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*PROPOSED/
TECHNICAL MEMORANDUM/

TECHNICAL RESULTS OF/ THE FIRST/ /MANNED ORBITAL FLIGHT /FROM THE UNITED STATES/

PART I - MISSION RESULTS

Prepared by
Mercury Project Office
Edited by J. H. Boynton

WORD ONE/KEYSEARCH MANNED SPACECRAFT CENTER REVIEW COPY

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CLASSIFICATION CHANGED TO
Unclassified
BY AUTHORITY OF EO 12356
1 Aug 82
DATE 11 Aug 82

ACKNOWLEDGEMENTS

General acknowledgement is made of the extensive effort on the part of the entire Mercury team. This notably includes the Department of Defense for its recovery support, McDonnell Aircraft and its subcontractors for the spacecraft, General Dynamics/Astronautics for the launch vehicle, the NASA Goddard Space Flight Center for its Mercury Network support, the NASA Manned Spacecraft Center, and in general the many industrial organizations and NASA agencies which directly or indirectly made possible the success of this historical flight. Individual acknowledgement is given the following editors for their direct contribution in publishing the preliminary document upon which this report is based:

R. G. Arbic	Data Coordination
P. C. Donnelly	Capsule Systems
E. M. Fields	Mercury Project Office
J. D. Hodge	Flight Operations Division
N. F. Smith	Flight Systems Division
Dr. R. B. Voas	Office of Director - Astro. Training
Dr. S. C. White	Life Systems Division

Acknowledgement is presented at the conclusion of this report to the many systems specialists who authored and assisted in updating specific portions of the text.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TECHNICAL MEMORANDUM X -

MERCURY-ATLAS MISSION 6 (MA-6 SPACECRAFT 13)
RESULTS, DESCRIPTION AND PERFORMANCE ANALYSIS

Edited by John H. Boynton

SUMMARY

The Mercury-Atlas Mission 6 was the first United States manned orbital flight, and all prescribed mission objectives were successfully accomplished. A complete description of the mission, including a listing of its preflight objectives and a postlaunch evaluation, is presented.

A comparison of all planned and actual sequence data indicates that mission parameters coincide with expected values. The spacecraft, launch vehicle, and Mercury Network functioned satisfactorily during the mission. Early in the flight, however, the onboard telemetry transmitted an ominous signal to the ground that the heat shield was not firmly attached to the spacecraft. A subsequent analysis resulted in a recommendation to Astronaut Glenn that the retropackage be retained into reentry in order to ensure correct placement of the heat shield. A postflight investigation revealed a faulty limit switch as the source of an incorrect

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telemetry signal, and the heat shield, in fact, was not improperly deployed during the orbital flight. During the second orbital pass, failure of the one-pound yaw thrushers, caused repeated loss of automatic orbital stabilization, requiring the astronaut to manually control the Spacecraft for the remainder of the mission. Despite these and other minor malfunctions, the mission was completed successfully, and recovery was effected in the prescribed area by the destroyer Noa within twenty minutes from landing.

The astronaut's performance during all mission phases was highly satisfactory, and no deleterious effects of weightlessness were noted. Astronaut Glenn was found to be in excellent physiological and psychological health during the postflight examination.

INTRODUCTION

The first manned orbital flight in conjunction with Project Mercury was successfully performed on February 20, 1962, from the Cape Canaveral Missile Test Center. Astronaut John H. Glenn, Jr., shown in Figures 1 through 4, was the assigned pilot for this Mercury-Atlas (MA-6) Mission. This was the third orbital flight of a Mercury specification spacecraft, and it marked the sixth of a series utilizing Atlas launch vehicles.

The MA-6 mission was planned for three orbital passes and was the culmination of a program to develop the Mercury spacecraft for manned orbital flight. The objectives of the flight were to evaluate the performance of the manned spacecraft system in a three-pass mission, to evaluate the effects of space flight on the astronaut, and to obtain the astronaut's evaluation of the operational suitability of the spacecraft and supporting systems for manned orbital missions.

All data telemetered and recorded during the flight has been thoroughly analyzed by specialists in their fields, and this report presents these results and their analyses. Brief descriptions of the mission, the spacecraft, and the launch vehicle precede the performance analysis and supporting data. All significant events of the MA-6 mission, beginning with delivery of the spacecraft to the launch site through recovery and post flight examinations, are documented.

Although the graphical information presented herein sufficiently supports the text, the reader is referred to THX______(reference 1) for a complete presentation, without analysis, of all MA-6 time history data.

MISSION DESCRIPTION

Mission Objectives

The mission objectives and systems priorities, as specified in the Project Mercury Mission Directive for MA-6/13, are listed below for reference.

Test Objectives

1. Evaluate the performance of a man-spacecraft system in a three-pass mission.
2. Evaluate the effects of spaceflight on the astronaut.
3. Obtain the astronaut's opinions of the operational suitability of the spacecraft and supporting systems for manned spaceflights.

Systems Priorities

(a) Communications system	Priority
(1) Command receiver no. 1	Primary
(2) Command receiver no. 2	Primary
(3) Low frequency telemetry (225.7 mc)	Primary
(4) High frequency telemetry (259.7 mc)	Primary
(5) UHF and HF voice	Primary
(6) C-band beacon	Primary

(7) S-band beacon	Primary
(8) SARAH beacon	Primary
(9) SUPERSARAH beacon	Primary
(10) SEASAVE beacon	Primary
(b) Automatic Stabilization and Control System	Primary
(c) Rate Stabilization Control System	Primary
(d) Reaction Control System	Primary
(e) Environmental Control System	Primary
(f) Electrical Power System	Primary
(g) Explosive devices	Primary
(h) Cabin equipment	
(1) Navigation instruments	Primary
(2) ECS indicators	Primary
(3) Electrical system indicators	Primary
(4) Sequential and warning lights	Primary
(5) ASCS indicators	Primary
(6) Satellite clock	Primary
(i) Rocket system	Primary
(j) Landing and recovery system	Primary
(k) Instrumentation system	Primary

MISSION EVALUATION

The MA-6 mission, with Astronaut John Glenn as the pilot, experienced unscheduled prelaunch holds totaling 2 hours and 17 minutes. This was the result of difficulties with the General Electric guidance rate beacon and a spacecraft-hatch bolt, in addition to allowances for topping fuel, loxing the launch vehicle, and verifying the Bermuda computer after a ground power failure. The vehicle lifted off at approximately 0947 e.s.t. on February 20, 1962; 3 hours and 42 minutes after the astronaut entered the spacecraft.

All Atlas flight parameters were normal during launch. Virbration amplitudes and frequencies were acceptable and comparable to those experienced during the MA-5 launch. Spacecraft orbital insertion conditions were excellent. Deviations from nominal values of inertial flightpath angle and velocity were -.05 degrees and -7 ft/sec, respectively, with a resultant capability of nearly 100 orbital passes. General Electric-Burroughs and AZUSA guidance data both indicated a "GO" condition after sustainer engine cut off. The perigee and apogee of the orbit differed from the nominal values of 87.0 and 144.4 nautical miles by 0.1 nautical miles and 3.5 nautical miles, respectively.

Spacecraft separation, rate damping, and turnaround were accomplished satisfactorily. With the exception of steadily rising temperatures on both inverters, all spacecraft systems performed satisfactorily during the first pass.

The astronaut observed the launch vehicle tankage in its slightly lower orbit for some time, checked out the spacecraft control systems, performed planned tasks and made scientific observations, including a report of small luminous-appearing particles around the spacecraft at sunrise.

At approximately the beginning of the second orbital period, the astronaut reported that the spacecraft was not maintaining acceptable attitudes in the orbit mode of control in right and later in left yaw. This was because of a thrust loss from the low thrusters. The astronaut elected to control the spacecraft manually to conserve fuel, and most of the remainder of the mission was flown in a manual control mode. Necessary attention to control of the spacecraft precluded accomplishment of some flight-plan items.

However, the astronaut accomplished the major planned tasks and confirmed the major weather phenomena were visible on the moonlite dark side of the earth. He controlled the spacecraft attitudes by visual reference to the horizon and stars on the dark side of the earth, and spacecraft maneuvers were performed manually, including 180° yaw maneuvers.

During the second and third passes, an indication from telemetry that the spacecraft heat shield might be unlocked caused some concern. A recommendation was made that the empty retropack be retained on the spacecraft during reentry at the end of the third orbital pass. The intent was to hold the heat shield in place until sufficient aerodynamic pressure was built up, in case it was unlatched. The retropack had no detactable effect on the reentry. It was later disclosed that the heat shield had not been prematurely released.

Spacecraft attitudes during the retrofire maneuver were controlled by both the automatic control system and the astronaut using manual control. Spacecraft oscillations diverged during reentry and were not satisfactorily controlled until the drogue parachute stabilized the spacecraft. The drogue parachute deployed at about 27,000 feet, rather than the planned 21,000 feet. Landing (at 04:55:16) occurred approximately 40 nautical miles uprange of the planned landing point. The spacecraft, with the astronaut inside, was recovered some 17 minutes after landing by the destroyer Noa. The astronaut was found to be in excellent physiological condition.

Network operations, including telemetry reception, radar tracking, communications, command control and computing were excellent, which permitted effective flight control during the mission.

SPACE VEHICLE DESCRIPTION

A photograph of the space vehicle lift-off configuration, consisting of the spacecraft and the launch vehicle, is shown in figure 5.

Spacecraft - Spacecraft No. 13, shown in figure 6 was utilized for the MA-6 manned orbital mission. The spacecraft axis system is shown in figure 7. The primary differences between spacecraft no. 13 and spacecraft no. 9 (MA-5 mission) are listed below:

1. An astronaut's couch was installed.
2. A personal-equipment container was installed.
3. Filters were provided for the astronaut's window.
4. An indicator was added to the instrument panel which displayed the temperature of the suit circuit steam vent.
5. The suit circuit incorporated a constant-bleed orifice (750 cc/min).
6. The suit shutoff valve spring force decreased to approximately 25 lbs., compared to about 40 lbs. for spacecraft no. 9.
7. The cabin-fan inlet duct incorporated improved screens.
8. The latching relay to lock in the number 2 suit fan was omitted.
9. The suit-inlet snorkel door was located on the conical afterbody.
10. Cooling plates of the new design were installed under the 150 VA and 250 VA main inverters, and the stainless steel check

valves were installed in the coolant line in lieu of aluminum valves.

11. The Manual Proportional control system linkage had shear pins added.

12. Improved heat-condition paths and heat sinks were installed near the thrusters for temperature control of the roll thruster fuel lines.

13. Indicating lights were added to the instrument panel to show which inverters were operative.

14. Direct manual switching without fuses to the inverters was incorporated.

15. The maximum altitude sensor was provided a separate battery.

16. One-ohm fuses were installed in all squib circuits.

17. An integrating accelerometer was installed.

18. A Super SARAH beacon was incorporated in lieu of an Ultra SARAH.

19. A reserve chute was installed.

20. A switch was installed to allow manual override of heat-shield deployment.

21. The escape tower legs were of heavier construction.

22. A manually actuated blood pressure measuring system was incorporated.

The weight and balance parameters for spacecraft no. 13 are shown in the following table:

Parameter		Mission Phase				
		Launch	Orbit	Normal Reentry Configuration	Normal Reentry Configuration Plus Retropack (Rockets Fired)	Flotation
Weight, pounds		4265.26	2986.78	2698.98	2815.95	2421.79
Center of Gravity station, inches	Z	167.96	121.18	124.62	123.02	119.74
	X	.31	-.04	-.07	-.06	-.33
	Y	-.08	.07	.01	.01	.16
Moments of Inertia, slugs-ft ^{2}	I_z	384.0	281.6	271.0	275.1	258.1
	I_x	7761.1	621.6	544.6	581.8	353.4
	I_y	7767.5	629.3	552.2	589.4	359.5

Launch Vehicle. - The MA-6 launch vehicle, Atlas No. 109-D, was modified for the mission as on previous Mercury-Atlas flights. A sketch showing the general configuration is shown in figure 8. It differed from the MA-5 Mercury-Atlas booster (93-d) in one major respect. The insulation and its retaining bulkhead between the lox and fuel tank dome was removed prior to launch when it was discovered that fuel had leaked into this insulation. The original requirement for this insulation and retainer had been deleted earlier in the Atlas development program as being non-essential, and this insulation is not retained in the operational ICBM version.

The following minor modifications were incorporated on MA-6 and are planned for future Mercury-Atlas flights:

1. The gyro canister was modified to include specially selected transistors of the original design type that had good thermal characteristics. This change decreases the possibility of thermal run-away in the gyro torquer and signal amplifier.

2. The booster lox-tank pressure parameter for the Abort Sensing and Implementation System (ASIS) was changed from 21.5 ± 1.0 psi to 19.5 ± 1.0 psi to protect against an inadvertent abort due to lox - tank-ullage pressure transients which occur at lift-off.

EVENTS, TRAJECTORY, AND GUIDANCE

Sequence of Events

The times at which the major events occured are given in table I.

Trajectory

The ground track of the flight is shown in figure 9, and the altitude-longitude profile is shown in figure 10.

The launch trajectory data, shown in figure 11, are based on the real time output of the Range Safety Impact Predictor Computer (which used AZUSA MK II and Cape FPS-16 radars) and the General Electric-Burroughs guidance computer. The data from these tracking facilities were used during the time periods listed below.

Facility	Time, Min:Sec
Cape Canaveral FPS-16	0 to 00:45
AZUSA MK II	00:45 to 01:03
GE-Burroughs	01:03 to 05:02

The parameters shown for the "planned" launch trajectory in table I were computed using the 1959 ARDC model atmosphere to maintain consistency with other published preflight trajectory documents. The density of the Cape Canaveral atmosphere is approximately 10 percent higher than that of 1959 ARDC atmosphere in the region of maximum dynamic pressure (about 37,000 feet altitude). As a result, the maximum dynamic pressure expected would be about 10 percent higher than that shown as "planned". For this flight, the maximum dynamic pressure experienced was about 12 percent higher than that shown as "planned".

The orbital portion of the trajectory, shown in figure 12, was obtained by starting with the spacecraft position and velocity vector obtained during the second pass near Woomera, as determined by the Goddard computer using Mercury network tracking data. Integration backward along the flight trajectory to orbital insertion and forward to the start of retrofire at the end of the third yielded the calculated orbit. These integrated values were in excellent agreement with the General Electric-Burroughs guidance system measured values at orbital insertion. They were also in accord with the position and velocity vectors determined by the Goddard computer for passes near the Canary Islands (first pass), Bermuda (second and third pass), and Muchea (during the third pass), thus establishing the validity of the integrated orbital portion of the flight trajectory.

The reentry portion of the trajectory, shown in figure 13, was obtained by starting with the spacecraft position and velocity vector near Corpus Christi, Texas, as determined by the Goddard Computer. Integration backward along the flight to the end of retrofire and forward to landing yielded the reentry trajectory. This exercise assumed that the retro-package had not been jettisoned and that the drogue chute was deployed at 04:49:17 GET (given by telemetry) at an altitude of approximately 27,000 feet, instead of the planned altitude of 21,000 feet. The spacecraft decelerations from the integrated reentry trajectory agree within reading accuracy, with the decelerations measured by the onboard accelerometer. In addition, the times of drogue and main chute deployment from the integrated reentry trajectory and from spacecraft onboard measurements agree within one second. This agreement between the spacecraft serves to verify the validity of the integrated reentry portion of the trajectory. The integrated valves at the end of retrofire were adjusted by adding the effects of a nominal retrorocket total impulse of 38,800 lb-sec at nominal spacecraft retrofire attitudes of -34° pitch, with zero roll and yaw. The results, when compared with the orbital integrated valves at the start of retrofire, show the velocity to be about 7 feet per second low indicating that the actual retrorocket performance was 7 feet per second greater. The fact that the spacecraft landed aproximately 40 nautical miles short of the nominal landing point can be attributed to a deviation in spacecraft pitch attitude during retrofire and excessive retrorocket performance. An error of 1 foot per second in retro-velocity will give corresponding error in landing range of 6.2 nautical miles from the nominal landing point, and an error of 1.0° in pitch attitude during retrofire will give an error in landing range of 10.0 nautical miles from nominal. The reentry trajectory and the landing point were only slightly affected by the retention of the retropackage. The integrated landing point was about 4 nautical miles short of the spacecraft pickup point.

