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SECOND UNITED STATES MANNED THREE-PASS ORBITAL MISSION (MERCURY-ATLAS 7, SPACECRAFT 18)

DESCRIPTION AND PERFORMANCE ANALYSIS

Edited by John H. Boynton

Manned Spacecraft Center
Houston, Texas

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • FEBRUARY 1967

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FOREWORD

The second United States manned orbital flight has added significantly to the knowledge gained from the previous orbital flight. An overall analysis of the mission performance is presented and only the minimum necessary supporting data is included.

General acknowledgement is made of the extensive effort on the part of the entire Mercury team. This team, consisting of many organizations that are external to the Manned Spacecraft Center, notably includes the Department of Defense, the spacecraft prime contractor and its subcontractors, the NASA Goddard Space Flight Center for the Mercury Worldwide Network, the launch vehicle prime contractor and its subcontractors, and, in general, the many organizations and government agencies which directly or indirectly made possible the success of this flight.

The contents of this report represent the contributions of an assigned flight evaluation team, which comprised system specialists and operations personnel from throughout the Manned Spacecraft Center, without whose analytical and documentary efforts a report of this technical completeness would not have been possible.

ABSTRACT

The results and analysis of the second United States manned orbital flight accomplished on May 24, 1962, as a phase of Project Mercury are presented. Spacecraft and launch vehicle descriptions, mission operations, and postflight analyses are included. Particular treatment is given to the investigations of spacecraft systems performance and the aeromedical analyses of the astronaut.

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DESCRIPTION AND PERFORMANCE ANALYSIS

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SUMMARY

The Mercury Atlas Mission 7 (MA-7) was the second United States manned orbital flight, and all mission objectives were accomplished. A description of the mission, the test objectives, and a comprehensive postlaunch evaluation are presented.

The MA-7 mission, with Astronaut M. Scott Carpenter as pilot, experienced unscheduled prelaunch holds totaling 45 minutes; and these delays were directly related to reduced visibility conditions and the measurement of atmospheric refraction in the launch area. A low-level fog and smoke condition precluded required optical coverage at the planned launch time of 7:00 a. m. eastern standard time (e. s. t.). Lift-off occurred at approximately 7:45 a. m. e. s. t., on May 24, 1962, 3 hours after the astronaut entered the spacecraft.

Launch vehicle performance was satisfactory, and all events during powered flight occurred as planned. Both the launch vehicle guidance system and range safety impact predictor computer (IP 7090) data indicated a mission-continue ("go") condition. Orbital insertion conditions were excellent, with deviations from planned values of space-fixed flight-path angle and velocity of 0. 0004° and 2. 0 ft/sec, respectively. The perigee and apogee of the orbit differed from the planned values by 0. 09 nautical mile and 0. 56 nautical mile, respectively.

Spacecraft separation and manual turnaround were accomplished satisfactorily. However, during the first two and one-half orbital periods, some difficulties were experienced in maintaining the desired suit-circuit temperature. In addition, spacecraft control-system fuel usage rates were higher than planned during the early part of this period.

The pilot tracked the expended launch vehicle tankage, checked out the spacecraft control system, performed planned tasks, and conducted scientific experiments. He also took numerous photographs of the launch vehicle tankage, a tethered baloon, meteorological phenomena, and general terrestrial features.

After contacting Hawaii on the third, and final, orbital pass, the pilot noted that the spacecraft's true attitude and indicated attitude in pitch were in disagreement and that the automatic stabilization and control system (ASCS) control mode appeared to have an error in attitude reference. Because of these problems and previous preoccupation with other observations, he was unable to maintain the schedule established for completing the pre-retrograde sequence checklist and was occupied with assessing the control problem until the time of retrofire. Retrorocket ignition occurred approximately 3 seconds late, and the pitch and yaw attitudes varied during retrofire. The pilot noted that the sensations during this period of retrofire did not equal the pronounced effects of deceleration that he had expected. Shortly after retrofire, computed trajectory data indicated that an overshoot of about 250 nautical miles beyond the planned landing area would occur, and subsequent tracking data confirmed the initially predicted coordinates of the landing point. Retropackage release and periscope retraction occurred at near nominal times, and the events were reported by the pilot. The pilot also reported depletion of the manual-system fuel supply prior to the start of ionization blackout. * After the end of ionization blackout, the pilot received information regarding the computed landing coordinates and his expected retrieval time of 1 hour after landing. The portion of the reentry through the heat pulse and deceleration buildup was accomplished satisfactorily, but oscillations of the spacecraft increased considerably thereafter. The pilot manually deployed the drogue parachute at an altitude of about 25 000 feet to damp these oscillations.

After landing, the pilot immediately began egress from the spacecraft through the recovery compartment, deployed recovery equipment, and entered the liferaft.

Recovery operations, which were successful, included the deployment of a pararescue team into the water about 1 hour after spacecraft landing. This team inflated additional rafts and mounted a flotation collar around the spacecraft to provide additional buoyancy. An HSS-2 helicopter from the U.S.S. Intrepid (aircraft carrier) recovered the astronaut in good condition about 3 hours after landing, and the spacecraft was retrieved by the U.S.S. J. R. Pierce (destroyer) about 6 hours after landing.

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*Ionization blackout is the term applied to that portion of reentry when communication with the spacecraft is cut off by the plasma sheath surrounding the spacecraft.

INTRODUCTION

The second manned orbital flight of the Mercury program was successfully accomplished on May 24, 1962, from the Cape Canaveral*, Florida, Missile Test Annex. This was the fourth orbital flight of a Mercury specification spacecraft and the seventh of a series of Mercury flights utilizing the Atlas launch vehicle. The flight was therefore designated as Mercury-Atlas Mission 7 (MA-7). Astronaut M. Scott Carpenter, shown in figures 1 and 2, was the pilot for this mission. The data and information presented add to that previously published (ref. 1) on the first United States manned orbital flight.

The MA-7 mission was planned for three orbital passes and was a continuation of a program designed to acquire operational experience and information for manned space flight. The objectives of the flight were to evaluate the performance of the manned spacecraft system in a three-orbital-pass mission; to evaluate the effects of orbital space flight on another astronaut and to compare this analysis with previous astronaut/simulator results; to obtain the astronaut's opinions on the operational suitability of the spacecraft and supporting systems for manned space flight; and to evaluate the performance of spacecraft systems replaced or modified as a result of the MA-6 manned orbital mission. All of these objectives were successfully achieved.

