrical power system

Radiator area

Distribution bus added

Cable harnessing

Pyrotechnic initiator

Wire deadfacing at separation

Unified S-band

Primary mode for all communications

Repackaged

Simultaneous data and tape dump or TV

Electrical redundancy

Voice VHF

Redundant and duplex

Guidance and control:

Guidance and navigation

Digital autopilot

Computer repackaged

Electronics repackaged

Navigation base support

Stabilization and control system

Revised interface

Electronics repackaged

Redundant attitude display

Atmospheric entry and touchdown:

Heatshield

Redistributed ablative thickness

Truncated apex

Umbilical location

Flush antennas

Earth-landing system

Steel parachute risers

Parachute attach points

Repackaged

Crew Safety Systems

- Launch escape system
- Emergency detection system

- Sequential events control system
- Earth-landing system
- Environmental control system
- Reaction control system
- Electrical power system
- Command module heatshield
- Structure system

Mission Success Systems

- Spacecraft adapter
- Waste management system
- Guidance and control system
- Stabilization and control system
- Communications system
- Displays and controls
- Service propulsion system

Subsystems with Internal Redundancy

(Subsystem)	(Major function)
CM reaction control system	Attitude control Lift vector control
SM reaction control	Attitude control S-IVB/CSM separation CM/SM separation
Communications system	Navigation data Voice, telemetry, and tracking Recovery
Electrical power system	Electrical power
Environmental control system	Equipment cooling Cabin environmental control

Sequential events control system	Separation signals Earth-landing functions
Emergency detection system	Launch vehicle malfunction
Earth-landing system	Atmospheric descent Uprighting at impact

Backup System Capabilities for Earth-Orbital Flight

Subsystem	Major Function	Backup
Service propulsion system	Deorbit	SM-RCS; CM-RCS
Command module reaction control system	Attitude control	SM-RCS spinup before separation for ballistic reentry
Guidance and control system	Attitude, translation, and lift vector control Control of SPS burns	Stabilization and control system
Stabilization and control system	Backup attitude, translation, and SPS control	Manual

Flight Safety Systems Changed in Block II

1. Earth-landing system
2. Service module reaction control system
3. Electrical power system
4. Environmental control system
5. Command module heatshield
6. Structural system
7. Service propulsion system

Environmental Control System Changes for Block II before AS-204 Accident

1. New radiator design:
 - o Increased size.
 - o Selective stagnation control.
 - o Secondary loop tubes.
2. Secondary coolant loop:

- Additional pump.
- Redundant cold plate passages.
- 3. Repackage environmental control unit (ECU):
 - Coolant pumps relocated external to ECU, repackaged, and capacity increased.
 - Coolant reservoir located external to ECU.
 - Redesigned suit heat exchanger.
- 4. LM pressurization capability.
- 5. Relocate postlanding ventilation valves.
- 6. Redesign steam duct.
- 7. Add rendezvous radar cold plates in SM.

Proposed ECS Changes for Block II after AS-204 Accident

- Add armor plating to exposed solder joints.
- Change soldered-aluminum oxygen lines to stainless steel.
- Rapid cabin repressurization.
- Improve accessibility of selected ECS controls.
- Shields for plumbing lines.
- Optional use of air in cabin during launch.
- Emergency breathing masks.
- Add quick disconnects to environmental control unit.
- Replace selected materials.

Block I - Major Ground Test Programs

Test Article	Test	Purpose
CM BP-6A	Parachute drop-testing of boilerplate CM	Flight-qualify earth recovery system by series of aircraft drop tests
SM-001	SPS propulsion ground test	Demonstrate SPS performance (oxidizer-to-fuel ratio = 2), 2nd SPS-structure compatibility
SLA	Static structural test of spacecraft-LM adapter	Test SLA static structural load capability (ultimate)
CSM 004	Static and thermal structural ground test	CM static structural load test (ultimate) CSM static structural load test (ultimate) CM thermal structural load test (reentry design)

CSM 007	Varied spacecraft testing	CM and SM acoustic vibration environment test CM water-landing impact drop test Postlanding systems operational/crew compatibility tests (uprighting, postlanding ECS, postlanding communications)
CSM 008	Thermal vacuum test of complete systems spacecraft	Demonstration of structural, integrated subsystems and crew compatibility under thermal vacuum environment