The aerodynamic parameters for the planned and integrated reentry trajectories were computed using the MSC model atmosphere. This is based on Discoverer Satellite program data above 50 nautical miles altitude, the 1959 ARDC model atmosphere between the 25-and 50-nautical mile altitudes, and the Patrick AFB atmosphere below 25 nautical miles altitude.

In the trajectory figures, the above integrated values are labeled "actual".

A comparison of the planned and actual trajectory parameters is given in table II. The difference between these is due to the actual cutoff velocity and flight-path angle being slightly lower than planned.

Guidance

The General Electric-Burroughs, Atlas guidance system performed excellently in this flight. The guidance system locked on the vehicle in both track and rate at 00:68, approximately as planned, and lost lock at 05:32, through 16, (31 seconds after sustainer engine cutoff, SECO).

In figure 14 the velocity and flight-path angle are shown in the region of sustainer cutoff. General Electric-Burroughs data are shown in figure 14, and the AZUSA data used in the Range Safety Impact Predictor Computer (IP 7000) are shown in figure 15 to illustrate the noise level during the time of the GO-NO-GO computations. Both the General Electric-Burroughs and the AZUSA data are considered excellent, except for two AZUSA points immediately after SECO.

The General Electric-Burroughs system gave a cutoff which was about 7 ft/sec low in velocity and about 0.30° low in flight-path angle. These values are within the expected accuracy range for the system.

In figure 16, these data are shown as flight-path angle versus velocity. This is the type of display used by the Flight Dynamics Officer in the Mercury Control Center for the orbital GO-NO-GO decision. Both General Electric-Burroughs and AZUSA data indicated a GO condition.

TABLE I. SEQUENCE OF EVENTS

Event	Planned Time,[1] Hr:Min:Sec	Actual Time, Hr:Min:Sec	Difference,[2] Seconds
Booster engine cutoff(BECO)	00:02:11.4	00:02:09.6	-1.8
Tower release	00:02:34.2	00:02:33.3	-0.9
Escape rocket firing	00:02:34.2	00:02:33.4	-0.8
Sustainer engine cutoff discrete (SECO)		00:05:02	-1.8
Tail-off complete	00:05:03.8	00:05:02	-1.8
Spacecraft separation	00:05:03.8	00:05:03.6	-0.2
Retrograde initiation	04:32:58	04:33:08	+10.0
Retrorocket no. 1 (left)	04:32:58	04:33:08	+10.0
Retrorocket no. 2 (bottom)	04:33:03	04:33:13	+10.0
Retrorocket no. 3 (right)	04:33:08	04:33:18	+10.0
Retropack jettison	04:33:58		
0.05 g relay actuation	04:43:53	04:43:31*	-22.0 (0)[3]
Drogue parachute deploy	04:50:00	04:49:17.2	-42.8
Main parachute deploy	04:50:36	04:50:11	-25.0 (-1.0)
Main parachute jettison	04:55:22	04:55:23	+1.0 (-27.0)

[1] Preflight calculated, based on nominal Atlas performance.

[2] The numbers in parentheses show the time difference between the actual event based on insertion parameters and the postflight-calculated reentry event.

[3] The 0.05 g relay was actuated manually by astronaut when he was in a "small g field".

[redacted]

TABLE II COMPARISON OF PLANNED AND ACTUAL TRAJECTORY PARAMETERS

Condition and Quantity	Planned	Actual	Difference
Cutoff conditions (including tail-off):			
Range time, seconds	303.3	302.0	-1.3
min:sec	05:03.3	05:02	
Geodetic latitude, deg north	30.4273	30.4533	0.0260
Longitude, deg west	72.3268	72.3865	0.0597
Altitude, feet	528,428	528,381	-47
nautical miles	87.00	86.96	-0.04
Range, nautical miles	436.4	433.7	-2.7
Space-fixed velocity, feet per second	25715	25708	-7.0
Space-fixed flight-path angle, deg	0	-.0463	-.0463
Space-fixed heading angle, deg east of north	77.4756	77.4826	.0070
Post-posigrade firing conditions:			
Range time, seconds	305.3	306.3	1.0
min:sec	05:05.3	05:06	
Geodetic latitude, deg north	30.4572	30.5128	0.0556
Longitude, deg west	72.3797	72.2923	-0.0874
Altitude, feet	528460	528361	-99
nautical miles	87.0	86.96	-0.04
Range, nautical miles	444.2	449.4	5.2

[redacted]

[redacted]

TABLE II COMPARISON OF PLANNED AND ACTUAL TRAJECTORY PARAMETERS

Condition and Quantity	Planned	Actual	Difference
Space-fixed velocity, feet per sec	25737	25730	-7.0
Space-fixed flight-path angle, deg	-0.0030	-0.0517	-.0487
Space-fixed heading angle, deg east of north	77.5541	77.6399	0.0858
<u>Orbit parameters:</u>			
Perigee altitude, statute miles	100.1	100.03	-0.07
nautical miles	87.0	86.92	-0.08
Apogee altitude, statue miles	166.2	162.17	-4.03
nautical miles	144.4	140.92	-3.48
Period, min:sec	88:32	88:29	-00:03
Inclination angle, deg	32.52	32.54	0.02
<u>Maximum conditions:</u>			
Altitude, statute miles	166.2	162.17	-4.03
nautical miles	144.4	140.92	-3.48
Space-fixed velocity, feet per sec	25737.0	25732.0	-5.0
Earth-fixed velocity, feet per sec	24420.0	24415.0	-5.0
Exit acceleration, g's	7.7	7.7	0
Exit dynamic pressure, lbs/ft^2	966^1 978^2	932	16.0
Entry deceleration, g's	7.6	7.7	0.1

TABLE II COMPARISON OF PLANNED AND ACTUAL TRAJECTORY PARAMETERS

Condition and Quantity	Planned	Actual	Difference
Entry dynamic pressure	447	472	25.0
Landing point:			
Latitude, deg:min	21°07'N	21°26'N[3]	00°19'N
Longitude, deg:min	68°00'W	68°41'W[3]	00°41'W

[1] Based on Cape Canaveral atmosphere.

[2] Based on 1959 ARDC model atmosphere.

[3] "Actual" landing coordinates shown above were those resulting from the trajectory integration. The retrieval point 20 minutes after landing was reported as 21°25'N and 68°37'W by the recovery ship (see section 9.0).

SPACECRAFT PERFORMANCE

The spacecraft as an entity performed adequately. Some malfunctions were experiences, and analyses of these are discussed in the following paragraphs. Also discussed, from an overall mission viewpoint, are the spacecraft systems' general performance. Flight data and measurements are generally not shown, other than to clarify an analysis or present measurements of particular interest.

Complete time histories of spacecraft data, without analysis, are presented in reference 1.

Spacecraft Control System

With the single exception of both 1-pound yaw thrusters failing, the spacecraft control system functioned normally throughout the flight. Discrepancies between the attitude indicators and the ground reference reported by the astronaut are discussed and a detailed analysis of the thruster malfunction is presented in the Reaction Control section.

<u>System description</u>.- The spacecraft is capable of the following control system modes:

1. Automatic stabilization control system (ASCS), with orbit mode, orientation mode, and auxiliary damping mode.
2. Fly-by-wire (FBW) manual system.
3. Manual proportional (MP) system.
4. Rate stabilization control system (RSCS).

Modes 1 and 2 employ the automatic reaction control system (RCS) thrusters, while 3 and 4 use the manual RCS thrusters. Each reaction control system is independent of the other. Combinations of 1 and 3, 2 and 3, or 2 and 4 may be used simultaneously. The amplifier-calibrator (AmpCal) incorporated a new single-pulse, orbit-mode logic, thus eliminating the double orbit pulses that have been experienced in the past with dirty repeater sectors. In addition, the horizon scanner reference levels were set at approximately 25 percent to lessen cold cloud effects, and scanner slaving was programed for 8.5 minutes in each 30-minute period.

<u>Flight description and analysis</u>.-

Powered flight and turnaround: Control system operation was normal in this period, although the 5 seconds of separation rate-damping was delayed 2.5 seconds by the sequence circuitry associated with the .20g switch, thus leading to a fairly large initial roll error at the start of turnaround. The source of this error was the reopening of the .20g relay when posigrade thrust acceleration was sensed, and a lockout feature will be included on future flights. Turnaround was managed adequately, although the time required (38 seconds) to settle into orbit mode was longer than normal because of the initial roll error. Spacecraft attitudes and rates near insertion are listed in the following table:

Axis	Attitude:Rate		
	Separation	Separation plus 2.5 sec (start of damping)	Separation plus 7 sec (start of turnaround)
Roll	0°:-1°/sec	-12°:-6°/sec	-22°:
Pitch	-8°:+0.4°/sec	+2°:+5.5°/sec	+4°:
Yaw	180°:-0.3°/sec	170°:-2.5°/sec	160°:

Orbital phase: Except for the thruster malfunction, the control system during this phase functioned essentially as designed. Control system exercises and usage modes are discussed in a later section. With the initiation of the first yaw maneuver, attitude indicators began to disagree with true spacecraft attitudes. Such disagreements are inherent in the system and will occur whenever the yaw or roll attitudes deviate from 0° for an extended period of time, as demonstrated mathematically and with operational hardware. Values will be different, depending upon the presence of either scanner slaving or fixed pitch orbital precession, but the effects will be similar. Each disagreement has been examined and can be explained per system design.

The following hypothetical maneuver is cited to best illustrate this point:

> Assume that the spacecraft and gyros are properly erected in the normal orbit attitude and that the spacecraft is then yawed 90° and maintained in this yaw heading for $\frac{1}{8}$ of an orbital period (11.25 minutes or 45° orbital travel),

while the astronaut maintains a local vertical using the window reference. During this $\frac{1}{8}$ pass the fixed pitch precession signal (about 4°/min) will drive the vertical gyro spin axis in a direction 90° from the orbital plane, and at the end of this period the pitch attitude indicator will disagree with the spacecraft true attitude by 45°. At the same time, the astronaut will have rolled the spacecraft 45° to maintain his vertical position with respect to the local horizon. If the spacecraft is then restored to the normal orbit attitude, the gyro spin axis will maintain its position in space. This results in permanent attitude errors in both axes, unless corrected by slaving.

The 180° yaw maneuver, initiated at 3:14:00 is offered as the best example of the above (see figure 17). Indicated attitude errors, produced by spacecraft maneuvering, can be avoided by leaving the gyros caged during such maneuvers. New gyro references can best be restored through continuous scanner slaving, combined with incaging the gyros at approximately 0° pitch and then permitting the spacecraft to remain at orbit attitude (-34°) for approximately five minutes.

Three gyro cagings were executed by the astronaut during his mission phase. In each instance the spacecraft was pitched down to -15°, rather than level. In addition, during the first caging the spacecraft roll attitude was -19°.

Horizon scanner operation was as expected, with short roll scanner "ignore" periods occurring just prior to sunset. All "ignores" produced by the pitch scanner can be correlated with maneuvers. Eight scanner slaving cycles occurred, which were controlled by the programer, and this promptly removed all maneuver and caging errors.

Retrofire: Retrofire occurred at 4:33:08 and was completed by 4:33:33. The astronaut provided backup to the ASCS system with manual proportional control, maintaining slightly better attitudes than were experienced on the MA-5 mission. Pitch and roll was held to within 1°, with the yaw deviation not exceeding 2°.

.05g and reentry: At 4:39:39, reentry pitch-up was initiated by the astronaut, with the .05g relay manually actuated at 4:43:31. The .05g roll rate was initiated at 4:44:41, utilizing both manual and fly-by-wire thrusters, and reached -11°/sec within 2 seconds. By 4:46:30, pitch and yaw oscillations, with a period of 1.5 sec, were in evidence, with rates changing 2°/sec. The astronaut attempted to provide damping utilizing both manual and fly-by-wire thrusters. By 4:47:17 the pitch oscillatory rates had increased to greater than 10°/sec, with a period of 1.1 sec, while yaw rates were kept within 6°/sec at the same frequency until 4:47:20, when they also exceeded +10°/sec. It is estimated that manual fuel depletion occurred at 4:47:04. Analysis of stick motions and rates shows that at least 50 percent of the thrust pulses opposed the direction of motion, 25 percent were approximately 90° out of phase; thus decreasing then aiding; and producing no net effect. The remaining

25 percent actually assisted in increasing the oscillations. Extrapolation of the rate traces provides a spacecraft swing of +5° in the center of this time period.

At 4:47:39, the astronaut switched on the auxiliary damping system. Pitch and yaw oscillation rates decreased to within 2°/sec in a 4-second period, while the roll rate decreased from -20°/sec to a nominal -11°/sec. At 4:48:32, the oscillations again began to build up in pitch and yaw. By 4:48:40, rates were changing ±10°/sec, with a period of 3.5 seconds per cycle, while the roll rate showed an irregular decrease. Automatic system fuel depletion is estimated to have occurred at approximately 4:48:30. For future mission, flight plan ground rules will ensure that sufficient fuel will be available to control adverse oscillations in the auxilliary damping mode, with RSCS as a backup. At approximately 4:49:17, the drogue chute was deployed, with antenna fairing release and main chute deploy occurring at 4:50:11.

Behavior during the second period of oscillation compares with estimates for reentry without control, although the direct cause of the divergent oscillations cannot be conclusively determined. Gross extrapolations of flight data provide a spacecraft swing of about ±25° in pitch and at least ±40° in yaw (Astronaut Glenn estimated amplitudes of up to 90°). It was not possible at this point in the flight to determine attitudes with respect to the vertical, since the spacecraft gyros had been de-energized.

Reaction Control System.-

Configuration: The Reaction Control System (RCS) was of the standard configuration in both the automatic and manual subsystems. Heat sink modifications to reduce temperatures in the hydrogen peroxide feedline to the automatic and manual roll thrust assemblies were incorporated on the launch pad.

Prelaunch Activities: Prelaunch servicing of the manual and automatic subsystems was normal, with all components functioning properly during system servicing operations and thrust chamber static firings. One abnormality was a high decomposition rate from the automatic subsystem during surveillance. The actual surveillance rate evolved was 99 percent of the system allowable maximum; however, because of the decomposition rate linearity with time, the system was considered flightworthy.

Flight Performance: Prior to 01:29:24, both the automatic and manual RCS subsystems functioned properly and delivered the expected thrust levels along all axes. At 01:29:24 (during the first orbital pass), the ASCS called for 1 pound yaw-left automatic thrust chamber operation from which no rate response was received for 5 orbit-mode pulse signals. Immediately after this malfunction, the astronaut selected the manual proportional control mode and returned the spacecraft to proper yaw attitude. Repeated signals to the thrusters in both ASCS and fly-by-wire control modes substantiated that the 1-lb yaw-left chamber was not functioning properly. This condition persisted until 01:48:22 when in the fly-by-wire mode, this thruster began to function and deliver the proper rate response. Except for a few isolated pulses of possible low thrust values, the 1 pound yaw-left operated properly for the remainder of the flight.

Within one minute and eighteen seconds of return to proper operation by the 1 pound yaw-left chamber, the 1 pound yaw-right chamber ceased to respond (01:49:40) in both ASCS and fly-by-wire control modes. The 1 pound yaw-right chamber remained inoperative for the duration of the flight, except for apparent intermittent operation in the period between 04:30:00 and 04:34:00.

With the exception of the 1 pound yaw thrust chambers, all remaining chambers in both the automatic and manual subsystems functioned properly throughout the flight with no notable exceptions. At one time the astronaut voiced the opinion that a possible pitch-thrust-chamber malfunction was evident, but this report was not substantiated by the data. The manual proportional control system exhibited proper operation at all times, with the possible exception of an instance where it appeared that the control handle may have retained a slight deflection from neutral following a control maneuver. This condition appeared to have been corrected by the astronaut with no difficulty.

Feed-Line Temperatures in Flight: Feed-line temperatures of both automatic 1-pound roll and manual-roll thrust chambers were measured during flight. The manual roll feed-line temperature increased approximately 30° F from prelaunch ambient conditions due to aerodynamic heating during powered flight. At the completion of spacecraft turnaround, manual roll feed-line temperatures were stable at approximately 106° F.