An analysis of the significant data has been made, and the important findings are presented in this report. Brief descriptions of the mission, the spacecraft, and the launch vehicle precede the performance analysis and supporting data. All significant events of the mission are documented, beginning with delivery of the spacecraft to the launch site and terminating with the recovery and postflight examinations.

Lift-off time for the MA-7 mission was 07:45:16.57 a.m. e.s.t., and all times in this document are given in ground elapsed time from 07:45:16.00 a.m. e.s.t. (range-zero time) unless otherwise noted.

Although the graphical information in this part of the MA-7 report sufficiently supports the text, a complete presentation of all MA-7 time-history data has been compiled for technical reference purposes.

*Since renamed Cape Kennedy.

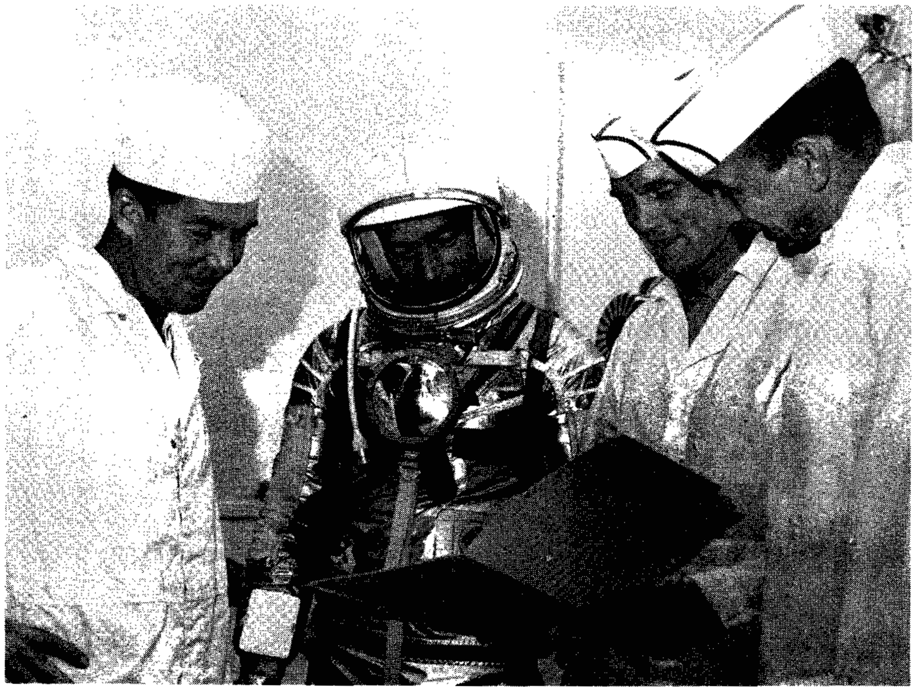


Figure 1.- Preflight photograph of Astronauts Schirra (MA-7 backup pilot), Carpenter (MA-7 pilot), and Glenn (MA-6 pilot). Spacecraft Engineer Graham (ground crew) is at extreme right.

Figure 2.- Astronauts Carpenter and Glenn during an informal postflight discussion.

SPACE VEHICLE DESCRIPTION

The space vehicle used for the MA-7 mission consisted of a Mercury specification spacecraft and an Atlas-D launch vehicle. A photograph of the lift-off configuration is shown in figure 3, and a sketch of the general configuration is shown in figure 4.

The spacecraft and launch vehicle used in the MA-7 orbital mission were very similar to those used in the previous manned orbital mission, MA-6. The MA-6 mission space vehicle is described in reference 1, and the more significant differences between the MA-7 and MA-6 vehicles are presented in the following paragraphs.

SPACECRAFT DESCRIPTION

Spacecraft 18 (shown in fig. 5) was used in the MA-7 orbital mission, and figure 6 displays the standard reference axis system that was employed. This spacecraft configuration was essentially identical to that of spacecraft 13 used in the MA-6 mission. The spacecraft 18 configuration differed from that of spacecraft 13 in the following ways:

1. The SOFAR bombs and radar chaff were deleted, since they were not considered necessary for an effective recovery.

2. The oxygen-quantity telelight was removed because the oxygen partial-pressure transducer, originally located in the cabin, was relocated in the suit. Later the transducer was reinstalled in the cabin, but the oxygen-quantity telelight was not reactivated.

3. The earth-path indicator and oxygen partial-pressure indicator were deleted, since they were not necessary to accomplish the mission.

4. The knee and chest straps were removed as a result of re-evaluation of their usefulness.

5. The coolant-quantity and humidity indicators located on the instrument panel were deleted since their performances were considered to be marginal.

6. The instrument-observer camera was removed because the data from this source were no longer considered essential. The astronaut-observer camera with a mirror attached performed a part of this function.

7. A 30-inch-diameter balloon, deployed in orbit to obtain drag and visibility data, was installed in the recovery compartment.

8. Zero-gravity experiment equipment was incorporated for the purpose of obtaining data on fluid behavior in a weightless state within a specific envelope configuration.

9. A low-level commutator and instrumentation for temperature measurements were added.

10. The low-frequency-telemetry center frequency was raised by 500 kc, from 225.7 mc, to eliminate the RF interference which occurred on the MA-6 flight.

11. The suit-circuit constant-bleed orifice was deleted.

12. The landing-bag limit switches were rewired so that both switches had to close for proper indication of heat shield deployment.

13. A "maneuver" switch was added to remove roll and yaw slaving of spacecraft gyros and pitch orbital precession at the astronaut's discretion.

14. The cabin and suit-circuit "steam" (evaporated water) vents were instrumented, and a dual indicator was installed on the instrument panel to enable the astronaut to evaluate cooling-system temperatures.

15. The check valve was deleted from the inverter cold-plate water cooling system, since a stuck valve could cause high inverter temperatures.

16. The $\frac{1}{4}$g relay was locked in after launch vehicle sustainer engine cutoff (SECO) to prevent interference with the spacecraft ASCS damping mode during posigrade-rocket firing.