White Sands Missile Range Flight Tests

Test Article	Test	Purpose
BP-6	Boilerplate - LES pad abort flight test	Demonstrate launch escape system's pad abort performance
BP-12	Boilerplate - LES transonic abort flight test	Demonstrate launch escape system's transonic abort performance
BP-23	Boilerplate - LES high-dynamic-pressure abort flight test	Demonstrate launch escape system's maximum-dynamic-pressure-region abort performance
BP-23A	Boilerplate - LES pad abort flight test	Demonstrate launch escape system's pad abort performance with Canard, BPC, and major sequencing changes
CSM 002	Spacecraft structure - SM boost environment and LES tumbling abort flight	Determine actual spacecraft SM's dynamic structural response to boost dynamic loads Demonstrate launch escape system's tumbling abort performance and plume-impingement-load capability of CSM

Block II - Major Ground-Test Programs

Test Article	Test	Purpose
BP-6B	Parachute drop-testing of boilerplate CM	Flight-qualify earth recovery system by series of aircraft drop tests

F-2A	Fixture for SPS testing	Evaluate performance effects on SPS engine of fuel and oxidizer mixture's ratio change from 2.0 to 1.6
180 degree SM segment	Acoustic test article (SM) testing	Quality SM structure and systems to launch and boost vibration environment
CM 28-1	Static and dynamic structural testing	Evaluate water impact on CM structure Docket CM/LM interface static structural tests
CMS 2S-2	Static structural testing	Static-test CM and SM structures (ultimate)
CMS 2TV-1	Complete systems spacecraft thermal vacuum testing	Demonstrate structural, integrated subsystems, crew compatibility, and life support in thermal vacuum environment

Block II - Revisions of and Additions to Major Ground-Test Programs

Test Article	Test	Purpose
2TV-1	Complete spacecraft thermal vacuum	Qualify fire related changes
004A, 007A	Unified hatch qualification	Functionally qualify acoustic testing, postlanding testing
CSM	Acoustic vibration	Demonstrate functional and structural integrity of stacked CSM-SLA
Material	Materials evaluation	Continue evaluation of non- or low-flammable material
Boilerplate	Command module fire test	Evaluate fire propagation in flight-configuration CM interior
EMU articles	Extravehicular mobility unit qualification	Qualify Block II unit with materials change
ECU articles	Environmental control unit qualification	Qualify Block II unit with all required modifications

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Appendix 9

Apollo Experiments

Part I: Lunar Surface Experiments

The lunar surface experiments were of two kinds:

1. The Apollo Lunar Surface Experiments Package (ALSEP) systems, which were left on the lunar surface by the astronauts and which continued sending telemetry data until turned off Sept. 30, 1977, and
2. experiments conducted on the lunar surface by the astronauts and returned to earth in the command module.

The dates and lunar coordinates are given in the following listing. The ALSEP-related experiments are listed next, by experiment number, with Apollo mission numbers.

Apollo 12:

The Apollo 12 ALSEP was deployed on November 19, 1969, at latitude 3 degrees 11' S, longitude 23 degrees 23' W in Oceanus Procellarum.

Apollo 13:

Because of service module problems, a lunar landing was not accomplished during the Apollo 13 mission.

Apollo 14:

The ALSEP was deployed on February 5, 1971, at latitude 3 degrees 40' S, longitude 17 degrees 27' W in the Fra Mauro formation.

Apollo 15:

The ALSEP was deployed July 31, 1971, at latitude 26 degrees 06' N, longitude 3 degrees 39' E in the Hadley-Apennine region.

Apollo 16:

The ALSEP was deployed April 21, 1972, at latitude 8 degrees 59' 34" S, longitude 15 degrees 30' 47" E in the Descartes Highlands.

Apollo 17:

The ALSEP was deployed on December 12, 1972, at latitude 20 degrees 09' 55" N, longitude 30 degrees 45' 57" E in the Taurus-Littrow region.