Automatic 1-pound roll feed lines were only slightly affected by the boost phase and indicated a total temperature increase of less than 10° F from prelaunch ambient to completion of spacecraft turnaround. Maximum temperature in orbit of the manual roll feed lines was approximately 106° F. Maximum temperature in orbit of the automatic roll feed line was approximately 120° F. The effect of solar radiation on feed line temperatures was evident from data taken during the second and third passes. During sunlight periods, slightly increasing temperature trends were noted, and in periods of darkness temperatures did not show an increasing trend.

Reentry heating effect on all instrumented feed lines was very pronounced, with manual roll reaching a maximum of approximately 145° F and automatic roll a maximum of approximately 200° F.

Postflight Inspection: All thrust chamber assemblies in Spacecraft 13 were disassembled on February 26, 1962, for the purpose of visual examination. Photography of noted observations was conducted concurrently with disassembly. Loose foreign particles found upstream of the fuel-metering orifices of both 1-pound yaw thrusters are believed to be the most probable cause of the intermitten malfunction of these thrusters. These foreign particles have been visually identified as portions of fuel distribution (Dutch weave) screens located downstream of the fuel metering orifices. The time and method by which these particles went upstream of the fuel orifice is unknown, but it is hypothesized that pressure transients in the thrust chambers provided the transport mechanism. Examination results are listed in table III, and typical photographs are shown in figure 18. For the MA-7 mission, what is commonly referred to as the "interim fix" has been incorporated into the reaction control system for spacecraft 18. This essentially involves replacing the stainless steel Dutch weave screens with platinum screens and a fuel distribution plate, reducing the volume of the heat barriers and solenoids, and moving the orifice to the solenoid inlet.

Fuel Consumption: The fuel consumption is shown in table IV, and the reentry portion is shown in figure 19.

TABLE III.- RESULTS OF POSTFLIGHT EXAMINATION OF THRUST CHAMBER

Thrust Chamber Assembly	Heat Barrier Screen	Orifice Condition	Dutch weave Condition	Remarks
1 pound Yaw Right, S/N 101	Clear	5 particles on upstream face	Top screen burned and heavily eroded in center	Particle diameter approx. same as .016 orifice and length somewhat larger than .016
1 pound Yaw Left, S/N 55	Clear	Numerous dust size particles on upstream face	Top screen burned and moderately eroded	Particle size of the order 100 to 200 microns
1 pound Pitch Down, S/N 114	Clear	1 particle on upstream face	Small hole in top screen. Slightly burned	Particle size of the order 100 to 200 microns
1 pound Pitch Up, S/N 108	Clear	9 particles on upstream face	Top screen burned and practially eroded in center	Particle size same as 1 pound Yaw Right, above
1 pound Roll CCW, S/N 12	Clear	Clean	Normal - only slightly discolored	
1 pound Roll CW, S/N 211	Clear	Clean	Normal - only slightly discolored	
Auto - 6 pound Roll CW, S/N 211	Clear	Clean	Normal	
Auto - 6 pound Roll CCW, S/N 12	Clear	Clean	Slight erosion	

[redacted]

TABLE III. - CONTINUED

Thrust Chamber Assembly	Heat Barrier Screen	Orifice Condition	Dutch weave Condition	Remarks
Auto - 24 pound Pitch Up S/N 241	Clear	Clean	NA	
Manual - 24 pound Pitch Up, S/N 215	Clear	Clean	NA	
Auto - 24 pound Pitch Down, S/N 12	Clear	Clean	NA	
Manual - 24 Pound Pitch Down, S/N 205	Clear	Clean & Wet	NA	
Auto - 24 pound Yaw left, S/N 107	Clear - appears as only 1 screen	Clean	NA	
Manual - 24 Pound, Yaw Left, S/N 85	Clear	Clean	NA	
Auto - 24 pound Yaw Right, S/N 54	Clear	Clean	NA	
Manual - 24 pound Yaw Right, S/N 213	Clear & wet	Clean & wet	NA	

TABLE III. - CONCLUDED

Thrust Chamber Assembly	Heat Barrier Screen	Orifice Condition	Dutch Weave Condition	Remarks
Manual - 6 pound Roll CCW, S/N 2	Clear & wet	Clean	Normal	
Manual - 6 Pound Roll CW, S/N 7	Clear & wet	Clean	Normal	

TABLE IV.- FUEL CONSUMPTION[a]

		Auto System		Manual System	
	Maneuver or Mode	Fuel Used lbs	Fuel Remain lbs	Fuel Used lbs	Fuel Remain lbs
00:00:00	Launch	0	36.0	0	24.4
00:06:00	Turnaround and damping	5.8	30.2	0	24.4
01:37:00	Orbital Pass 1	4.2	26.0	0.6	23.8
03:10:10	Orbital Pass 2	6.0	20.0	11.8	12.0
04:33:00	Orbital Pass 3 (to retro)	8.6	11.4	5.2	6.8
04:43:27	Retro to .05g	4.0	7.4	5.6	1.2
04:49:20	.05 to drogue parachute deploy	7.4[b]	0	1.2[b]	0
04:50:11	Drogue parachute to main parachute	0	0	0	0

[a] Data accuracy to ±0.5 pound fuel.

[b] Fuel depletion occurred during this period

Postflight examination of data recorded onboard revealted that the automatic fuel depleted near 04:48:30 and manual at approximately 04:47:20. The manual fuel quantity indicator averaged an error of approximately 8 percent more fuel than actual for fuel quantities below 70 percent. The automatic fuel quantity indicator averaged an error of approximately 3 percent more fuel than actual for all fuel indications. Neither of the above percentage errors reflects a visual reading error of the FQI gauges.

Environmental Control System

The Environmental Control System (ECS) provided adequate environmental conditions for the astronaut throughout the flight. The uncomfortably warm conditons reported by the astronaut after landing are discussed in a later section.

System Description.- The primary change in the ECS from spacecraft nO. 9 (MA-5) was the addition of a constant-bleed orifice to the suit circuit. This orifice provided a continuous oxygen flow greater than the astronaut's anticipated metabolic requirement. The excess gas was exhausted into the cabin.

Countdown.- The temperature of the main inverters increased to higher than expected levels during the countdown. This indicated that the freon flow to the inverter cold plates, though adequate during pre-count checks, was inadequate during the final count. Temperatures of the 150-v amp and 250-v amp inverters at lift-off were 162° F and 120° F, respectively.

Launch Phase.- The launch phase was normal. The cabin and suit pressures maintained a 5.5 psi differential above ambient during ascent and held at 5.7 and 5.8 psia, respectively.

Orbital Phase.- Cabin and suit pressures maintained 5.7 and 5.8 psia, respectively, throughout the orbital flight. The decay in these pressures that had been observed in previous flights was absent for three primary reasons:

1. The low cabin leakage (less than 500 cc/min.).
2. Excess oxygen, exhausted into the cabin from the suit circuit constant-bleed orifice.
3. Minor leakage from the secondary oxygen supply.

The oxygen partial pressure agreed with suit pressure to within 0.5 psia althought it was consistently lower. The cause of part of this difference is contributed by water vapor in the suit circuit, which added a partial pressure of approximately 0.3 psi that is not included in the oxygen partial pressure measurement. A more careful calibration than those made for previous flights has resulted in a more satisfactory performance of this instrument.

The cabin air temperature, after the initial heating period, fluctuated as expected when the spacecraft passed through the alternate periods of darkness and sunlight. The astronaut reported that at least five attempts to reduce cabin air temperature, by increasing water flow to the cabin heat exchanger resulted in illumination of the excess water light. This indicated that the cabin heat exchanger was operating near its maximum capacity for the existing conditions. Nevertheless, the mean cabin air temperature was steadily reduced after the first hour in orbit.

The suit inlet temperature (figure 20) varied between 65° and 75° F during the orbital phase. The astronaut reported a coolant flow of 1.7 pounds/hour to the suit heat exchanger, and a stream exhaust temperature of 65° F. These values are both higher than anticipated and contradict each other, since freezing of the exchanger would be expected at this flow rate. No explanation of this anomaly can be offered at this time.

The 150- and 250-v amp inverter temperatures (figure 20) increased steadily from the launch values of 162° and 120° F, to 204° and 197° F, at landing, respectively. Postflight testing revealed that the check valve between the coolant supply and the cold plates was stuck in the closed position and would not permit the coolant to flow to the cold plates in orbit. The coolant tank was charged with 25 pounds of water before the flight. The coolant quantity indicating system showed a usage of 7.2 pounds. Postflight weighing indicated a usage of 11.8 pounds. The difference in calibration and final system temperatures can account for about 3.8 pounds of the 4.6 pounds discrepancy, while the remaining 0.8 pounds is considered to be instrument error.

Reentry and Postlanding.- The maximum cabin temperature during this period was 103° F, which is undesireable but satisfactory. The suit inlet temperature increased to 86° F during the postlanding phase. This value is reasonable since the air temperature in the landing area was 76°, and the suit compressor raises the temperature in the suit circuit by approximately 10° F. The sequence of operation regarding cooling techniques during this period will be modified to reduce the suit inlet temperature to a more tolerable level.

Anomalies.- Examination of the flight data and postflight checks of the environmental control system have revealed several anomalies. As shown in figure 21, the secondary oxygen supply exhibited an unexpected decay in pressure, which was first noted after approximately 01:50:00. However, it is not known when this decay began, since the secondary oxygen bottle was serviced to about 8,000 psig before flight, and the pressure transducer had a maximum indicating value of only 7,500 psig. The indicating range of future transducers will be increased to 10,000 psig. Postflight tests indicated that the secondary system was free of leaks. Also, the postflight checks indicated a usage rate of only 0.13 pounds per hour through the suit circuit, compared with about 0.18 pounds per hour obtained during prelaunch tests. Finally, the pressure decay rate of the primary supply decreased to much lower than expected values during the final portion of the mission, and, during the last three quarters of an hour in orbit, the decay rate of the secondary supply was essentially zero. No explanation for these anomalies can be offered at this time, but investigations are being conducted to isolate and reveal the source of this anomaly.

Mechanical and Rocket Systems

All systems functioned normally, with the exception of early drogue chute deployment and an indication of heat shield deployment during orbital flight. These anomalies, along with general systems performance, are discussed in the following paragraphs.

Parachutes.- The performance of the drogue and main parachutes upon deployment were satisfactory. Since neither parachute was recovered, a detailed postlaunch visual inspection could not be made. However, observation by the astronaut verified that both parachutes were deployed cleanly and were undamaged during descent. The main chute deployed at a pressure altitude of 10,000 feet, as determined from pressures measured onboard. This is within the specification limits of 10,000 ± 750 feet.

The drogue parachute deployed at a higher-than-normal altitude, probably about 27,000 feet pressure altitude. Onboard pressure measurements (commutated) indicate a pressure altitude of approximately 29,000 feet at the time of drogue chute deployment, and the integrated trajectory is consistent with a drogue deployment at about 27,000 feet. The astronaut reported an altitude of 30,000 to 35,000 feet indicated at the time of drogue deployment. The astronaut stated that he had raised his arm approximately halfway to the drogue deploy switch to manually initiate drogue deployment when it occurred automatically. The drogue chute barostats actuated properly within specification pressure altitudes of 21,000 ± 1,500 feet in postflight tests.

The possible causes of an early deployment of the drogue parachute were isolated to those listed below and investigated separately.

1. Inertial barostat actuation as a result of high spacecraft oscillation.

2. Dynamic pressure (q) effects caused from tumbling of the spacecraft.

3. Actual astronaut actuation of the manual drogue parachute switch.

4. Structural failure within the parachute compartment, particularly the drogue mortar cover.

5. Static pressure buildup in the parachute compartment.

6. Spurious or random signals in the drogue mortar-firing circuit.

The first source was ruled out after comparison of the estimated 2g acceleration imposed by the spacecraft oscillations with the rigid qualification specifications governing on the flight hardware. Strong evidence exists that a dynamic pressure could not have built up without being sensed by the static pressure transducer in the parachute compartment. Item 3 was eliminated as a cause through postflight interviews with the astronaut and examination of photographs taken in the spacecraft during the period in question. Postflight examination of the parachute compartment revealed no structural failure, and recorded sequence data indicates that the mortar was fired by a nominal electrical signal, disproving item 4. Tests at McDonnell Aircraft have shown that any oscillatory pressure buildup in the parachute compartment is sensed by the pressure transducer, and, therefore, this would have been evident on the flight record. The last item represent the most plausible cause. Postflight tests have shown the entire circuitry to be sound, however, these tests were conducted under static conditions and are therefore inconclusive.

Rockets and Pyrotechnics.- A postflight examination of the spacecraft and an analysis of the pertinent data indicates that all rockets and pyrotechnics functioned as intended. It cannot be determined whether certain pyrotechnics actually fired (such as redundant clamp-ring bolts and tower jettison rocket ignition), since the available evidence shows only that the resulting function was satisfactory.

Explosive-Actuated Hatch.- After the spacecraft was secured onboard the recovery ship, the astronaut initiated the hatch explosive-mechanism through the use of the internal actuator on the hatch. The hatch appeared to have fired satisfactorily.

Ablation Shield.- Reentry heating for spacecraft 13 (MA-6) is considered to be nearly identical to that experienced on spacecraft 9 (MA-5). Since heating data recorded during the MA-6 reentry is unavailable at this time, the results of the MA-5 reentry temperature survey are presented in figure 22. Temperature readings on the conical and cylindrical portions of the spacecraft employed thermocouples spot welded to the inboard side of the exterior shingles. It should be noted that this is the first formal publication of the MA-5 reentry heating data. These data are currently being analyzed, with a detailed report of the study forthcoming.

Landing Bag.- The landing-attenuation system performed normally, as evidenced by the astronaut's statements and from postflight examinations. The landing bag was found to be torn in several places from unknown causes, but no restraining cables or straps were broken. The usual minor damage to ablation shield retaining studs and to the bulkhead-protective shield was experienced. The main pressure bulkhead was undamaged except for a small dent near the center.

Heat Shield-Deploy Mechanism.- A comprehensive postflight inspection of the limit switch circuitry and hardware revealed that both lateral and axial translation would generate a signal, although the switch is designed to actuate only after a rotational deflection. The cause of this improper operation was traced, after disassembly, to a poorly machined shaft (see fig. 23). The shaft was dented in several places and bent some five or ten degrees. Quality control and production techniques of future limit switches will be improved. The pilot reported noises and other indications of heat shield deployment when he manually initiated the heat shield deployment at $2\frac{1}{2}$ minutes after main chute deployment, thus leading to the conclusion that the shield mechanism was not unlatched in orbit.

Electrical and Sequential Systems

Electrical System.- The spacecraft electrical system was of a specification configuration. One-ohm fuse resistors were installed in all squib firing circuits. Inverter monitor lights were installed to tell the astronaut when the 150 v-amp and 250 v-amp inverters were operating. Main bus voltage and d-c current were as expected throughout the mission. Fans and ASCS a-c bus voltages were also normal.

The inverter temperatures were about 162° F on the 150 v-amp inverter and 120° F on the 250 v-amp inverter at lift-off and increased gradually throughout the mission to 212° and 203°, respectively. This indicated that the inverters received little or no inflight cooling. Inverter cooling is discussed in a previous section.

<u>Sequential System</u>.- The sequential system performed as was expected during the flight, with the following exceptions:

1. Spacecraft separation (T/M segment 47), cap-sep telelight, periscope extend, and damping command to the ASCS were received three seconds after the spacecraft separation indication from booster telemetry. The time discrepancy is attributed to MA-6 not having electrically latched spacecraft adapter bolt fire relays to keep the spacecraft separation circuitry armed during posigrade firing. Earlier spacecraft had this latching feature, as will subsequent spacecraft.

2. The heat-shield-deployed indication (segment 51) on telemetry was realized prematurely, and it then cycled ON-OFF several times during the flight. This was caused by a defective left-hand limit switch. In addition to the mechanical failure of the limit switch, the circuit design did not provide for optimum reliability with the two redundant switches installed. Therefore, future limit switch circuits will be modified such that both switches must actuate to generate a shield-unlocked signal. The landing bag was deployed manually by the astronaut at about $2\frac{1}{2}$ minutes after main-chute deploy and functioned properly.