17. The main parachute deployment bags, reefing lines, and reefing cutters were modified to prevent premature cutting of the reefing lines.

18. The Reaction Control System (RCS) 1-pound and 6-pound thruster fuel-distribution plates and screens were modified.

19. The red filter was removed from the window.

20. A barostat was added to the parachute circuitry to disarm the recovery system at altitudes above 11 200 feet.

21. A semiautomatic blood-pressure measuring system was installed.

The weight and balance data for spacecraft 18 are summarized in the following table.

Parameter	Mission phase				
	Launch	Orbit	Normal reentry	At main parachute deployment	Flotation
Weight, lb	4,244.09	2,974.56	2,663.36	2,557.70	2,407.83
Center-of-gravity station, in.					
Z	168.40	121.45	125.10	122.51	119.89
X	-.07	-.10	-.10	-.09	-.40
Y	.02	-.01	.00	.03	.05
Moments of inertia, slug-ft^2					
I_z	354.60	288.90	272.10	268.50	262.80
I_x	7,709.50	646.30	562.20	445.60	376.10
I_y	7,720.70	658.80	575.30	458.90	389.00

LAUNCH VEHICLE DESCRIPTION

The MA-7 launch vehicle (Atlas 107-D) was an Atlas Series-D missile modified for the missions as on previous Mercury-Atlas flights.

This 107-D launch vehicle configuration did not differ in any major respect from the Atlas 109-D launch vehicle utilized for the MA-6 mission (see ref. 1). The configuration of the Atlas 107-D differed from that of Atlas 109-D in the following minor ways:

1. The staging time was reduced from 131.3 to 130.1 seconds after lift-off, and backup staging time was altered from 136 to 132.2 seconds.

2. The propellant-utilization manometer calibration procedure was revised.

3. The boiloff-valve spring rate was changed.

4. The lox-tank pressure regulator operating range was changed.

5. Servomechanism stabilization was provided to eliminate the need for special selection of booster-engine hydraulic actuators.

6. The propellant utilization telemetry-signal conditioning was changed.

7. Booster engine main-oxidizer-valve material was changed from aluminum to stainless steel to reduce thermal expansion effects.

8. The pneumatic regulators on the booster engines were improved.

9. The interference between the high-pressure fuel drain fitting and the vehicle structure was eliminated.

10. The head-suppression and propellant-utilization solenoid valves were modified by reversing the electrical-mechanical position stops in an effort to improve reliability.

11. The fuel tank bulkhead insulation was retained.

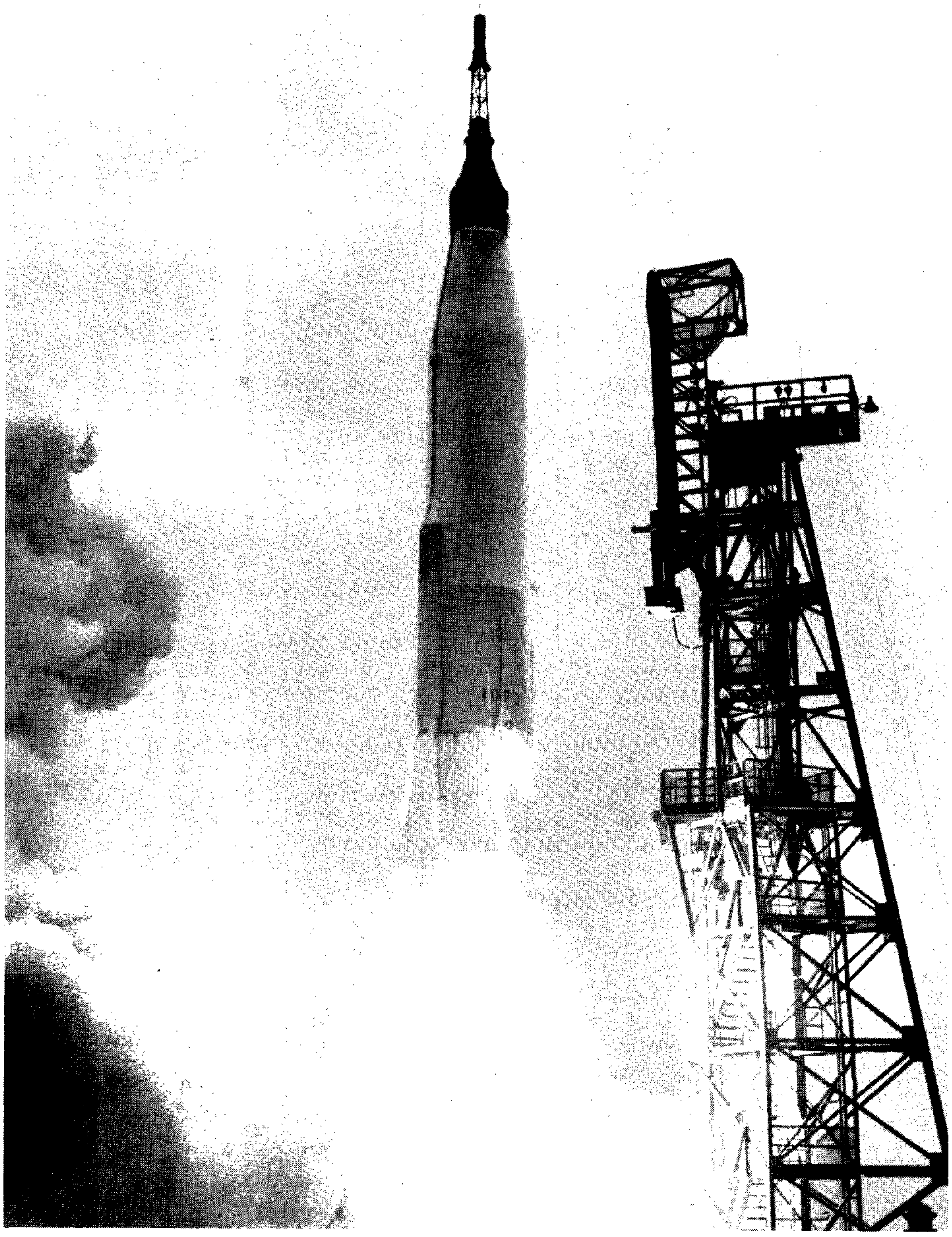


Figure 3.- MA-7 launch configuration at lift-off.