Apollo ALSEP Experiments

Number & Experiment =====	Apollo Mission				
	12 ===	14 ===	15 ===	16 ===	17
S 031 Passive Seismic	X	X	X	X	
S 033 Active Seismic		X		X	
S 034 Lunar Surface Magnetometer	X		X	X	
S 035 Solar-wind Spectrometer	X		X		
S 036 Suprathermal Ion Detector	X	X	X		
S 037 Heat flow				X	(1)
X					
S 038 Charged Particle		X			
S 058 Cold Cathode Gage	X	X	X		
S 059 Lunar Geology	X	X	X	X	X
S 078 Laser Ranging Retroreflector	X	X	X		
S 152 Cosmic Ray Detector				X	
S 198 Portable Magnetometer		X		X	
S 199 Traverse Gravimeter					X
S 200 Soil Mechanics	X	X	X	X	X
S 201 Far UV Camera/Spectrograph				X	
S 202 Lunar Ejecta and Meteorites					X
S 203 Lunar Seismic Profiling					X
S 204 Surface Electrical Properties					X
S 205 Lunar Atmospheric Composition					X
S 207 Lunar Surface Gravimeter					X
S 229 Neutron Probe	X	X	X	X	X
M 515 Dust Detector	X	X	X		

(1) Cable broken during deployment.

Part II: Lunar Orbital Experiments

Most of the lunar orbital experiments were added to the Apollo program during missions *15*, *16*, and *17*. The objectives of these experiments were to determine and understand regional variations in the chemical composition of the lunar surface, to study the gravitational field of the moon, to determine the induced and permanent magnetic fields of the moon, and to make a detailed study of the morphology and albedo of the lunar surface. These experiments and the missions during which they were performed

are listed in the following table.

Apollo Orbital Experiments

Number & Experiment =====	Apollo Mission				
	12 ===	14 ===	15 ===	16 ===	17
S 160 Gamma-Ray Spectrometer			X	X	
S 161 X-Ray Fluorescence			X	X	
S 162 Alpha-Particle Spectrometer			X	X	
S 164 S-Band Transponder (subsattellite)			X	X	
S 164 S-Band Transponder (CSM/LM)	X	X	X	X	X
S 165 Mass Spectrometer			X	X	
S 169 Far UV Spectrometer					X
S 170 Bistatic Radar		X	X	X	
S 171 Infrared Scanning Radiometer					X
S 173 Particle Shadow/Boundary Layer (subsattellite)			X	X	
S 174 Magnetometer (subsattellite)			X	X	
S 175 Laser Altimeter			X	X	X
S 209 Lunar Sounder					X

Part III: Apollo Experiment Principal Investigators

The principal investigators for the lunar surface and lunar orbital experiments are listed by experiment numbers. The lunar surface group is listed first.

Lunar Surface Experiment Investigators

S 031 Passive Seismic

G. V. Latham, Marine Biomedical Institute, Galveston, Texas

S 033 Active Seismic

Robert L. Kovach, Stanford University

S 203 Lunar Seismic Profiling

Robert L. Kovach, Stanford University

S 034 Lunar Surface Magnetometer

Palmer Dyal, Ames Research Center;

Charles P. Sonett, Lunar and Planetary Laboratory, University of Arizona

S 035 Solar-wind Spectrometer

Conway W. Snyder, Jet Propulsion Laboratory

S 036 Suprathermal Ion Detector

John W. Freeman, Rice University

S 037 Heat Flow

Marcus E. Langseth, Columbia University

S 038 Charged-Particle Lunar Environment Experiment

D. L. Reasoner, Rice University

S 058 Cold Cathode Gage

Francis S. Johnson, University of Texas at Dallas

S 059 Lunar Geology

Gordon A. Swann, Center of Astrogeology, U.S. Geological Survey.;

William R. Muehlberger, University of Texas

S 078 Laser Ranging Retroreflector

James E. Faller, Wesleyan University

S 152 Cosmic Ray Detector

R. L. Fleischer, General Electric Research and Development Laboratory, Schenectady, N.Y.;

Buford Price, University of California at Berkeley.;

Robert M. Walker, Washington University St. Louis, Mo.