3. Reentry was performed with the retropack attached. This prevented the .05g event from occurring automatically, which was initiated manually by the astronaut. Retropackage separation indications did not occur, since the electrical signal to fire the retropack separation bolt was never given. This caused the cameras to remain on high speed from retroattitude command until power was removed after impact.

4. The drogue chute was deployed prematurely at about 27,000 feet. The 21,000 foot barostats were removed after the flight, subjected to a pre-installation acceptance test, and found to be functioning properly. Further tests of the static system were performed and are discussed in the Mechanical Systems section of this report.

Telemetry and Recording Systems

The instrumentation system flown on the MA-6 mission was essentially the same as in the MA-5. Small changes between the two spacecrafts were required to accommodate those parameters associated with a manned mission. Other changes are as follows:

1. Heat shield temperature for MA-6 was measured by means of a chromel-alumel thermocouple.

2. The MA-6 spacecraft contained only two cameras, the pilot-observer and instrument-observer, deleting the earth-sky and periscope cameras.

3. A different type of color film was used in the pilot-observer camera.

4. For MA-6, the mixed sequence of events were superimposed on the vernier-clock signal.

A complete list of the instrumented parameters is included in table V.

Telemetry.- Both telemetry transmitters exhibited a center-frequency shift and signal strength rise when the escape tower was jettisoned. This effect, resulting from a change in antenna VSWR, was anticipated and will be taken into account when setting the center frequencies for the transmitters on future spacecrafts. The change in VSWR is generally not significant enough to prevent the transmitters from being adjusted to bring the center frequencies within specification for both tower-on and tower-off conditions. The signal strengths and deviation from center frequency, as read by AMR when the spacecraft passed over Cape Canaveral, are shown in table VI.

Data quality.- The quality of the data reduced from the onboard tape was very good. Scatter and noise caused by tape speed variations was insignificant and easily compensable on the continuous channels. The only problem area occurred during the time of exit maximum dynamic pressure, at which point the vibrational affects on the recorder caused almost complete loss of data. However, the real-time data during the same period covers the lapse.

A comparison of the hand controller (stick position) data, as instrumented on continuous and commutated channels, shows the definite advantage of instrumenting this parameter by means of a continuous channel. About 50 percent of the stick position data are lost on the commutated channel, and that which remains is difficult to interpret.

Photographic.- The instrument-observer camera malfunctioned during the 60-second test at T-55 minutes in the countdown. The film slipped out of the film gate while the camera continued to run, which indicated it was operating properly. This camera, which does not yield significantly useable data, will be removed in future flights. The results obtained from the pilot-observer camera were satisfactory. The use of the Ecktachrome ER, color film is an improvement over previously used types.

Onboard timing.- The vernier-clock channel malfunctioned throughout the entire flight. Each time the pilot-observer camera operated, a spurious pulse was produced in the vernier clock signal. At times when the camera operated at high speed, the signal was rendered nearly useless. The satellite clock is presently being redesigned to include a 1-PPS output, which can be used to directly modulate the voltage-controlled oscillator. The new design will utilize, as a trigger, the same 28-v d-c signal which steps the clock digital counters. This will result in a great improvement in signal-to-noise ratio and should eliminate the problem.

From the instrumentation standpoint, the most serious problem resulting from the MA-6 mission was in the respiration rate and depth channel. The principle of operation of the circuit is a thermistor sensor which is heated by a d-c voltage. When the subject breathes on the sensor, it cools and changes resistance, producing a voltage change on the output of a direct-coupled transistor amplifier. The basic problem is that the thermistor temperature is subject to changes in ambient temperature and flow. Because of changes in these quantities, the baseline of the respiratory signal varied from a value of 10 percent, which was set during the suiting procedure, up to a maximum of 85 percent at lift-off. After lift-off, the baseline fell steadily until it reached a low of 10 percent at 02:08:00. It then began to rise again and had attained a 40 percent level at loss of signal. The sensitivity of the signal degraded in direct proportion to the baseline shift, since the sensitivity decreases as the baseline increases. The sensitivity problem is further complicated by the fact that the position of the sensor is not fixed to the position of the pilot's head. In the MA-6 mission, much of the data were lost because the pilot was not breathing directly on the sensor. Both the subcarrier oscillators which encoded the respiration data performed within specification and did not contribute to the above effects.

Vibration

Vibrations measured during the powered flight phase of the MA-6 mission were almost identical with those experienced during the MA-5 mission. These vibrations can be seen as oscillations on the spacecraft pitch-rate gyro output, as shown in fugure 24. The information available indicates that the astronaut's performance was not impaired by these vibrations.

Postflight Inspection

The general condition of the spacecraft was excellent as indicated in figure 25. The exterior of the spacecraft showed the usual slight discoloration caused by aerodynamic heating. Also, there were deposits of 2024 aluminum alloy which had evidently been deposited in a molten state and adhered to the surface of several widely separated shingles. The aluminum retropack cover is undoubtedly the source of these deposits. A brownish deposit was found on a portion of the spacecraft window exterior surface. The nature of this deposit has not been determined. As on previous flights, the window was found to be fogged with water condensate between the two outer panes.

Structure.- The spacecraft did not experience any structural damage which would have compromised the safety of the mission in any way.

Ablation shield.- The external surface of the shield (see figure 26) had charred in the normal pattern. The center plug of the shield had separated and extended outward approximately 0.5 inch, as in previous missions. A pie-shaped segment of the shield is of a darker background color than the adjacent area. The same area contains several radial marks approximately 4 inches in length. It is likely that a large piece of the retropack slipped off in this direction. There are two small deposits, metal-like but of undetermined composition, on the shield.

Heat-shield deployment instrumentation.- The heat-shield deploy switch between stringers 2 and 3 had a very loose rotary stem. The switch would make and break electrical contact when the rotary stem was moved up and down along its longitudinal axis. This malfunction could account for the impact-bag-deployed signal that was received during the flight, as discussed in an earlier section.

Landing bag.- The landing bag had several tears, and it was impossible to determine whether these occurred during landing or in postflight handling. Experts believe the most probable time of damage occurred during the landing-bag stowage operation aboard ship. No landing bag straps or cables were broken, but some straps were kinked. There was minor damage to the heat shield retaining studs and the bulkhead protective shield, probably from landing as in previous flights. However, no damage occurred to the spacecraft equipment in this area.

The large pressure bulkhead had a dent from an undertermined cause near the center approximately 1.5 inches long. The center area is not covered by the bulkhead shield.

[redacted]

TABLE V.- COMMUTATOR POINT ASSIGNMENT FOR MA-6

COMM. HF	COMM. LF	PARAMETER	RANGE
1	1	3-volt reference	3 v
2	2	Zero ground reference	0.v
3	3	AC amplifer power supply monitor	7 v ac
4	4	Body temperature	95° - 107° F
5	5	Command receiver, all channels signal	On-Off
6	6	Oxygen partial pressure	0 - 800 mm Hg
7		"A" command receiver signal strength	0 - 80 μ volts
	7	"B" command receiver signal strength	0 - 80 μ volts
8	8	Suit pressure	0 - 15 psia
9	9	Oxygen supply pressure primary	0 - 7500 psig
10	10	Cabin air temperature	40° - 200° F
11	11	Suit inlet air temperature	40° - 100° F
12	12	Oxygen supply pressure secondary	0 - 7500 psig
13	13	Y-axis accelerometer (13, 43 and 73)	± 0.5g, ± 4g
14	14	X-axis accelerometer (14, 44 and 74)	± 0.5g, ± 4g
15	15	Z-axis accelerometer (15, 45 and 75)	± 30g
16	16	Pitch attitude ASCS calibrator	-140° to + 180° F
17	17	Roll attitude ASCS calibrator	-130° to + 200° F
18	18	Yaw attitude ASCS calibrator	-70° to + 250° F
19		Roll CW manual - fuel line temperature	0 - 250° F
	19	Roll CCW manual - fuel line temperature	0 - 250° F
20		Lo roll CCW auto - fuel line temperature	0 - 250° F
	20	Lo roll CW auto - fuel line temperature	0 - 250° F
21	21	250 va inverter temperature	40° - 300° F
22	22	Static pressure	0 - 15 psia
23	23	Stick position roll	± 13°
24	24	Stick position pitch	± 13°
25	25	Stick position yaw	± 13°
26	26	Elapsed time (10 seconds)	
27		"A" command receiver signal strength	0 - 80 μ volts
	27	"B" command receiver signal strength	0 - 80 μ volts
28	28	Elapsed time (1 minute)	
29	29	Elapsed time (10 minutes)	
30	30	Elapsed time (1 hour)	
31	31	Elapsed time (10 hours)	
32	32	150 va inverter temperature	40° - 300° F
33	33	Time of retrograde (10 seconds)	
34	34	Time of retrograde (1 minute)	
35	35	Time of retrograde (10 minutes)	
36	36	Time of retrograde (1 hour)	
37	37	Time of retrograde (10 hours)	

[redacted]

[redacted]

TABLE V.- COMMUTATOR POINT ASSIGNMENT FOR MA-6 (continued)

COMM. HF	COMM. LF	PARAMETER	RANGE
38	38	Horizon scanner pitch ignore	On-Off
39	39	Reaction control supply pressure (auto)	600 - 2200 psig
40	40	Reaction control supply pressure (manual)	600 - 2200 psig
41	41	AC voltage monitor (fans bus)	95 - 120v ac
42	42	DC current monitor	0 - 50 amps
43	43	Y-axis accelerometer	
44	44	X-axis accelerometer	
45	45	Z-axis accelerometer	
46	46	Tower release	On-Off
47	47	Capsule separation	On-Off
48	48	Retro attitude command	On-Off
49		"A" command receiver signal strength	
	49	"B" Command receiver signal strength	
50	50	Retrofire timing signal	On-Off
51	51	Impact bag deploy	On-Off
52	52	Integrating accelerometer signal	0 - 600 ft/sec
53	53	Retro assembly jettison	On-Off
54	54	Drogue chute deploy	On-Off
55	55	Antenna fairing release	On-Off
56	56	Main chute deploy	On-Off
57	57	Main Chute Jettison	On-Off
58	58	Reserve chute deploy	On-Off
59	59	Pilot abort	On-Off
60	60	Mayday	On-Off
61	61	Tower escape rockets	On-Off
62	62	Standby inverter "On"	On-Off
63	63	ASCS slaving signal	On-Off
64	64	Calibrate Z/Cal, R/Cal(also 25%,50%,75% Ref.)	On-Off
65	65	High pressure reaction jet solenoids (+ pitch)	On-Off
66	66	High pressure reaction jet solenoids (- pitch)	On-Off
67		18-volt ISOL voltage	16 - 22v dc
	67	18-volt standby voltage	16 - 22v dc
68	68	Oxygen emergency rate mode	On-Off
69	69	High pressure reaction jet solenoids (+ roll)	On-Off
70	70	High pressure reaction jet solenoids (- roll)	On-Off

[redacted]

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TABLE V.- COMMUTATOR POINT ASSIGNMENT FOR MA-6 (continued)

COMM. HF	COMM. LF	PARAMETER	RANGE
71		"A" command receiver signal strength	
	71	"B" command receiver signal strength	
72	72	Periscope retract signal	On-Off
73	73	Y-axis accelerometer	
74	74	Y-axis accelerometer	
75	75	Z-axis accelerometer	
76	76	Heat shield temperature (thermocouple)	0° - 2500° F
77	77	ASCS bus voltage	95 - 125v ac
78	78	High pressure reaction jet solenoids (- yaw)	On-Off
79	79	High pressure reaction jet solenoids (+ yaw)	On-Off
80	80	Retrorocket temperature	0° - 150° F
81		HF telemetry transmitter temperature	40° - 300° F
	81	LF telemetry transmitter temperature	40° - 300° F
82	82	Cabin pressure	0 - 15 psia
83	83	DC voltage monitor	18 - 28v dc
84	84	Coolant pressure	230 - 485 psig
85	85	Horizon scanner roll ignore	On-Off
86	86	Horizon scanner output monitor roll	± 35°
87	87	*.05g relay actuation	On-Off
88	88	Horizon scanner output monitor pitch	± 35°
89	89	Synchronize pulse	
90	90	Synchronize pulse	

[redacted]

[redacted]

TABLE V.- COMMUTATOR POINT ASSIGNMENT FOR MA-6 (concluded)

HIGH FREQ. SYSTEM	CONTINUOUS CHANNELS	RANGE
0.40	Roll rate and low roll thruster (mixed)	± 10°/sec.
0.56	Vernier clock and sequence of events (mixed)	1-PPS
0.73	DC volts	18 - 28v dc
1.3	R.R. and D	
1.7	EKG (left side, right side)	
2.3	EKG and blood pressure (upper chest, lower chest)	
3.0	Reference	
3.9	Stick position, roll	± 13°
10.5	High frequency commutator (PAM)	

LOW FREQ. SYSTEM	CONTINUOUS CHANNELS	RANGE
0.40	Pitch rate and low pitch thrusters (mixed)	± 10°/sec.
0.56	Yaw rate and low rate thrusters (mixed)	± 10°/sec.
0.73	D.C. Current	0 - 50 amp
1.3	R.R. and D	
1.7	EKG (left side, right side)	
2.3	EKG and blood pressure (upper chest, lower chest)	
3.9	Stick position pitch	± 13°
5.4	Stick position yaw	± 13°
10.5	Low frequency commutator (PAM)	

ON-BOARD TAPE RECORDER TRACK ASSIGNMENTS

TRACK	INFORMATION
1	Open
2	High frequency telemetry multiplex
3	Voice
4	PDM high frequency
5	PDM low frequency
6	Low frequency telemetry multiplex
7	Open

[redacted]

[redacted]

TABLE VI. - TELEMETRY SIGNAL STRENGTH

Mission Phase	S/S, DBM		Deviation[a] from center frequency, kc	
	Low	High	Low	High
Lift-off	-30	-30	+13.9	-45.2
Tower release	-52	-52	-1.0	-29.0
First pass	-35	-52	-5.0	-21.5
Second pass	-30	-45	-3.0	-20.9
Third pass	-60.5	-55.5	0	-18.0

[a] Specification deviation: High link, ±26 kc; low link, ±22 kc

[redacted]

LAUNCH VEHICLE PERFORMANCE

All booster systems performed satisfactorily. The following items are noted for information.

Abort Sensing and Implementation System (ASIS)

The ASIS performed satisfactorily. None of the abort parameters was near its abort threshold. As expected in normal sequence, an ASIS abort signal was generated following SECO (sustainer engine cutoff).

Engine Cutoff

SECO and ASCO (auxiliary sustainer cutoff) signals were transmitted, and at least one was received and properly acted upon by the booster. Instrumentation does not permit determination of whether or not both signals were acted upon by the booster.

Booster Lifetime in Orbit

Computed data based upon probable thrust having been imparted to the booster tankage by the spacecraft posigrade rockets (-4 feet per second) indicated at least 10 orbital passes to be expected from the booster. The final stage tankage, however, was later found to have reentered some 6 passes following launch. Tracking during the third orbital pass indicated a perigee of about 95 nautical miles, an apogee of about 131.0 nautical miles, and a period of approximately 87 minutes. No useful tracking data were obtained after the fourth orbital pass.

Aerodynamic loads.- The angle of attack times dynamic pressure (αq) for the flight is shown in figure 27 and is based on the measured wind profile at launch.

AEROMEDICAL ANALYSIS AND FLIGHT ACTIVITIES

Introduction

This chapter reports in three sections the reactions of the astronaut during this first orbital mission. The first section contains a medical report covering the detailed medical examinations and an evaluation of inflight physiological data. These medical findings indicate that the pilot's reactions both during and after the flight were normal. The first section is followed by a report on the many diverse activities of the astronaut and his performance during the flight in controlling the spacecraft and making scientific observations. The chapter is concluded with a narrative account of the mission obtained from Astronaut Glenn within two hours after landing. The pilot discusses with clarity and good understanding the major events of the flight, expressing satisfaction with his ability to manually control the spacecraft.