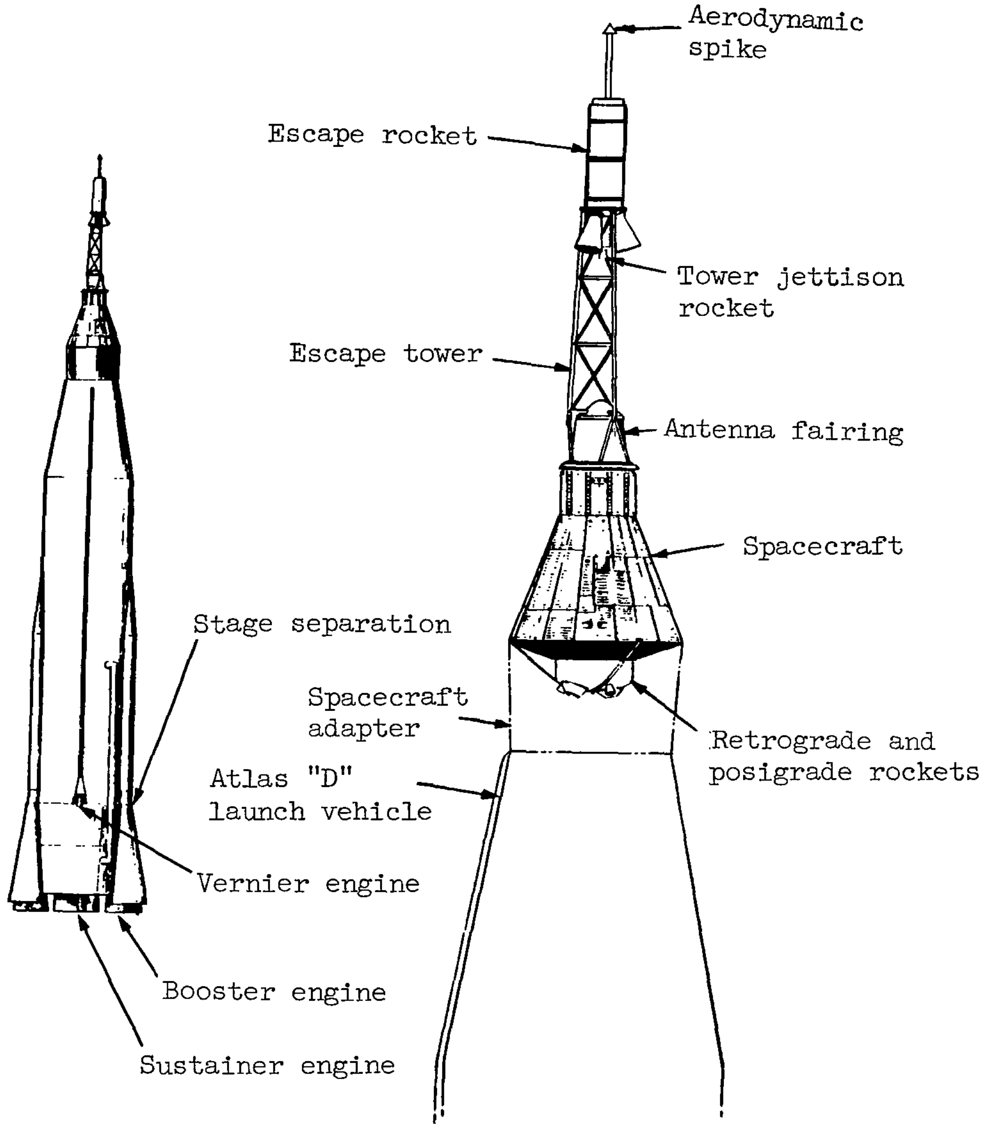


Figure 4.- Sketch showing general configuration.