S 198 Lunar Portable Magnetometer

Palmer Dyal, Ames Research Center

S 199 Traverse Gravimeter

Manik Talwani, Columbia University

S 200 Soil Mechanics

J. Mitchell, University of California at Berkeley

S 201 Far UV Camera/Spectrograph

G. R. Carruthers, E. O. Hurlburt Center for Space Research, Naval Research Laboratory, Washington, D.C.;

Thornton Page, Johnson Space Center

S 202 Lunar Ejecta and Meteorites

Otto E. Berg, Goddard Space Flight Center

S 204 Surface Electrical Properties

M. Gene Simmons, Massachusetts Institute of Technology.;

David W. Strangway, University of Toronto

S 205 Lunar Atmospheric Composition

J. R. Hoffman, University of Texas at Dallas

S 207 Lunar Surface Gravimeter

Joseph Weber, University of Maryland

S 229 Lunar Neutron Probe

D. S. Burnett, California Institute of Technology

M 515 Dust Thermal Radiation Engineering Measurement

James R. Bates, Johnson Space Center

Lunar Orbital Experiment Investigators

S 160 Gamma-Ray Spectrometer

James R. Arnold, University of California at San Diego

S 161 X-Ray Fluorescence

Isidore Adler, University of Maryland

S 162 Alpha-Particle Spectrometer

Paul Gorenstein, Smithsonian Astrophysical Observatory, Cambridge, Mass.

S 164 S-Band Transponder

William L. Sjogren, Jet Propulsion Laboratory

S 165 Lunar Orbital Mass Spectrometer

J. H. Hoffman, University of Texas at Dallas

S 169 Ultraviolet Spectrometer

William E. Fastie, Johns Hopkins University

S 170 Bistatic Radar

H. Taylor Howard, Stanford University

S 171 Infrared Scanning Radiometer

Frank J. Low, University of Arizona.;

W. W. Mendell, Johnson Space Center

S 173 Subsatellite Particles and Shadows

Kinsey A. Anderson University of California at Berkeley

S 174 Particles and Fields Subsatellite Magnetometer

P. J. Coleman, University of California at Los Angeles.

S 175 Laser Altimeter

William M. Kaula, University of California at Los Angeles.;

William L. Sjogren, Jet Propulsion Laboratory

S 209 Lunar Sounder

Roger J. Phillips, Jet Propulsion Laboratory.;

Stanley Ward, University of Utah.;

Walter E. Brown, Jr., Jet Propulsion Laboratory

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APPENDIX 10

Organization Charts

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The Authors

Ivan D. Ertel has been a contract historian to NASA's History Office since November 1972. He retired from NASA's Johnson Space Center in June 1972 after serving as the Center's Assistant Historian since September 1964. Born in Marion, New York (1914), he received his B.B.A. degree from Georgia State University, Atlanta, Georgia (1958). He was news editor of *Atlanta's Suburban Reporter*, East Point, Georgia, and the *Decatur-De Kalb News*, Decatur, Georgia (1954-1957). Before coming to NASA in 1961 he was Press Officer at Headquarters, Third U.S. Army. Ertel established the Manned Spacecraft Center's official news organ, *Space News Roundup*, authored fact sheets and brochures about each Mercury and Gemini manned flight and is co-author of *The Apollo Spacecraft: A Chronology*, Volume I (1969) and Volume III (1976) and *Skylab: A Chronology* (1977).

Roland W. Newkirk was born in Palenville, New York (1915). Following retirement from the Army and before joining NASA at the Johnson Space Center in 1965, Newkirk received his B.A. in history at the College of the Ozarks (1963) and his M.A. at the University of Arkansas (1965). He has also done graduate work in political science (public administration) at the University of Houston (1966-1970). Newkirk left the NASA Johnson Space Center in June 1973. He then served as a NASA contract historian for a short period. He authored *Skylab: Preliminary Chronology*, NASA HHN-130, May 1973, and is coauthor of *Skylab: A Chronology* (1977).

Courtney G. Brooks has been a Research Associate with the History Department of the University of Houston July 1969. Born in Savannah Georgia (1939), he received his B.A. degree from Huntingdon College, Montgomery, Alabama (1964), and his M.A. (1966) and Ph.D. (1969) degrees in history from Tulane University, New Orleans, Louisiana.

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