[redacted]

Aeromedical Investigations

The aeromedical investigations conducted with the MA-6 mission can be logically grouped into two distinct areas: (1) the preflight and postflight clinical examinations (static examinations) and (2) the preflight and inflight physiological studies (dynamic studies). These investigations are designed to ascertain the state of the astronaut's health and to provide information reflecting human responses to space flight. The MA-6 mission provided a sufficient period of weightlessness such that the pilot's physiological responses attained a relatively steady state. In the much shorter Mercury-Redstone Flights, little time was available in weightlessness for the astronaut's physiological adjustment mechanisms to stabilize.

The astronaut's activities during the time immediately prior to his insertion into the spacecraft have a moderate effect on his countdown and flight responses. For this reason his activities for the approximate nine-hour period prior to his arrival at the spacecraft are listed in table VII.

Astronaut Glenn began his 72-hour, prelaunch low-residue diet on February 16, 1962. On the night prior to flight, the pilot obtained 4 hours and 50 minutes of dozing, light sleep. No medication was administered.

[redacted]

Clinical studies.- Detailed medical examinations were performed prior to the MA-6 flight, and similar investigations were conducted as soon after the flight as recovery practices permitted. Initial examinations were accomplished to determine the astronaut's state of health and his medical fitness for flight. In addition, such clinical evaluations serve as baseline medical data which may be later correlated with inflight physiological information.

The schedule and sources of medical data regarding Astronaut Glenn are listed below:

1. Prior physical examinations beginning with astronaut selection in 1959.

2. Detailed preflight clinical examinations conducted on January 22, 1962 and February 12, 1962.

3. Preflight examination conducted on launch morning.

4. Postflight medical evaluations on the recovery ships and at Grand Turk Island Medical Facility.

The numerous preflight examinations of Astronaut Glenn disclosed no significant medical abnormalities; his physical and mental health remained excellent throughout.

The postflight examination of the astronaut began with his emergence from the spacecraft onboard the Destroyer Noa some 39 minutes after landing. The pilot was described as appearing hot, sweating profusely and fatigued. He was lucid, although not talkative and voiced no medical complaints other than being hot.

After removal of his pressure suit and a shower, he became more communicative and described a mild sensation of "stomach uneasiness" or "stomach awareness" as having occurred during the 17 minutes while awaiting recovery. This sensation did not commence until after spacecraft landing and cleared spontaneously within $1\frac{1}{2}$ hours. Neither nausea nor vomiting was experienced. This stomach uneasiness can be attributed to several factors. One is the combination of temperature and humidity immediately after landing. The ambient air was at 76°F and 60-65 percent relative humidity, and the water temperature was 81°F. The suit inlet temperature was 85°F, and the cabin air temperature was 103°F. A second major factor is the moderate dehydration of the astronaut. This is evidenced by his weight loss (5-5/16 pounds vs. a pound loss during a three-orbit centrifuge simulation), diminshed urine output with increased specific gravity for the 24-hour, post-recovery period, increased blood concentration, and the recovery physician's clinical impression.

The astronaut had a minimal fluid intake during the 13 hours from breakfast at 0250 to shipboard at 1545 e. s. t., since the equivalent of only 94 cc of water was ingested as applesauce puree. The only other intake during the flight was one 5.0 gram sugar (xylose) tablet for a test of intestinal absorption, the results of which were normal. His urine output during this period was 800 cc which he reported as voiding just prior to reentry. The fluid intake and output is shown in the following table:

FLUID INTAKE AND OUTPUT		
Urine output[a]	countdown	0 cc
	inflight	800 cc (Sp. Gr. 1.016)
	postflight (shipboard)	0 cc
		Total 800 cc
Fluid intake	countdown	0 cc
	inflight[b]	94 cc
	postflight (shipboard)	
	1545 hours[c]	265 cc iced tea
	1830 hours	240 cc water
	1850 hours	125 cc coffee
		Total 724 cc

[a] See also Table V
[b] 119.5 grams of applesauce puree (78 percent water).
[c] All times are e. s. t., February 20, 1962.

A comparison of the positive physical parameters and vital signs for Astronaut Glenn after the flight are listed in table VIII.

The vital signs noted in table VIII were recorded during the postflight physical examination conducted onboard the destroyer. There were two small, superficial skin abrasions of the knuckles of the second and third fingers of the right hand, but these occurred without deformation or fracture. They were received when the explosive hatch actuator recoiled against the pilot's gloved hand. The skin also exhibited an area of moderate erythema (reddening) and a skin depression at the point where the left arm blood pressure microphone had been attached. There was also a mild reaction to the moleskin adhesive plaster which attached the four ECG electrodes. Results of the head, eye, ear, nose and throat examinations were normal. The heart rhythm, size, and sounds were normal, and the lungs were clear without physical evidence of atelectasis (local lung collapse). Results of the examination of the abdomen were normal, and the lower extremities showed no evidence of edema (swelling) nor venous thrombosis (clotting). The results of the general neurologic examination were also normal.

Blood and urine samples were obtained and processed for later analysis. Results available to date are listed in tables IX through XII.

range stations and the continuous onboard recording. In addition, various inflight tests and the pilot-observer camera film were utilized for further objective analysis. Subjective evaluation included pilot reports from onboard voice and the total postflight debriefing. The countdown period provided baseline preflight information. Useful comparative measurements were available from the Mercury-Atlas three-orbital centrifuge simulation; and from the pad simulated launch, simulated flights, and the January 27 launch attempt. Environmental control system data were correlated with physiological responses were appropriate.

Bioinstrumentation: In addition to the sensors used for the manned Mercury-Redstone flights (two ECG leads, respiratory rate sensor, and body temperature sensor), a blood pressure measuring device was utilized in flight. The blood pressure apparatus consisted of a pneumatic nylon cuff placed on the left upper arm and a microphone located under the cuff over the brachial artery. To obtain the blood pressure, the cuff was inflated manually. The record consisted of the sound pulses superimposed on a cuff pressure decay curve. This record was displayed on the second ECG channel. Preflight and postflight calibrations of the blood pressure system showed no significant change.

The total biosensor monitoring time, from astronaut insertion until just prior to landing, was eight hours and thirty-three minutes.

Approximately three hours after landing, the astronaut was transferred to the Aircraft Carrier U. S. S. Randolph were posterior-anterior and lateral chest X-rays, a standard 12-lead electrocardiogram reading, and body weight were obtained.

Later the astronaut flew to Grand Turk Island were a general physical examination was begun at 2130 hours e.s.t., approximately 6-3/4 hours after spacecraft landing. The vital signs at that time are included with the postflight values above. Except for the previously described superficial skin abrasions, the results of the entire examination were normal. During the subsequent 48 hours, comprehensive examinations were conducted by the medical specialists who examined the astronaut prior to flight. Special tests were performed in an effort to delineate any effect of space flight upon the astronaut's balance (inner ear) and no effect was detected. Both the general and the specialists' examinations revealed no significant changes. The medical studies were completed at 1400 e.s.t., February 22, 1962.

In summary, the preflight and postflight clinical studies revealed no significant differences and, except for the immediate postflight dehydration, were completely within normal limits.

<u>Physiological studies</u>.-

Data sources: Data reflecting physiological responses to flight were obtained by evaluating the biosensor real time recordings from

The biosensor readout quality was excellent throughout the countdown and flight, with the exception of the respiratory trace. As in prior flights, variation with head position and air density combined to reduce the quality of the respiration trace. There were brief periods of noise on the ECG channels during countdown and flight, usually occurring during vigorous pilot activity.

Preflight: Figure 28 depicts the pulse rate, respiration rate, body temperature, suit inlet temperature, and blood pressure values recorded during the MA-6 countdown. Values for the physiological functions obtained from the simulated launch of January 19 and the launch attempt of January 27, 1962, are also shown. These are plotted coincident with significant events.

Minute pulse and respiration rates were determined by counting the rates for 30 seconds every 5 minutes until ten minutes prior to lift-off, and, thereafter, 30 second duration counts were made each minute. During approximately 45 minutes in the transfer van, the astronaut's pulse varied from 58-82 beats per minute, with a mean 72, and blood pressure was 122/77 mmHg. The pulse rates during the scrubbed flight countdown of January 27 varied from 60-88 beats/minute, with a mean of 70. These were essentially the same as those observed during the MA-6 countdown when the mean pulse was

68 beats/minute. Respiration rates were similar, varying from 12-20 breaths/minute. Blood pressure values from the simulated launch also approximated those observed during the MA-6 countdown. A pulse rate of 110 beats/minute and a blood pressure of 139/88 was observed at lift-off. The low suit inlet temperature maintained during countdown resulted in the pilot feeling cold, which was accompanied by a fall in body temperature from 98.6° at insertion to 97.6°F at lift-off.

An examination of the electrocardiographic waveform obtained during the MA-6 countdown revealed a number of variations in the pacemaker activity, which is the point where the stimulus of the heart beat originates. These included sinus pauses, sinus bradycardia (slowing), premature atrial and nodal beats, and premature ventricular beats. On several instances, some of these reported findings occurred with deep respiration. Similar findings were recorded from the simulated launch of January 19 and the scrubbed flight of January 27. In addition, a brief run (16 beats) of atrial rhythm with a rate of 100 beats/minute occurred during countdown, and an isolated run (19 beats) of a rhythm originating adjacent to the atrio-ventricular node with aberrant conduction occurred during the attempted launch of January 27. However, these were not observed at any other time. All of the above are not unexpected physiologic variations. Samples of MA-6 records taken at the time of insertion and at T-50 seconds are shown in figures 29 and 30 respectively.

Flight: Figure 31 depicts the inflight physiological data, and included values from the Mercury-Atlas, three-orbit centrifuge simulation are for comparison. Minute pulse rates were counted every 30 seconds during the MA-6 launch and reentry phases and for 30 seconds at three minute intervals throughout the orbital flight. Because of the variation in respiratory recording quality, rates were counted for 30 seconds whenever quality permitted, and these varied from 8 to 19 breaths/minute throughout flight.

The pulse rate from lift-off to spacecraft separation (powered flight phase) reached a maximum of 110 beats/minute. The pulse rate varied from 88 to 114 beats/minute during the first 10 minutes of weightlessness. It then remained relatively stable, with a mean rate of 86 beats/minute during the next 3 hours and 45 minutes of flight. At the time of retrorocket firing, the rate was 96 beats/minute. During reentry acceleration and parachute descent, the highest rate was 134 beats/minute just prior to drogue parachute deploy which was the period of maximum spacecraft oscillation. This rate was the highest noted during the mission. These rates suggest that acceleration, weightlessness, and return to gravity were within physiologically tolerable limits.

The ECG variations noted during the preflight observation period were not observed in flight, and analysis of the inflight record revealed only normal sinus rhythm with short periods of sinus bradycardia and sinus arrhythmia (variation). There were rare periods when trace quality deteriorated to a point where only pulse rate determinations were possible. ECG variations noted during Astronaut Glenn's Mercury-Atlas, three-orbit centrifuge simulation included sinus arrhythmia, sinus bradycardia, atrial and nodal premature beats, and rare premature ventricular contractions. These are interpreted as being normal physiological variations.

Ten blood pressure determinations were made in flight, the first at 00;18:30 and the last at 03:14:00. Values as shown in figure 27 range from 119 to 143 mmHg systolic and from 60-81 mmHg diastolic. The mean blood-pressure values from various major blood pressure data sources are presented in the following table.

Data Sources	No. of determination	Mean Blood Pressure mmHg	Mean Pulse Pressure mmHg	Systolic Pulse Pressure, mmHg	Diastolic Range mmHg
Physical exams	14	110/66	44	98 to 128	60 to 80
Procedure trainer	15	121/76	45	110 to 132	66 to 87
3-orbit Mercury-Atlas centrifuge simulation	56	114/80	34	92 to 136	68 to 92
Launch-pad tests	26	104/76	28	91 to 125	64 to 91
MA-6 countdown	14	123/87	36	101 to 139	83 to 93
MA-6 flight	10	129/70	59	119 to 143	60 to 81

The MA-6 inflight mean pulse pressure value shows some widening when compared with the centrifuge preflight values. The mean blood pressure value from static Procedures Trainer simulations was 120/73. The widened pulse pressure, which appeared after one hour of flight, is of uncertain physiological significance and more information is needed before conclusions can be reached. Samples of physiologic data from the onboard record are shown in figures 32 through 34.

The inflight exercise device is illustrated in figure 35. Exercise was accomplished by a series of pulls on the elastic bungee cords. An exercise period over Zanzibar during the first orbital pass raised the pilot's pulse rate from 80 to 124 beats/minute after 30 seconds. The pulse rate returned to 84 beats/minute within two minutes. The blood pressure before exercise was 129/76 mmHg and 129/74 after exercise, which is similar to procedures trainer values.

The environmental control system effectively supported the pilot throughout the mission. It should be noted, however, that body temperature gradually rose from a lift-off value of 97.6°F to 99.5°F at biosensor disconnect. The suit inlet temperature increased slowly during most of the flight, with a more rapid rise after reentry and during parachute descent. During and immediately following descent, the suit inlet temperature increased approximately 1°F/minute for a 15 minute period and probably contributed to the pilot's overheated status observed at egress. Since biosensor disconnect occurred 13 minutes before loss of signal, the maximum body temperature may not have been observed.

Pilot inflight observations: The astronaut's voice reports were consistently accurate, confident, and coherent through all phases of the flight. His voice quality conveyed a sense of continued well being. His mental state appeared entirely appropriate for the situation. The pilot's mood and level of performance was effectively conveyed by his voice reports. His prompt responses to ground transmissions and to sounds from the spacecraft suggest no decrement in hearing ability. Visual acuity was maintained, and his report of visual perceptions, especially with regard to colors, was confirmed as being accurate by the inflight photographs.

The pilot's voice report contained observations of physiological significance. During his postflight debriefing these reports were amplified. Those considered most significant are discussed below.

No disturbances in spatial orientation were reported, nor were any symptoms suggestive of vestibular (inner ear) disturbances described during the flight. Voluntary rapid head turning movements produced no unpleasant sensations. No sensory deprivation of "break-off phenomena" was noted.

[redacted]

A brief sensation of tumbling forward occurred just after SECO, which was similar to that described by the astronauts in the MR-3 and MR-4 missions. This sensation ended promptly and was not associated with nausea. Coincident with retrorocket firing, a feeling of movement opposite from flight direction was noted. This could be expected with the sudden change in spacecraft velocity. The pilot noted no difference in the sensations associated with reentry accelerations from those experienced during launch.

Food chewing and swallowing was accomplished without difficulty. No water as such was ingested during flight.

The pilot urinated without difficulty shortly before reentry. He described "normal" sensations of bladder fullness with the associated urge to urinate.

The astronaut described weightlessness as a "pleasant" sensation. Control manipulation was not a problem, and there was no observable performance decrement. The restraint harness and couch combination was reported to be comfortable.

In summary, the MA-6 mission provided a period of extended weightlessness during which the astronaut's physiolocigal responses apparently stabilized. The values attained were within ranges compatible with normal function. No subjective abnormalities were reported by the pilot.

[redacted]

[redacted]

Conclusions.-

1. The physiological responses observed during the MA-6 mission are all consistent with intact, normal function.

2. Comparison of the preflight and postflight medical evaluations revealed no significant differences, and each was completely within normal limits with the exception of moderate dehydration.

3. The MA-6 mission provided an exposure to weightlessness of sufficient duration to permit physiological responses to reach a relatively steady state.

4. No symptoms reflecting disturbed vestibular function were reported. This lack of findings occurred even though specific attempts were made to stimulate the vestibular organ in flight.

5. Four hours and thirty-eight minutes of weightlessness were tolerated without observable performance decrement.

6. The pilot's subjective evaluation of his body processes and sensations during the flight all conveyed normal function.

7. Acceleration-weightlessness transition periods did not produce any recognized physiological deterioration. Specifically, reentry acceleration after 4 hours and 38 minutes of weightlessness did not produce any unexpected symptoms, and physiological data remained within functional limits.