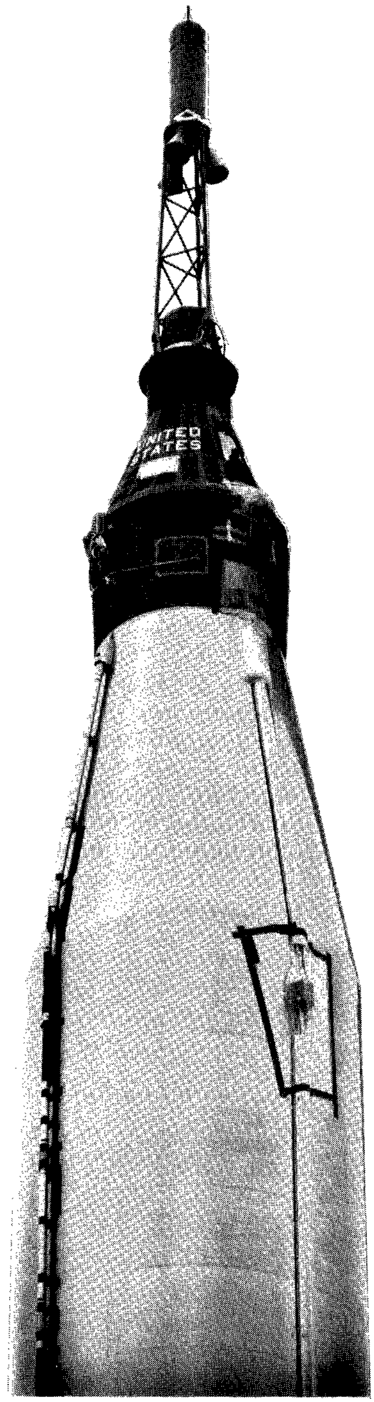
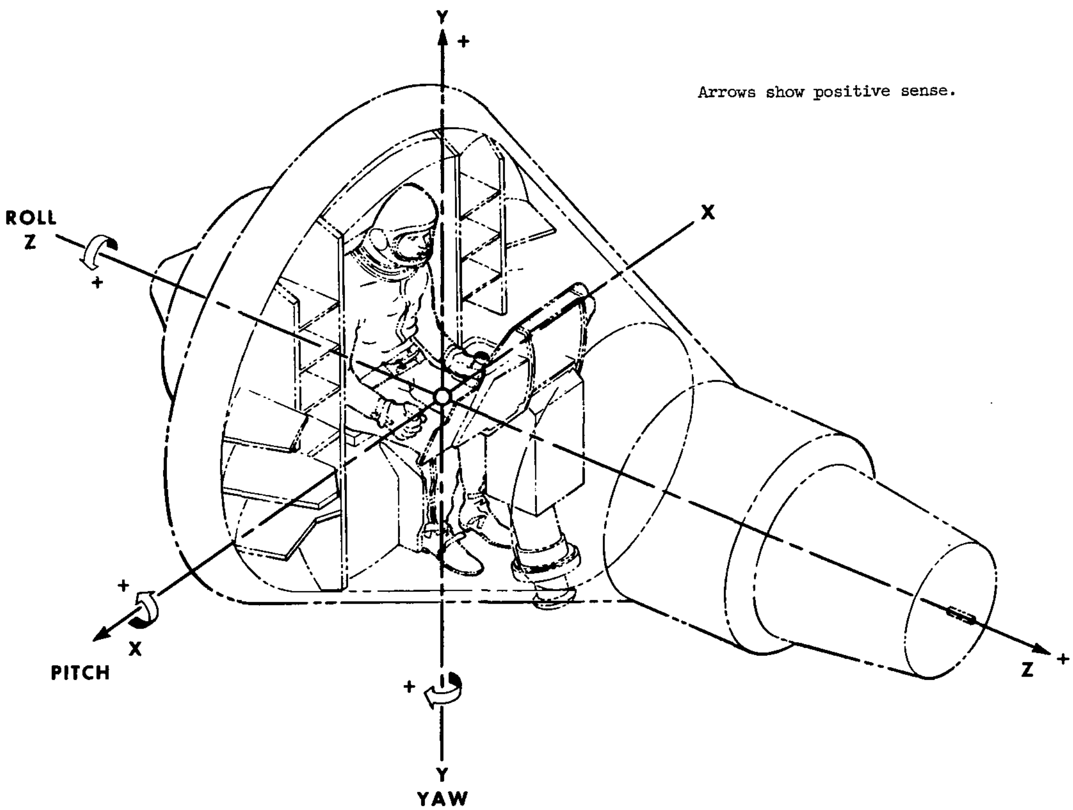


Figure 5.- MA-7 Spacecraft 18 mounted on the launch vehicle. (Preflight checkout photograph showing ground-support-equipment still attached.)



Pitch

Pitch is defined as the rotation of the spacecraft about its X-axis. The pitch angle is 0° when the Z-axis lies in a horizontal plane. Using the astronaut's right side as a reference, positive pitch is achieved by counterclockwise rotation from the 0° plane. The rate of this rotation is the spacecraft pitch rate and is positive in the direction shown.

Yaw

Yaw is defined as the rotation of the spacecraft about its Y-axis. Clockwise rotation of the spacecraft when viewed from above the astronaut, is called right yaw and is defined as positive.

Yaw angle is considered 0° when the spacecraft is in normal orbital position (blunt end of spacecraft facing line of flight). When the positive Z-axis of the spacecraft is directed along the orbital flight path (recovery end of spacecraft facing line of flight), the yaw angle is 180°.

Roll

Roll is defined as the rotation of the spacecraft about its Z-axis. Clockwise rotation of the spacecraft, as viewed from behind the astronaut, is called right roll and is defined as positive (+). When the X-axis of the spacecraft lies in a horizontal plane, the roll angle is 0°

Accelerometer Polarity with Respect to Gravity

With the spacecraft in the launch position, the Z-axis will be perpendicular to the earth's surface and the Z-axis accelerometer will read +1g.

Figure 6.- Spacecraft axis system.

MISSION OPERATIONS

The various ground operations required to support a Mercury orbital mission may be grouped according to appropriate mission phases: prelaunch, launch, orbital flight, and recovery. The prelaunch operations include the preparations necessary to bring the astronaut, spacecraft, launch vehicle, and ground-support personnel up to flight-ready status. The launch operations begin with the countdown, when all flight systems and flight-control stations are checked for readiness, and concludes with insertion of the spacecraft into its orbital trajectory. The orbital portion of the flight entails the flight monitoring and data-acquisition operations of personnel stationed along the Mercury Worldwide Network. The recovery operations begin when a landing point is predicted by appropriate network stations, and involve the combined efforts of thousands of Department of Defense personnel stationed at the various prescribed landing locations along the orbital ground track.

PRELAUNCH OPERATIONS

The prelaunch operations consist of the training of the astronaut for a specific flight, preparations conducted at the launch site for the spacecraft and the launch vehicle, and flight-safety reviews. Although each astronaut has received training since his introduction into the Mercury program, special training is required for the mission involved. This training primarily involves participation in a series of mission simulations which present realistic operational situations which require assessment and action. These simulations are often conducted in conjunction with the detailed checkout operations completed for the spacecraft, launch vehicle, and the Mercury Network.

Program management personnel attend scheduled review meetings to evaluate the status of prelaunch preparations for the spacecraft and launch vehicle and to initiate necessary remedial action in order to maximize astronaut safety throughout the mission. The following paragraphs outline the operations required in preparation for launch.

Astronaut Training

The astronaut training program for Project Mercury can be divided into six basic categories which are essentially dependent on the training devices used. These categories are academics, static training, environmental familiarization, dynamic training, egress and survival training, and specific mission training. The first five categories are discussed briefly in the report on the MA-6 mission (ref. 1). Specific training for the MA-7 mission is discussed as follows.

Preflight operations schedule. - The preflight pilot activities and dates (from March 16, 1962, to launch date) are given in table I. During the preflight preparation period, the pilot maintained a rigid schedule of training activities in conjunction with a large number of other demands on the pilot's time resulted in a somewhat crowded schedule.