8. The environmental control system effectively supported the pilot throughout the mission.

[redacted]

9. The astronaut's apparent fatigue noted in the immediate post-flight evaluation can be attributed to a number of factors. The most logical explanation is the dehydration following overheating plus the cumulative effects of the various stresses experienced in the pre- and inflight periods.

10. His mild gastrointestinal discomfort which occurred after landing may likewise be attributed to the increased environmental temperature and moderate dehydration of the astronaut. The motion of the spacecraft on the sea may be a contributory factor. This sensation cleared after a brief period of rest and rehydration.

[redacted]

TABLE VII.- SIGNIFICANT EVENTS PRIOR TO LAUNCH

Date	Time[1]	Event
February 19, 1962	2130	Retired
February 20, 1962	0220	Awakened and showered
	0250	Breakfast
	0305	Physical examination
	0428	Suiting started
	0505	Entered transfer van
	0520	Arrived at Pad 14 and remained in transfer van
	0558	Ascended gantry
	0606	Insertion
	0625	Countdown resumed
	0947	Launch

[1] All times e.s.t.

[redacted]

[redacted]

TABLE VIII.- PRE- AND POSTFLIGHT PHYSICAL PARAMETERS OF THE ASTRONAUT

Variables	Preflight	Postflight
General status	Eager for flight	Alert, but not talkative; sweating profusely; appeared fatigued; not hungry.
Weight	171 7/16 pounds at 0315 hours[1]	166 2/16 pounds at 1850 hours
Temperature	98.2°F (oral)	99.2°F (rectal at 1600 hours) 98°F (oral at 2400 hours)
Respiration	14	14
Pulse	68	76 (shipboard); 72 (Grand Turk)
Blood pressure	118/80 (sitting)	105/60 (standing) and 120/60 (supine) at 1545 hours 128/68 (sitting) at 2130 hours
Heart and lungs	Normal	Normal - no change
Skin	No erythema or abrasions	Erythema or biosensor sites; superficial abrasions second and third fingers of right hand.
Extremity measurements, inches		
Wrist		
Left	6 7/8"	6 3/4"
Right	7"	7"
Calf (max)		
Left	16 7/8"	16 5/8"
Right	16 1/2"	16 1/8"
Ankle (min)		
Left	9 3/8"	9"
Right	9 1/8"	9 1/4"

---

[1] All times e.s.t.

[redacted]

TABLE IX.- PERIPHERAL BLOOD

	Preflight				Postflight		
	Mar. 1959	Aug. 1960	Aug. 1961	-29 days[1]	-8 days[1]	+8 hr[1]	+46 hr[1]
Hematocrit, percent	45	45	42	-----	39.5	46	42
Hemoglobin (Cyanmethemoglobin method), grams/100 ml-	15.7	15.3	13.6	14.5	14.1	16.1	14.7
Red blood cells X $10^6/\text{mm}^3$-------	------	------	------	4.75	4.96	4.82	5.03
White blood cells/mm^3----------	5, 000	5, 000	6, 310	5, 100	4, 650	8, 200	5, 450
Differential white-blood count:							
Lymphocytes, percent---------	40	41	45	37	47	36	33
Neutrophiles, percent--------	58	49	42	57	47	58	57
Monocytes, percent-----------	1	6	7	3	3	3	3
Eosinophiles, percent--------	1	4	5	1	2	2	5
Basophiles, percent----------	1	0	1	2	1	1	2

[1] Determinations by same technician.

TABLE X.- BLOOD SUMMARY[1]

	Centrifuge			MA-6 flight				
	Prerun	Postrun		Preflight		Postflight		
		+2 hr	+6 hr	-29 days	-8 days	+1 hr	+8 hr	+46 hr
Glucose (whole blood) mgm/100 ml	97	112	121	95	109	---	96	99
Sodium (serum), mEq/L-----------	143	140	154	155	160	146	144	143
Potassium (serum), mEq/L--------	4.8	4.8	5.6	5.4	4.6	3.9	4.4	4.4
Calcium (serum), mEq/L----------	5.2	6.0	5.2	4.9	4.3	4.3	4.2	4.4
Chloride (serum), mEq/L---------	80	83	83	95	98	104	104	104
Protein (total serum), g/100 ml-	7.9	7.7	8.0	6.9	6.6	6.9	6.6	6.7
Albumin (serum), g/100 ml-------	4.3	4.1	4.7	4.1	3.8	3.8	3.8	3.8
Albumin/Globulin ratio (serum)--	1.2	1.1	1.2	1.4	1.4	1.2	1.4	1.3
Urea Nitrogen (serum) mg/100 ml-	15.4	16.0	14.3	14.1	15.5	10.5	10.5	11.6
Ephinephrine, plasma µg/L-------	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Norepinephrine, plasma µg/L-----	0.1	0.1	0.1	5.1	18.1	---	6.0	3.8

[1] Operational priorities precluded making a biochemical requirement for fasting specimens.

TABLE XI.- PLASMA ENZYMES SUMMARY

	Normal values	Centrifuge				MR-3 backup	MR-4 backup	MA-6 flight			
		Prerun	Postrun +6 hr	Prerun	Postrun +2 hr			Pre-flight	Postflight		
									+1 hr	+8 hr	+46 hr
Transaminases:											
SGOT----------------	0 to 35	19	27	68	62	33	48	18	33	27	23
SGPT----------------	0 to 20	6	10	50	50	10	4	---	---	---	---
Esterase:											
Acetylcholine-------	130 to 260	165	185	---	---	250	220	240	305	245	275
Peptidase:											
Leucylamino---------	100 to 310	220	250	350	350	380	370	300	250	290	255
Lecucylamino, heat-stable	----------	---	---	250	150	---	---	---	---	---	---
Aldolase----------------	50 to 150	25	---	50	40	41	13	112	90	209	120
Aldolase, heat treated	0	---	---	---	---	---	---	22	40	35	25
Isomerse:											
Phosphohexase-------	10 to 20	10	9	30	51	13	23	0	24	22	9
Dehydrogenases:											
Lactic----------------	150 to 250	190	125	560	860	250	235	265	220	390	250
Lactic, heat stable-	----------	---	---	375	595	---	---	95	60	95	85
Percent residual----	14 to 15	---	---	---	---	---	---	39.6	19.7	38.7	30.9
Malic-----------------	150 to 250	250	---	530	905	225	280	---	---	---	---
Malic heat stable--	----------	---	---	330	420	---	---	---	---	---	---
Succinic ------------	0	0	0	0	0	0	0	---	---	---	---
Inosine--------------	0	0	0	22	15	5	3	---	---	---	---
Alpha-ketoglutaric--	0	0	0	---	---	---	---	---	---	---	---
Beta-glutamic--------	0	0	0	---	---	10	---	---	---	---	---
Phosphatase:											
Alkaline------------	10 to 20	---	---	11	0	8	5	---	---	---	---
Lactic Acid------------	----------	---	---	---	---	---	---	36	185	88	55
Cholesterol------------	----------	---	---	---	---	---	---	197	---	---	185
Cholesterol esters, percent--------------	----------	---	---	---	---	---	---	70	---	---	71
DPNH Oxidation (non-specific ensyme activity)------------	0	---	---	---	---	---	---	26	65	92	46

TABLE XII. —*Urine Summary*

	Centrifuge		MA-6 flight														
	Prerun	Postrun	Preflight			03:30 a.m. e.s.t. flight day	03:30 a.m. to 02:10 p.m. e.s.t. in-flight	Postflight									
		+2 hr	−29 days	−8 days	−2 days			+8 hr	+10 hr	+18 hr	+24 hr	+27 hr	+34 hr	+41 hr	+46 hr	+51 hr
Volume, cc.	180	195	-----	120	185	135	800	205	76	182	210	250	720	365	105	335
Specific gravity	1.024	1.025	1.021	1.018	1.022	1.019	1.016	1.024	1.031	1.029	1.024	1.011	1.014	1.011	1.012	1.018
Albumin	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Glucose	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Ketones	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
pH	6.3	6.2	6.0	6.1	6.0	6.2	6.0	6.0	6.0	-----	-----	-----	-----	-----		-----
Na, mEq/L	123	155	-----	-----	-----	225	157	103	89	96	88	61	73	49	125	115
K, mEq/L	95	97	-----	-----	-----	64	27	59	66	38	35	17	15	23	41	11
Cl, mEq/L	-----	-----	-----	-----	-----	223	152	100	30	20	77	45	67	39	140	141
Ca, mEq/L	-----	-----	-----	-----	-----	11.2	6.9	3.5	4.9	15.8	24	8.1	8.3	5.9	7.7	10.6
Osmolarity (millicsmoles)	-----	-----	-----	-----	-----	1010	613	599	920	1111	1000	432	400	511	590	720
Microscopic examination	No formed elements.				Occ. squamous epithelial cell.	No formed elements.										

~~CONFIDENTIAL~~

Astronaut Activities

This section presents a brief review of the astronaut's activities in preparation for and during the MA-6 mission.

Preflight training summary.-

Spacecraft checkout activities: Astronaut Glenn's involvement in the preflight checkouts provided him with the opportunity to become thoroughly familiar with the MA-6 spacecraft and launch vehicle systems. Table XIII summarizes his checkout activities. He spent 25 hours and 55 minutes in the spacecraft itself, and many more hours were consumed before and after each pad checkout operation in preparation, trouble-shooting, observation, and discussion.

Training activities: Table XIV is a brief summary of the training activities using the procedures trainer from December 13, 1961, to February 17, 1962. During this period, the astronaut spent 59 hours and 45 minutes accomplishing 70 simulated missions and experiencing 189 simulated systems failures. The main emphasis during this period was on procedural training, particularly launch and early mission failures usually calling for an aborted mission. Glenn also accomplished several three-pass missions on the trainer, as well as several simulations involving the MCC, the blockhouse, and the entire Mercury Network. The astronaut also spent a great deal of time in briefings on the various subsystems and flight planning and in individual study.

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[redacted]

Flight preparedness: Astronaut Glenn achieved a high level of skill and knowledge several weeks prior to the actual launch date. There was a gradual reduction in the intensity of the preflight training program, particularly on the procedures trainer. Nevertheless, there was no decline in his level of preparedness, as demonstrated in part by figure 36, which shows his sustained effectiveness in retrofire practice. Astronaut Glenn's comments during postflight debriefing sessions recognizes the value of his preflight training. His major comments were (1) that his participation in the spacecraft checkouts was very useful, (2) that personal briefings from systems experts were helpful, and (3) that the ALFA trainer was less valuable than the procedures trainer as an attitude control trainer.

Chronology of pilot's activities during flight.- Figure 37 is a simplified chronology of the pilot's activities during the MA-6 flight from lift-off to landing. Identification of continental limits, certain celestial observations, photography, and communications modes are not included in the table, since the communications tapes do not provide sufficient time correlation. Spacecraft systems problems during the flight prevented the pilot from completing all the tasks in the MA-6 flight plan. These problems also interfered with his providing a complete running commentary on those he did complete.

[redacted]

Attitude control.- The pilot's attitude control activities are summarized in table XV. The pilot was able to control the vehicle adequately throughout the flight with the exception of the last portion of reentry. The general ability of the pilot to control the vehicle is illustrated by the brief review of the major manual maneuvers discussed below.

Control systems check: The control systems check is designed to check all of the primary control modes in a minimum amount of time and with minimal fuel usage. This series of maneuvers was accomplished smoothly and efficiently, and was almost identical to the performance on the procedures trainer prior to the flight. The attitudes achieved varied less than 10 degrees and the rates did not vary over 1/2 degree per second from the procedures trainer simulation at any time.

60° right-yaw maneuver: The astronaut performed this smoothly, overshooting only three or four degrees, which is within the accuracy of his visual abilities to determine the exact 60° position on his indicator (see figure 38).

Three 180° right-yaw maneuvers: The first 180° maneuver, using the window as the primary attitude reference, was intended as a precise 180° maneuver, keeping the pitch and roll errors minimized. The second and third yaw maneuvers were done only for the purpose of observing and taking pictures of the sunrise and the particles surrounding his spacecraft. These maneuvers were accomplished satisfactorily as can be seen in figure 39.

Holding on constellation: The astronaut held on the constellation Orion on two different occasions during the flight. Figure 40 illustrates the attitude variations during the second period on Orion. These variations are within the limits normally held on instruments on the ALFA and Procedures Trainers.

Gyro caging: The astronaut caged and uncaged the gyros immediately after completion of each of the three 180° yaw maneuvers because of disagreement between indicated and true attitude. The third caging occurred shortly before the second sunrise while still on the dark side of the earth; the other two cagings were performed during the daylight periods. The records indicate that he uncaged at approximately zero yaw and roll and a minus 14 degrees in pitch for both day operations, but that he caged and uncaged at zero yaw, minus 14 degrees pitch, and a minus 20 degrees in roll during the night-side operation. It is unlikely that the pilot would have been able to aline the spacecraft so well in yaw and yet make an error in roll which should be easier to determine using the window. It therefore seems likely that the astronaut's attention was diverted by other duties. The pilot caged and uncaged the gyros at a -14° in pitch, even though he reported to the ground that he was going to zero, zero, zero attitude during the first caging operation. Caging at a -14° in pitch, using the window reference, is necessary to see the horizon. The astronaut's report to the ground was a communication error.

Retrofire control: The astronaut backed up the ASCS during the retrosequence and retrofire events using the manual proportional control mode. It is impossible to assess individually the operations of the ASCS or of the astronaut at this time. The attitudes did not deviate more than ±3 degrees during this event.

Reentry pitch maneuver: Astronaut Glenn used the manual proportional control system and the rate and attitude indicators to pitch to the reentry attitude. As can be seen from figure 41 he performed this maneuver with precision and was well within his capability demonstrated on ground trainers.

Reentry damping: The early part of the reentry through peak deceleration (max. g) was controlled by employing fly-by-wire and manual proportional systems. The oscillations were small during the early part of reentry prior to max. g (see figure 42). After 04:47:00, the pitch and yaw oscillations built up rapidly and the pilot's stick inputs did not result in satisfactory control. From analysis of the fuel usage, his manual fuel was depleted at 4:47:04.

The fly-by-wire control mode apparently still had fuel available, as indicated by the effectiveness of the Auxiliary Damping System at 04:47:42. The lack of satisfactory control was due to the change in control effectiveness because of depletion of manual fuel.

Pilot's use of external reference: The pilot reported that, in general, he was able to orient the vehicle, using external reference without difficulty, particularly in the roll and pitch axes. The pilot stated that there was a period of learning to use the periscope and the window as a yaw reference; however, he felt that by the end of the flight he was able, on the daylight side, to adjust yaw within a few degrees. During the flight he developed the procedure of pitching down to -60° in pitch in order to be better able to pick up terrain drift due to the orbital velocity. At a pitch attitude of -34°, apparent velocity of terrain movement is .60° per second, whereas at -60° pitch attitude the apparent velocity due to orbital movement is 1.41° per second. The greater apparent drift as the vehicle pitches toward the nadir point aids yaw determination by increasing the ratio of the terrain movement due to orbital rate in comparison to apparent terrain movement due to spacecraft attitude rate. The pilot did not like the periscope as well as the window for yaw alinement. He did not like the periscope high-magnification view because of the unclear area at the border between the high- and low-magnification views. The astronaut reported that he felt that going forward was the "best way to travel", "just like sitting up in front of a Greyhound bus watching the world come at you."

On the nightside, the pilot reported that the horizon was always visible through the window. With full moon illumination he felt that he could aline the spacecraft in yaw almost as well as on the daylight side. Glenn was not able to use the eye patch to dark-adapt; therefore, he was able to see little, if anything, of the ground or clouds before moonrise. With good dark-adaptation and lower cabin illumination, it well may be possible to see clouds even without the moon, since a fair amount of illumination will be provided from other night light phenomena. In general, the pilot reported that the periscope was not very useful for determining drift on the nightside. Even with a full moon, the clouds were too dim in the periscope to pick up a specific point and follow it for yaw heading information.

The pilot reported that he could use star drift as a reference at yaw angle close to 90°, but that within ten degrees of zero yaw, it was quite difficult. The pilot was also able to use constellations as a heading reference. He reported that the number of stars that he could see were approximately the same as normally can be seen from the ground on a dark night. He had no trouble recognizing constellations and therefore could use the stars to determine heading by referring to his Star Navigation Device.