Spacecraft checkout activities. - The pilot's participation in the spacecraft preflight checkout activities enabled him to become familiar with the MA-7 spacecraft and launch-vehicle systems. Table II summarizes the checkout activities during which the pilot spent 31 hours 30 minutes in the spacecraft itself and many additional hours before and after each checkout operation in preparation, trouble shooting, observation, and discussion. The pilot also spent 79 hours 30 minutes in the MA-6 spacecraft which added considerably to his knowledge of the Mercury spacecraft and launch-vehicle systems.

Training activities. - Table III is a brief summary of the training activities on the Langley and Cape Canaveral procedures trainers and the air-lubricated free-attitude trainer (ALFA) from March 25 to May 22, 1962. During this period the pilot spent 70 hours 40 minutes in which he accomplished 114 turnarounds and 92 retrofires, and experienced 143 simulated systems failures. The main training emphasis during these simulations was on the practicing of specific attitude maneuvers and rehearsing inflight activities. The pilot also received training in the detection and correction of systems' failures and in mission anomalies which would usually result in an abort or early reentry. He participated in several of the launch abort and network simulations during which the mission rules were discussed and rehearsed.

Training analysis. - On the Mercury procedures trainers, the pilot achieved a high level of skill in performing maneuvers such as turnaround, retrofire, and reentry rate damping. The pilot reported that during the flight these particular maneuvers seemed familiar. However, he was less well prepared for some activities which could not be properly simulated and practiced before flight, such as the gyro re-alinement and the more extensive attitude-change maneuvers.

In addition, it should be noted that the horizon-scanner malfunction encountered during the flight could not be simulated on the procedures trainer, nor could practice be given in the analysis of instrument reference problems because of the lack of a system for simulating the view through the spacecraft window. These factors, together with the higher fly-by-wire (FBW) low-thrust levels simulated on the trainer, may have contributed to the pilot's tendency to use the high torque thrusters excessively and thus to the resulting high rate of fuel consumption.

Spacecraft Prelaunch Preparations

Prelaunch preparations for spacecraft 18 were basically the same as those for spacecraft 13 which was used in the MA-6 mission. These preparations are described in the report on the MA-6 mission (ref. 1). Major changes and modifications made on spacecraft 18 prior to launch are presented in the Spacecraft History section of this report.

Spacecraft History

Spacecraft 18 arrived at Hangar S, Cape Canaveral, Forida, on November 1, 1961. The preparation period in the hangar totaled 100 days, of which 40 days were spent on tests. The spacecraft was transported to the launch site on April 28, 1962. A brief history of the spacecraft is graphically presented in figure 7.

Major spacecraft changes and modifications prior to launch are chronologically listed in table IV.

The spacecraft was mechanically mated to the launch vehicle at the launch site 26 days prior to launch. The specific activities accomplished during that period are presented in table V.

Launch Vehicle Preparation

Prelaunch preparations of the Atlas 107-D launch vehicle were basically the same as those for the Atlas 109-D launch vehicle, which was used in the MA-6 mission, and these preparations are described in the report on the MA-6 mission (ref. 1).

Flight-Safety Reviews

A series of flight-safety review meetings were held prior to the MA-7 flight. The purpose of these meetings was to establish firmly the flightworthiness of the spacecraft and the launch vehicle. Mission review meetings were also conducted to ascertain readiness of all supporting elements of the mission. These meetings are discussed briefly in the following paragraphs.

Spacecraft. - The review meeting for spacecraft 18 was held at 4:00 p.m. on May 14, 1962. The history of the spacecraft after arrival at Hangar S and the current status of all the systems were reviewed. The spacecraft was approved as ready for flight, pending satisfactory completion of the final simulated flight test scheduled for May 15, 1962. The simulated flight test was satisfactory, and the spacecraft was then committed ready for flight.

Launch vehicle. - Three meetings were held for a specific review of the status of the MA-7 launch vehicle, and for a general review of the results of previous Atlas flights. The first meeting was held on the morning of May 16, 1962, at which time a review was made of the history of the launch vehicle after arrival at Cape Canaveral and the current status of the systems. The missile was approved ready for flight, pending a test of the telemetry system which was scheduled for and successfully completed on May 17, 1962.

The second review meeting was held in the afternoon of May 16, 1962, to brief NASA-MSC management on all anomalies that had occurred in the Atlas research and development (R&D) and operational flight programs since the MA-6 mission. The attempted launches and resulting failures of Atlas vehicles 11-F and 1-F were discussed in this meeting.

The third meeting was held on May 18, 1962, at 2:00 p.m. to discuss the latest information on the Atlas vehicles 11-F and 1-F incidents. It was agreed that the information available at the time of the meeting would not affect the MA-7 launch vehicle flight-readiness status, but that intensive investigation would continue and be reported upon at the Flight Safety Review Board meeting scheduled 1 day prior to the flight.

Mission. - Two mission review meetings were held prior to the MA-7 mission. The first meeting was held at 10:00 a.m. on May 16, 1962, and all elements for the flight were found to be in readiness. However, after the review meeting, a decision was made to install an additional barostat in the spacecraft parachute circuitry and to replace flight-control canisters in the Atlas launch vehicles. A decision was also made to reschedule the launch date to May 24, 1962.

The second mission review meeting was held at 3:00 p.m. on May 22, 1962. This meeting was scheduled because of work performed on the space vehicle after the meeting of May 16, 1962. The spacecraft, launch vehicle, and all support systems were found to be ready for the MA-7 mission. The Flight Safety Review Board met on May 23, 1962, and this board was advised that the Status Review Board which had met earlier that morning had found the launch vehicle and spacecraft ready for flight. Additional information on the Atlas 11-F and 1-F flight failures indicated that the differences between the E- and F-series and the Mercury D-series start sequences were significant enough to eliminate doubt in the performance of the MA-7 launch vehicle.

LAUNCH OPERATIONS

The launch operations discussed in the following paragraphs include the launch procedure, weather conditions, and photographic coverage. The launch procedure section presents the major events which occurred during the countdown. The weather section includes a summary of the weather conditions reported at lift-off at the launch site and in the Atlantic recovery areas. The photographic section presents a summary of the photographic coverage committed for the mission and contains a discussion of the quality and usefulness of the data obtained.