Communication Activities.- Table XVI summarizes the flight communications. The pilot reported that he felt more time was devoted to formal operational reports during the MA-6 mission than would be desirable for future flights. Reduction of the high proportion of communications involved in making radio contact, reporting switch positions, and relaying instrument readings would permit more detailed reports by the pilot of his activities and observations.

Scientific Observations.-

Celestial Observations: Numerous small particles of 1/16" to 3/8" in size were observed during each sunrise period as moving rearward past the spacecraft at a relative velocity estimated at 1.3 to 2.2 meters per second. Since some of the particles were seen to drift into the spacecraft's shadow, the estimated sizes and the velocities can be relied upon. The small difference in the relative velocity between the spacecraft and the particles indicates nearly the same orbit, which makes it certain that the particles came from the spacecraft. They undoubtedly drifted due to some aerodynamic drag. The most plausible material for the particles is frozen water, since other substances are either not present in sufficient quantities, or are limited in source, which ought to be exhausted by the third orbital pass. Water from the spacecraft environmental control system is more slightly probable than from the thrusters, because of the low observed velocities. This supply is sufficient and frozen water is consistent with the observed colors and movements.

A luminous band observed around the horizon may be the result of internal reflections of the moonlit earth between two inclined windows in the spacecraft. This explanation has been strenghened by observation of the band in earth photos from the spacecraft, by calculation from the blueprints, and by direct observation in the trainer and in spacecraft 18. The tan to buff color is found in one of ten observed reflections. If not a reflection, the pilot may have seen the 6300 and 6464 A° red layer which is known to exist at about the altitude reported.

The sun was observed to be highly flattened on some sunset photographs, although the phenomenon was not reported visually. Spectra of half a dozen stars in Orion were obtained with a hand-held, objective-prism spectrograph.

Meteorological observations: U. S. Weather Bureau Scientists suggested a program of observations for the astronaut which was designed to provide information for the development of improved optical sensing equipment for satellite weather-observation systems. Three of the requested observations reported by Glenn are listed below.

1. Determine whether cloud heights can be evaluated from orbital altitude. Report: The astronaut reported he could identify cloud types and determine cloud heights.

2. Determine whether clouds can be seen on the dark side of the earth. Report: The pilot reported that with the full moon up he was able to see clouds on the dark side and some vertical development.

[redacted]

3. Determine whether lightning can be seen on the dark side of the earth. Report: Astronaut Glenn reported that he could clearly see lightning in two storms in the Indian Ocean, which were flown over in the night time.

The Weather Bureau also suggested that pictures, using infrared film and a special set of filters, be taken of cloud cover in order to evaluate the relative effectiveness of various wave length intervals for cloud observation. The required filter and film was aboard the MA-6 flight spacecraft. However, this was scheduled for the third pass and because of the RCS malfunction the pilot was not able to carry out this exercise.

Terrestrial Observations: It is important to learn what the effective visual horizon for the pilot in orbital space may be and at what distance he can recognize landmarks for use in navigation and attitude control. The pilot's observations for the MA-6 flight are summarized in the following paragraphs.

Astronaut Glenn confirmed what earlier earth-sky pictures and Tyros photographs have indicated, namely that a large percentage of the earth's surface is covered by clouds. Only four land areas, the western African desert, western Australia, the western United States, and the eastern coast of the Unites States, were relatively free of clouds during the four and a half hours of the MA-6 flight.

[redacted]

Glenn reported that he could see the following landmarks during the daylight periods across the United States: the cities of El Paso, New Orleans, Charleston, and Savannah; the Salton Sea in California, the Mississippi Delta, and Cape Canaveral. He also reported a V-shaped figure in the water in the Atlantic, which he interpreted to be a wake from a ship. This is probably the smallest object reported by the pilot. If it was the wake of a destroyer, the wake would be approximately 120 feet in width and perhaps 300 yards long.

The only non-illuminated feature seen at night, other than clouds, was a faint indication of the western coastline of Australia. Two types of illuminated features were reported, lightning produced by two storms in the Indian Ocean and the lights of the City of Perth. The Indian Ocean Ship flare was not seen, undoubtedly because of cloud cover.

Color Photographs: The pilot was able to take a total of seventy photographs, thirty-eight of which were on one roll and the balance on a second. Table XVII contains a complete listing of the subjects and the approximate times of exposure. The pilot attempted to take pictures of the particles seen during sunrise using the color film. While there are several photographs containing specks, it cannot be definitely determined that these specks are actually the particles observed.

[redacted]

Orientation and Sensations During Weightlessness.-

General Sensations: The pilot reported that weightlessness was not unpleasant, no problem at all, and that in several respects it was easier or more enjoyable than the 1g condition. For example, there were no pressure points from the seat, and certain tasks were easier such as using the camera and other personal equipment. This equipment could be left hanging in midair while another task was performed.

Of operational significance was his report that, under weightlessness, the head assumes a new position due to the helmet tie-down straps. This suggests that the visual angles through the window and the periscope would be slightly different.

The pilot reported no problem in reaching for and activating controls. There was no tendency to overreach. This was not unexpected, since experience has shown that the eyes will quickly correct for muscular reaction inaccuracies. A more positive demonstration of psychomotor adjustment to weightless conditions would be by demonstrating capability to locate areas in the spacecraft with the eyes closed.

Russian Astronaut Titov reported[1] vertigo and nausea by the sixth orbital pass under three conditions, when the heat was rotated, when he tracked rapidly moving objects, and when he

[redacted]

tapering very slowly toward the horizon. I could not pick up any appreciable Zodiacal light. I looked for it closely; I think perhaps I was not enough night adapted to see it. Sunrise, I picked up in the periscope. At every sunrise, I saw little specks, brilliant specks, floating around outside the capsule. I had no idea what they were. On the third orbit, I turned around at sunrise so that I could face into the sun and see if they were still heading in the same direction and they were. But I noticed them every sunrise and tried to get pictures of them.

Just as I came over Mexico at the end of the first orbit, I had my first indication of the ASCS problem that was to stick with me for the rest of the flight. It started out with the yaw rate going off at about one and one-half degrees per second to the right. The capsule would not stay in orbit mode, but would go out of limits. When it reached about 20° instead of the 30° I expected, it would kick back into orientation mode and swing back with the rate going over into the left yaw to correct back to its normal orbit attitude. Sometimes, it would cross-couple into pitch and roll and we'd go through a general disruption or orbit mode until it settled down into orbit attitude. The yaw would again start a slow drift to the right and the ASCS would kick out again into orientation mode. I took over manually at that point and from then on, through the rest attempted to reach switches which required head and body movements. Glenn reported that he repeated these same activities at approximately half-hour intervals throughout the flight, beginning cautiously with very slow head movements and proceeding to more rapid and vigorous motions as time progressed. He reported there was no difference in sensation between zero g and 1g. The difference between Glenn's and Titov's experiences can be logically explained by either or both of two factors. First, Titov's symptoms appeared after approximately twice the weightless period that Glenn experienced, and, secondly, Titov may be physiologically more sensitive to certain effects of weightlessness than Glenn.

Orientation: John Glenn reported that he experienced two illusions of motion, but both of these were associated with changing acceleration fields and not with zero g per se. The first occurred at SECO, when he felt as if he were slightly pitching forward head over heels. The second illusion of motion occurred during retro-rocket firing, at which time he reported that he felt like he was going back towards Hawaii. He stated that following retrofire, when he was able to look out the window and see the terrain moving away from him, this illusion disappeared.

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[1] Some results of physiological reactions to space flight conditions, by O. G. Gazenko, USSR, Academy of Sciences, Moscow.

[redacted]

No illusions of position occurred during zero g. Glenn did not feel at any time that he was standing still and the earth was moving, or that he was in any position other than the true spacecraft position during the flight.

The pilot reported that he could feel accelerations which produced rates above 5 degrees per second. This is approximately in agreement with the tests on the pilot conducted at Pensacola on the Human Disorientation Device (a two dimensional rotational apparatus). There is no indication of greater sensitivity to rotational forces under zero g than 1g, however, the observations are too limited to warrant firm conclusion.

A final area of interest was his judgement of veritical and horizontal during weightlessness. Normally, this perception is strongly affected by the otolith organs of the inner ear. Variations in the ability to determine the horizontal have been demonstrated when the individual is asked to adjust a visible line in a completely dark room while lying on his side. Errors in this adjustment usually occur after approximately two minutes with the lights out. Provisions for conducting this test have been built into the miniaturized photometer carried aboard the spacecraft. The pilot's adjustment to the horizontal was accurate. However, interpretation of the results is difficult since, because of the control problem, the pilot was rushed and made the line adjustment very shortly after looking into the device.

[redacted]

[redacted]

Personal Equipment.- The equipment that the pilot used and his relavant comments are presented in this section.

The daylight color camera: (See figure 43). A 35mm Ansco Autoset with a photoelectric cell to automatically adjust the F stop was provided. It has a 50mm, F2.8 lens and has been provided with controls permitting rapid one-hand operation. The only comment regarding camera operation concerned changing film. He released the casette, and, in reaching for it, it got away and floated behind the instrument panel. The results of the efforts with this camera are in the section labeled Photographic Efforts.

Ultra-violet spectrograph: (See figure 44). A Leica 35mm camera with a special lens system adapted for ultra-violet spectral photography was included. The results of this experiment are contained in the section on Astronomical Observations.

Photometer: (See figure 45). This is a miniature device used by the pilot to view the sun at sunset and to evaluate his capability to orient to the horizontal.

Air glow filter: (See figure 46). This device filtered all light except the 5577 line. The only attempt to use this filter produced no results. This is primarily because of a low level night adaptation at the time.

[redacted]

Night adaptation eye patch: (See figure 47). The form-fitted mold which is attached with tape prior to sunset, worked well prior to lift-off but failed to remain positioned during the flight. The combined effects of minute dust in the spacecraft, low himidity, and perspiration of the astronaut undoubtedly reduced the effectiveness of the adhesive.

Map booklet and star navigation device: The location of these devices was reported as having been awkward.

Flight plan cards: These are similer in style to figure 37 and three cards were provided to aid in maintaining schedules and to serve as a reminder of upcoming events.

Food Tube: (See figure 48). Two tubes were provided, one containing beef and vegetables and the other applesauce. He consumed the applesauce without difficulty, but did not have an opportunity to open the other tube.

Food Tablets: (See figure 49). A food tablet dispenser was provided containing one xylose tablet and several malt tablets.

TABLE XIII.- TIME EXPENDED IN ASTRONAUT PRELAUNCH ACTIVITIES

DATE	ACTIVITY	DURATION[1], HRS:MIN
January 15	Flight Acceptance Composite Test	7:45
January 17	Launch simulation	5:10
January 19	Launch simulation	4:15
January 20	Simulated flight	1:30
January 23	Simulated flight	2:00
January 27	Countdown	4:00
January 29	Simulated flight	1:15
	TOTAL TIME -	25:55

Time does not include allowance for preparation, monitoring, debriefing, trouble shooting, conferences, and the like.

[redacted]

BRIEF SUMMARY OF MA-6 ORBITAL FLIGHT BY ASTRONAUT GLENN[1]

There are many things that are so impressive, it's almost impossible to try and describe the sensations that I had during the flight. I think the thing that stands out more particularly than anything else right at the moment is the reentry during the fireball. I left the shutters open specifically so I could watch it. It got a brilliant orange color; it was never too blinding. The retropack was still aboard and shortly after reentry began, it started to break up in big chunks. One of the straps came off and came around across the window. There were large flaming pieces of the retropack - I assume that's what they were - that broke off and came tumbling around the sides of the capsule. I could see them going on back behind me then and making little smoke trails. I could also see a long trail of what probably was ablation material ending in a small bright spot similar to that in the pictures out of the window taken during the MA-5 flight. I saw the same spot back there and I could see it move back and forth as the capsule oscillated slightly. Yes, I think the reentry was probably the most impressive part of the flight.

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[1] This extemporaneous report by Astronaut John H. Glenn, Jr., was recorded onboard the Destroyer Noa shortly after the MA-6 mission on February 20, 1962 and is presented with superficial editing only.

[redacted]

Starting back with highlights of the flight: Insertion was normal this morning except for the delays that were occasioned by hatch-bolt trouble and by the microphone fitting breaking off in my helmet. The weather cleared up nicely and after only moderate delays, we got off.

Lift-off was just about as I had expected. There was some vibration. Coming up off the pad, the roll programing was very noticeable as the spacecraft swung around to the proper azimuth. There also was no doubt about when the pitch programing started. There was some vibration at lift-off from the pad. It smoothed out just moderately; never did get to very smooth flight until we were through the high q area. At this time - I would guess a minute and fifteen to twenty seconds - it was very noticeable. After this, it really smoothed out and by a minute and a half, or about the time cabin pressure sealed off, it was smooth as could be.

The staging was normal, though I had expected a more sharp cutoff. It felt as though the g ramped down for maybe half a second. For some reason, it was not as abrupt as I had anticipated it might be. The accelerometers read one and a quarter g's when I received a confirmation on staging from the Capsule Communicator.

I had been waiting for this message at that point because I was set to go to tower jettison as we had planned, in case the booster had not staged. At this time, I also saw a wisp of smoke and I thought perhaps the tower had jettisoned early.

The tower really had not jettisoned at that time and did jettison on schedule at 2+34. As the booster and capsule pitched over and the tower jettisoned, I had a first glimpse of the horizon; it was a beautiful sight, looking eastward across the Atlantic.

Toward the last part of the insertion, the vibration began building up again. This I hadn't quite expected; it wasn't too rough but it was noticeable. Cutoff was very good; the capsule acted just as it was supposed to. The ASCS damped and turned the spacecraft around. As we were completing the turnaround, I glanced out of the window and the booster was right there in front of me. It looked as though it wasn't more than a hundred yards away. The small end of the booster was pointing toward the northeast and I saw it a number of times from then on for about the next seven or eight minutes as it slowly went below my altitude and moved farther away. That was very impressive.

I think I was really surprised at the ease with which the controls check went. It was almost just like making the controls check on the Procedures Trainer that we've done so many times. The control check went off like clockwork; there was no problem at all. Everything damped when it should damp and control was easy. Zero-g was noticeable at SECO. I had a very slight sensation of tumbling forward head-over-heels. It was very slight; not as pronounced an effect as we experience on the centrifuge. During turnaround, I had no sensation of angular acceleration. I acclimated to weightlessness in just a matter of seconds; it was very surprising. I was reaching for switches and doing things and having no problem. I didn't at any time notice any tendency to overshoot a switch. It seemed it's just natural to acclimate to this new condition. It was very comfortable. Under the weightless condition, the head seemed to be a little farther out of the couch which made it a little easier to see the window, though I could not get up quite as near to the window as I thought I might.

The rest of the first orbit went pretty much as planned, with reports to the stations coming up on schedule. I was a little behind at a couple of points but most of the things were going right according to schedule, including remaining on the automatic control system for optimum radar and communications tracking. Sunset from this altitude is tremendous. I had never seen anything like this and it was a truly beautiful, beautiful sight. The speed at which the sun goes down is very remarkable, of course. The brilliant orange and blue layers spread out probably 45° to 60° each side of the sun of the flight, this was my main concern. I tried to pick up the flight plan again at a few points and I accomplished a few more things on it, but I'm afraid most of the flight time beyond that point was taken up with checking the various modes of the ASCS. I did have full control in fly-by-wire and later on during the flight, the yaw problem switched from left to right. It acted exactly the same, except it would drift off to the left instead of the right. It appeared also that any time I was on manual control and would be drifting away from regular orbit attitude for any appreciable period of time that the attitude indications would then be off when I came back to orbit attitude. I called out some of these and I remember that at one time, roll was off 30°, yaw was off 35°, and pitch was off 76°. These were considerable errors and I have no explanation for them at this time. I could control on fly-by-wire and manual very adequately. It was not difficult at all. Fly-by-wire was by far the most accurate means of control, even though I didn't have accurate control in yaw at all times.