Launch Procedure

The spacecraft launch operations were planned for a 610-minute split countdown with a $17\frac{1}{3}$-hour built-in hold at T-390 minutes for spacecraft reaction control system (RCS) fuel and pyrotechnic servicing. To provide additional assurance that the projected launch time of 7:00 a.m. e.s.t., May 24, 1962, could be met, a 90-minute built-in hold was scheduled at T-135 minutes.

The second half of the split countdown was started at 11:00 p.m. e.s.t. on May 23, 1962. Launch occurred at 7:45 a.m. e.s.t. on May 24, 1962, after

45 minutes of unplanned holds. The following is a sequence of major events, including holds, which occurred in the countdown:

T-390 min	Start of second half of countdown.
T-135 min	Astronaut insertion into the spacecraft
T-94 min	Spacecraft hatch closure started.
T-74 min	Spacecraft hatch secured; shingle installation started.
T-64 min	Spacecraft shingle installation complete.
T-47 min	Service tower (gantry), first motion.
T-33 min	Service tower stowed.
T-32 min	Lox pumping started.
T-11 min	15-minute hold for weather (launch-area smoke and ground fog). Hold extended for an additional 15 minutes for weather. Hold extended for an additional 10 minutes for evaluation of atmospheric-refraction data. Hold extended for an additional 5 minutes to complete refractometer data evaluation.

Weather Conditions

Weather in the launch area was initially unsatisfactory for required camera coverage because of ground fog and smoke conditions. By 7:30 a.m. e.s.t., conditions had improved considerably and at launch time were as follows:

Sky cover	broken at 700 ft
Wind, knots	8 (from 240°, WSW)
Visibility, miles	1
Temperature, °F	77
Dewpoint, °F	73
Relative humidity, percent	88

Although the ground visibility at lift-off was limited to 1 mile, the estimated camera coverage through 250 000 feet was predicted to be good at the time of launch.

A plot of the launch-area wind direction and speed is shown in figure 8 for altitudes up to 60 000 feet.

Weather and sea conditions in all Atlantic recovery areas were reported to be satisfactory prior to launch. Weather and sea conditions in the planned landing area at the end of the third orbital pass are given as follows. These conditions were reported by the U.S.S. John R. Pierce at noon e.s.t. on May 24, 1962.

Cloud cover	$\frac{4}{10}$ scattered at 1 000 ft
Wind, knots	11 (from 096°, easterly)
Visibility, miles	10
Air temperature, °F	84
Wet bulb temperature, °F	79 (dewpoint)
Water temperature, °F	77 (insertion)
Wave height, ft	3

Photographic Coverage

Atlantic Missile Range (AMR) optical coverage, including the quantity of instrumentation committed and data obtained during launch and reentry phases, is shown in table VI. AMR optical tracking from lift-off or first acquisition to limits of visibility is shown in figure 9. The coverage times shown as bars in this figure represent the periods during which either the spacecraft, launch vehicle, or the exhaust flame was first visible until all three were out of sight. It is evident from the figure that optimal camera coverage is in the region near maximum dynamic pressure, and that adequate data were available had a failure occurred at this time. Optical data obtained at other times are considered marginal. At lower altitudes, coverage was primarily limited by ground fog and haze, and, at higher altitudes, both ground haze and image reduction caused by slant range affected optical tracking capability.

Metric film. - Metric films were processed, and the results were tabulated by the AMR. However, these data were not required for evaluation by the Manned Spacecraft Center, since the powered flight phase was normal.

Engineering sequential film. - Engineering sequential coverage at AMR Station 1 during the launch phase was generally satisfactory. This statement is qualified by the fact that a detailed film analysis was not required as a result of normal mission sequence from lift-off. The quality of fixed and tracking camera coverage was poor because of fog and ground-haze conditions. Twelve films were reviewed, including 16mm and 35mm films from three fixed cameras and nine tracking cameras. The quality of fixed camera coverage with respect to exposure and focus was generally good, with the exception of one underexposed film. Lox boiloff, umbilical ejection, periscope retraction and umbilical-door closure, launch-vehicle ignition, and lift-off appeared to be normal. The quality of tracking camera coverage with respect to exposure, focus, and tracking was generally good, with the exception of one underexposed and one overexposed film. Four tracking cameras indicated normal launch-vehicle staging and two tracking cameras indicated normal tower separation.

Documentary film. - Documentary coverage of the mission provided by available motion picture films was very good in quality but limited in quantity, particularly in the recovery area. Four motion picture films were available for review. Two of these films presented a portion of the prelaunch activities, including astronaut preparation at Hangar S, transfer to the launch site, and portions of the operational activity at the Mercury Control Center and the blockhouse. One of these two films also presented a portion of the recovery operation, including helicopter pickup of the astronaut and transfer to the recovery aircraft carrier. The two remaining motion picture films included views of the astronaut arriving on board the carrier, suit removal and physical examination, and arrival of the astronaut and debriefing personnel at Grand Turk Island. Documentary coverage of the mission with respect to still photographs available for review exceeded that of motion picture films. These photographs were excellent both in quality and quantity, particularly in the recovery area. Still picture coverage during and after the recovery operation included views of the astronaut and pararescue personnel in the water prior to helicopter pickup, pickup of the astronaut and transfer to the recovery aircraft carrier, spacecraft retrieval from the water by the recovery destroyer, loading of the spacecraft on board the aircraft for transportation to Cape Canaveral, and closeup views of the spacecraft after recovery. Numerous engineering still photographs were also available showing closeup views of the spacecraft during the usual postflight inspection at Cape Canaveral.

FLIGHT CONTROL OPERATIONS

The preparation of the flight control team and the Mercury Network followed the same procedure used for the MA-6 mission and the previous unmanned Mercury orbital flights. Simulations carried out prior to the flight are considered to be one of the most important steps in the preparation of the flight controllers and the astronaut for the flight. This process is absolutely essential to the safety of the flight.

The countdown for the launch vehicle, spacecraft, and network was satisfactory. There were some minor problems, but none of these resulted in the necessity for a hold; and the cooperation between the blockhouse and the Mercury Control Center was excellent.