Retrorockets were fired right on schedule just off California and it was surprising coming out of the zero-g field that the retrorockets firing as though I were accelerating in the other direction back toward Hawaii. However, after retrofire was completed when I could glance out of the window again, it was easy to tell, of course, which way I was going, even though my sensations during

[redacted]

retrofire had been that I was going in the other direction. I made retrofire on automatic control. Apparently, the solid-on period for slaving just prior to retrofire brought the gyros back up to orbit attitude, because they corrected very nicely during that period. The spacecraft was just about in orbit attitude as I could see it from the window and through the periscope just prior to retrofire. So, I feel that we were right in attitude. I left it on ASCS and backed up manually and worked right along with the ASCS during retrofire. I think the retroattitude held almost exactly on and I would guess that we were never more than 3° off in any axis at any time during retrofire.

Following retrofire, a decision was made to have me reenter with the retropackage still on because of the uncertainty as to whether the landing bag had been extended. I don't know all the reasons yet for that particular decision, but I assume that it had been pretty well thought out and it obviously was. I punched up .05g manually at a little after the time it was given to me. I was actually in a small g-field at the time I pushed up .05g and it went green and I began to get noise, or what sounded like small things brushing against the capsule. I began to get this very shortly after .05g and this noise kept increasing. Well before we got into the realy heavy fireball area, one strap swung around and hung down over the window. There was some smoke. I don't know whether

[redacted]

the bolt fired at the center of the pack or what happened. The capsule kept on its course. I didn't get too far off of reentry attitude. I went to manual control for reentry after the retros fired and had no trouble controlling reentry attitude through the high-g area. Communications blackout started a little bit before the fireball. The fireball was very intense. I left the shutters open the whole time and observed it and it got to be a very, very bright orange color. There were large flaming pieces of what I assume was the retropackage breaking off and going back behind the capsule. This was of some concern, because I wasn't sure of what it was. I had visions of them possibly being chunks of heat shield breaking off, but it turned out it was not that.

The oscillations that built up after peak-g were more than I could control with the manual system. I was damping okay and it just plain overpowered me and I could not do anymore about it. I switched to Aux. Damp as soon as I could raise my arm up after the g-pulse to help damp and this did help some. However, even on Aux. Damp, the capsule was swinging back and forth very rapidly and the oscillations were divergent as we descended to about 35,000 feet. At this point, I elected to try to put the drogue out manually, even though it was high, because I was afraid we were going to get over to such an attitude that the capsule might actually be going small end down during part of the flight if the oscillations kept going the way they were. And just as I was reaching up to pull out the drogue on manual, it came out by itself. The drogue did straighten the capsule out in good shape. I believe the altitude was somewhere between 30,000 and 35,000 at that point.

I came on down; the snorkels, I believe, came out at about 16,000 or 17,000. The periscope came out. There was so much smoke and dirt on the windshield that it was somewhat difficult to see. Every time I came around to the sun - for I had established my roll rate on manual - it was virtually impossible to see anything out through the window.

The capsule was very stable when the antenna section jettisoned. I could see the whole recovery system just lined up in one big line as it came out. It unreeled and blossomed normally; all the panels and visors looked good. I was going through my landing checkoff list when the Capsule Communicator called to remind me to deploy the landing bag. I flipped the switch to auto immediately and the green light came on and I felt the bag release. I was able to watch the water coming towards me in the periscope. I was able to estimate very closely when I would hit the water. The impact bag was a heavier shock than I had expected, but it did not bother me.

Communications with the recovery ship Noa were very good. The Noa had me in sight before impact and estimated 20 minutes to recovery which turned out to be about right. When the destroyer came alongside, they hooked on with the shepherd's hook and cut the HF antenna. During capsule pickup, I received one good solid bump on the side of the ship as it rolled. Once on deck I took the left hand panel loose and started to disconnect the suit hose in order to hook up the hose extension prior to egressing through the upper hatch. By this time I was really hot - pouring sweat. The capsule was very hot after reentry and I really noticed the increase in humidity after the snorkels opened. I decided that the best thing at that point was to come out the side rather than through the top. I am sure I could have come out the top if I had had to, but I did not see any reason to keep working to come out the top. So I called ship and asked them to clear the area outside the hatch. When I received word that the area was clear, I removed the capsule pin and hit the plunger with the back of my hand. It sprung back and cut my kunckles slightly through the glove. The noise of the hatch report was good and loud but not uncomfortable.

In summary, my condition is excellent. I am in good shape; no problems at all. The ASCS problems were the biggest I encountered on the flight. Weightlessness was no problem. I think the fact that I could take over and show that a pilot can control the capsule manually, using the different control modes, satisfied me most. The greatest dissatisfaction I think I feel was the fact that I did not get to accomplish all the other things that I wanted to do. The ASCS problem overrode everything else.

FLIGHT CONTROL AND NETWORK PERFORMANCE

The Mercury Network consists of the Mercury Control Center (MCC) at Cape Canaveral (CNV); stations at the Atlantic Missile Range (AMR), Bermuda (BDA), and at fourteen other locations along the orbital ground track; and communications and computing centers at the Goddard Space Flight Center. The Network affords a data acquisition capability for real-time monitoring, mission control, and postflight analysis. This section describes the flight monitoring and control and presents information on the performance of the communications, telemetry, tracking, computing, and command systems.

Flight Control Summary

The orbital launch and insertion parameters very closely approximated nominal conditions. The pilot's performance throughout the flight was excellent, and he was able to cope with the unusual situations which arose. Several problems developed in the spacecraft automatic control system. The ASCS system was unable to maintain the spacecraft within the preset attitude limits about the yaw axis after approximately one orbital pass because of the lack of thrust from the 1-pound yaw thrusters. This same malfunction was reflected in the system's operation when the astronaut selected the fly-by-wire mode however, he was able to maintain satisfactory attitude control about the yaw axis by using the larger thrusters. The horizon scanner and gyro reference system appeared to be in error mainly in the roll axis while the spacecraft was on the dark side of the earth.

The manual-proportional control system worked well throughout the flight. The cooling system for both main inverters appeared to be inoperative throughout the entire flight and the inverter temperatures reached values as high as 210 to 220°F however, no inverter malfunctions occurred.

On the first pass over Canaveral, segment 51 of the commutator showed a signal indication which, if correct, indicated that the spacecraft heat shield had been deployed. Considerable analysis and discussion followed, and a conclusion was first made that the signal, although a correct telemetry output, was the result of a faulty switch and that the normal sequence of events should be followed. Further discussion, however, indicated that the safest approach would be to allow the retropackage to remain attached. The retropackage straps would then hold the heat shield in place until sufficient dynamic force was exerted to maintain its position throughout reentry heating. The opinion was that the heat effects of the retropackage on the capsule heat shield and afterbody would not be damaging. Therefore, the pilot was directed during the retrofire maneuver over CAL to keep the retrojettison switch in the disarm position. The remainder of the flight was normal, and no other major system malfunctions occurred. It must be strongly emphasized that with a pilot in the spacecraft to make decisions and take corrective action, the malfunctions which occurred would have made an unmanned flight extremely difficult, and these quite possibly could have resulted in failure to reenter the spacecraft and effect successful recovery.

Mercury Network Performance

Mercury Network performance was excellent, all systems were fully operational at lift-off, and the few minor malfunctions which occurred did not affect the flight monitoring and control of the mission. Acquisition of data from tracking, telemetry, and air-ground voice systems was satisfactory in both quantity and quality for real-time monitoring and postflight analysis. The relaying of air-ground voice back to the Mercury Control Center (MCC) from all sites with a point-to-point voice capability contributed substantially to the real-time monitoring of the mission.

Tracking.- Radar tracking on this flight was satisfactory and superior to that of MA-4 or MA-5 Missions. All stations provided data for all passes whenever the spacecraft was above their horizon. The quantity and quality of these data were more than adequate. Minor problems existed in S-band phasing and handover, but this caused a negligible loss of data. The communications used for this were satisfactory.

Interference of an unknown source caused some concern on C-band at Cape Canaveral and Bermuda, but this did not cause any extensive loss of data. It is apparent that the extensive maintenance, training, and refinement of tracking procedures for the network has yielded dividends. Satisfactory C-band tracking was accomplished during most of the "blackout" period. Two Cape Canaveral radars had satisfactory S-band tracking for the first two minutes of blackout, and they were then turned off because the end of their range interval had been reached.

S- and C-band Radar-tracking coverage is shown in figures 50 and 51 respectively. The performance of acquisition-aid was satisfactory, and, in all cases acquisition was accomplished without difficulty.

Data transmission.- The transmission of both high-speed and low-speed data was satisfactory throughout the mission.

Trajectory Computation.- At lift-off, the selected source for display at the MCC was the output of the IP 7090. FPS-16 tracking at Cape Canaveral was utilized until approximately 00:00:50, at which time the IP 7090 switched to AZUSA tracking was displayed for approximately the next 20 seconds, at which time General Electric-Burroughs data through Goddard Space Flight Center was selected and was displayed throughout powered flight. The General Electric radar acquired both rate and track at 00:01:08 and never lost lock throughout the remainder of the boost phase. The quality of the General Electric data was excellent up to SECO and during the GO-NO-GO computation.

The programed phase of the flight showed minor deviations of +0.75° in flight-path angle and +1.0 n.m. in altitude at BECO. After launch vehicle staging guidance corrected these deviations. A maximum deviation of +2.8 n.m. in crossrange and a residual of 50+ fps in yaw velocity existed at cutoff. The yaw velocity looked very good up to approximately 35 seconds before cutoff, but it then appeared to lack response to steering with the final results as stated above. There appears to be conflicting evidence on this particular point, since the calculated impact point at the Canary Islands Station was right on the expected ground track, which is difficult to resolve with a residual velocity of 50 fps in yaw. It was later disclosed, however, that an error in the scale of the plotboard at the MCC existed, which accounts for this misrepresentation in your velocity. The cutoff conditions displayed in MCC are listed in table XVIII.

Low-speed tracking data from the remote sites were excellent, that the orbit was well-defined by the end of the first orbital pass. Subsequent tracking during the second and third passes showed negligable improvement in the orbit parameters. The number of radar observations received from each site is shown in table XIX.

The "A" computer was lost during the second pass between Hawaii and California. A restart was made in less than 5 minutes using the HAW vector, thus, the computer was ready to accept the White Sands data. A malfunction of the "B" computer caused the Texas and Eglin data for the second pass Eglin data on reentry to be ignored.

During the reentry, tracking data appeared to pinpoint the landing location with a high degree of confidence, and the final values from the Goddard computers indicated only 2 n.m. difference between the landing location as obtained from the California Station data and the Cape Canaveral FPS-16 data (see table XX). However, the landing point as reported by the recovery ship, as well as that computed by the Cape IP 7090 computer using Cape Canaveral and San Salvador FPS-16 data, does not agree with the Goddard computations.

The actual landing point was 39 n.m. short of the planned location. The weight loss of RCS fuel, attributable to the requirement for manual control during two orbital periods, was much greater than anticiapted. This weight difference contributed the major error of 31 n.mi. from that predicted, since the lower weight for a given quantity of retrograde impulse will result in a ligher negative velocity increment at retrofire. A variation in spacecraft attitude during retrofire resulted in an additional error of 4 n.mi., and a slightly greater impulse than the normal value provided another 2 n.mi. deviation. These factors account for 37 n.mi. of the actual landing point discrepancy.

The low-frequency cyclic noise pattern was apparent in both General Electric-Burroughs and AZUSA data, but this was slightly lower in amplitude than that for the MA-5 Mission and much lower than MA-4. At insertion, General Electric gave an inertial velocity of 25,727.6 feet/second and an inertial flight-path angle of -0.0674 degrees, while AZUSA figures were 25,733.3 and -0.0907, respectively.

Telemetry.- The data provided by the telemetry system was adequate and of good quality. Coverage was satisfactory, with data acquisition at all stations throughout each pass whenever the spacecraft was above the radio horizon. Coverage is shown graphically in figure 52 (a, b, and c) and in tabular form with decommutator figures, range and elevation in table XXI. Signal strengths were satisfactory, ranging up to 400 microvolts. Several sites reported low signal levels when compared with previous missions.

Ionization blackout of telemetry began at approximately 04:42:52, as seen at Canaveral, and ended at approximately 04:47:14, as seen at

Grand Turk. Thus, the blackout period lasted 4 minutes and 22 seconds. Data flow charts were drawn up based on the telemetry summary messages from the sites. The majority of the data points fall within ± 3 percent of a faired curve. A few exceptions were evident, however, in that figures from several sites were consistently off the faired curves of fuel quantity by as much as 10 percent as shown in figure 53.

Air-ground voice.- The performance of the primary air-ground voice system (UHF) was good throughout the mission. Signal strengths were adequate enough to provide excellent signal-to-noise ratios whenever the spacecraft was above the local visual horizon. In most instances, RF refraction increased the coverage over visual line-of-sight by one to two minutes of arc. UHF in-range times averaged almost seven minutes per orbital pass.

The HF voice system provided some additional coverage, but, as expected; it was not as satisfactory as the UHF was of particular value during the first and third passes where the Canary, California, Guaymas, Zanzibar, Indian Ocean Ship, Muchea, and Canton Stations were able to converse with the astronaut beyond the capability of the UHF system. It is interesting to note that in some instances where the HF was being used as the spacecraft approached the station, the quality of communications improved considerably as the elevation angle became positive, particularly as the switch was made to UHF.

Figure 54 shows approximate coverage compared with times above the visual horizon. Through the air-ground voice system, MCC was able to to follow the recovery procedure and monitor all conversations until after the spacecraft was aboard the recovery ship.

Command System.- The command system for MA-6 operated in a satisfactory manner during the mission. The few airborne-system anomalies are discussed below. The 600-watt stations appeared to have had coverage beginning at a slant range of 400-450 N.M., and the 10 KW stations had coverage beginning at a slant range of 650-700 N.M. A summary of the command handover exercises is shown in Table XXII and a summary of the command transmissions is shown in Table XXIII.

Ground System: There were several problems involving the command equipment and the coder relay panels during the month prior to launch, however, no delays in the launch countdown resulted. A total of eleven (11) functions were successfully transmitted from the sites: Auxiliary Sustainer Cutoff (ASCO) was transmitted from San Salvador, three sets each of R and Z calibrations were transmitted from Muchea, and two sets each of R and Z calibrations were transmitted from Cape Canaveral. Command coverage from all sites was satisfactory with the exception of Muchea on the third pass. A combination of slant ranges in excess of 450 nautical miles, airborne antenna patterns, and 600 watts of RF power resulted in only one minute and 30 seconds of coverage above receiver threshold.

Airborne System: Command Receiver "A", operating from the 18-volt isolated bus, appeared to be much more sensitive to signal strengths above 30 microvolts than Receiver "B", which operates from the 18-volt standby bus. Below 30 microvolts both receivers' operation coincided. The onboard recorded signal strengths although acceptable, were about 6 db, or less, below those of the MA-4 and MA-5 missions. The reason for the difference in recorded signal strengths is not known at this time, however, this magnitude of decrease is of no great concern. The air borne antenna pattern problem, which was experienced on MA-4 and MA-5, was again evident from the MA-6 onboard records. Spacecraft attitude changes are definitely reflected on the signal strengths records. Ionization blackout occurred on the Command frequency between 04:43:03:5 GET and 04:47:12 GET.

Triggering of the "All-Function Events Channel" occurred five times during ionization blackout. The tone channels triggered are unknown, but are coincident with a burst of signal into the receivers. It is known that the tones keyed were not clock changes, R and Z calibrations, nor Mayday. Later tests of the communication revealed that interference between the telemetry and UHF voice transmitters produced a signal with a frequancy on the edge of the command receiver bandwidth. An increase of 0.5 MC in the low TM frequency has apparently corrected this. The characteristics of the inputs to the command receivers are shown as oscillograph record reproductions in figure 55.

What is assumed to be random noise with a signal strength from one to 4 microvolts was recorded between 01:14:00 GET to 01:15:07 GET. Command carrier was not present during this period.

Ground communications.- All the ground communications networks provided good support for the mission. Except for a few short prelaunch outages, all the voice, teletype, and datalines were available at all times, and the quality of transmission was satisfactory. Single-sideband voice communication with the two ships was very satisfactory, as provided by AMR. Part of the link from the Indian Ocean Ship had to be relayed through Ascension Island.