The powered portion of the flight was completely normal, and no problems were experienced in achieving the proper information or in making the "go--no-go" decisions at the required times in the flight. The communications to the astronaut throughout the entire mission were satisfactory, although slightly inferior to those of the MA-6 mission. The "go--no-go" decision at SECO was made rapidly, and there was no doubt that the proper conditions had been achieved. It was immediately apparent in the early reports from the African sites that the suit cooling system was not functioning properly and that the astronaut was uncomfortable. However, the suit temperature began to decrease as a result of increased water flow in the suit circuit; and by the end of the first orbital pass it was down to a satisfactory value. Other than a slight discomfort caused by the suit temperature, the astronaut was obviously in good condition and performing satisfactorily throughout the first orbital pass. A report from Canton of a body temperature of 102° F, which was also noticed at loss of signal at Woomera, was of some concern until it was determined that the transducer had either failed or had been affected by an inflight calibration. The only other problem was the large amount of automatic system fuel being used by the astronaut during the first orbital pass and he was cautioned, while passing over the continental United States, against further gross usage.

During the second orbital pass, the suit temperature again increased to a high value, but showed a decreasing trend before the end of the pass. It was obvious that the pilot was having difficulty in achieving the proper water-flow setting for the suit cooling system.

The inverter temperatures showed increases similar to previous flights, but these temperatures caused no concern because of past experience. The cabin-air temperature followed trends almost identical to the MA-6 flight, although somewhat higher temperatures were reached during the second orbital pass. This increase, however, did not cause any great concern.

More than the normal amount of fuel was consumed during the first two orbital passes, and this excessive fuel usage resulted in a number of requests to the astronaut to conserve fuel on both the automatic and manual systems. As a result, when the astronaut reached Hawaii at the end of the third orbital pass, approximately 40 percent of the fuel was remaining in both systems. This amount of fuel would normally have been ample to perform a retrofire maneuver and reentry on either system.

Throughout the flight the astronaut made voice reports regarding visual observations and various experiments carried out in the flight. The Astronaut's Flight Report and the Scientific Experiments sections of this report contain discussions of the observations and experiments.

Upon contact with Hawaii at the end of the third orbital pass, the astronaut was instructed to begin his pre-retrosequence checklist and to revert from his present manual-control mode to the ASCS system in preparation for retrofire. This action was initiated but when the astronaut switched back to ASCS, he reported having trouble with this system, and, as a result, was unable to complete the retrosequence checklist properly. It was obvious from both the voice reports and the telemetry readouts on the ground that the astronaut was concerned over the apparent unsatisfactory operation of the automatic control system and the large amounts of manual and automatic fuel which were used over both the Hawaii station and prior to acquisition at the California station.

The astronaut continued to have ASCS problems, in that the pitch horizon scanner yielded erroneous attitudes; and he performed the retrofire maneuver by using manual control. The astronaut was directed by the California Capsule Communicator to bypass the attitude permissive relays and to initiate retrofire manually. It was apparent, mainly from the time of retrojettison, that the retrofire had taken place several seconds late. Initial reports from the astronaut indicated that the attitudes had been held fairly well during retrofire, but later reports from California did not corroborate this report. Also, the California station reported that the measurement of the velocity decrement from the integrating accelerometer was approximately 450 feet per second. Because of the first report on spacecraft attitudes, the initial radar data from California and the resulting impact prediction were suspected to be in error. However, as additional radar data became available from other sites it was obvious that the data were correct and that the landing point would be approximately 250 nautical miles downrange from the planned location. Because of the small amount of automatic fuel remaining following retrofire, and the complete depletion of manual fuel, the astronaut was instructed to use as little fuel as possible in orienting the spacecraft to reentry attitude and to conserve the fuel for use during reentry. He was also instructed to use the auxiliary damping system during the atmospheric reentry portion of the flight.

Upon contact with Cape Canaveral just prior to communications blackout, the astronaut was queried as to the position of the faceplate. He indicated it was still open and was therefore directed to close it. The ionization blackout occurred about 40 seconds late, lending further evidence to the longer reentry range, and the astronaut was told that his landing point would be long and at approximately 19°23' North latitude and 63°53' West longitude. From this point, no voice communications were received from the astronaut. A number of communications were made from the Mercury Control Center both on the command voice system and over the normal HF/UHF voice system during the ionization blackout. However, these transmissions were not received by the astronaut. The Atlantic Missile Range C-band radars at Cape Canaveral, Grand Bahama Island, and San Salvador tracked the C-band beacon until the spacecraft reached the local horizon, indicating that it had reentered satisfactorily, and these data continued to give the same landing-point prediction. All sources of data and methods of calculations, in fact, gave essentially the same impact prediction.

The remainder of the mission involved primarily the recovery operation, which is described in detail in the Recovery Operations section of this report.

RECOVERY OPERATIONS

The recovery operations discussed in the following paragraphs include the recovery plans, procedures, and aids. The section on recovery plans contains a descriptive and graphical presentation of recovery areas and forces. The section on recovery procedures shows in chronological order the significant events pertinent to the recovery operations. The section on recovery aids summarizes the effectiveness of the spacecraft equipment utilized to help the recovery forces locate the spacecraft after it had landed.

Recovery Plans

The Atlantic recovery areas where ships and aircraft were positioned at the time of launch are shown in figure 10. Recovery forces were distributed to provide for recovery within a maximum of: 6 hours in areas B, D, E, and the first 610 nautical miles of area A; 9 hours in the remainder of area A; and 3 hours in area C. Recovery forces were located to provide recovery within a maximum of 3 hours in areas F, G, and H at the end of orbital passes 1, 2, and 3, respectively. A total of 20 ships and 13 aircraft was on station in these Atlantic recovery areas at launch time. Helicopters, amphibious surface vehicles, and small boats were also positioned for close recovery support in the vicinity of the launch site.

Figure 11 shows the contingency-recovery aircraft that were on alert at various staging bases in the event that a landing occurred at any place along the orbital ground track. These aircraft were equipped to locate the spacecraft and to provide emergency on-scene assistance if required.

Recovery Procedure

A chronological summary of significant events pertinent to the recovery operation is presented in table VII. This summary was prepared primarily from information available at the Mercury Control Center throughout the operation.

Since the landing was outside the planned landing area (area H), contingency recovery procedures were followed at the Mercury Control Center. The downrange recovery commander aboard the aircraft carrier U.S.S. Intrepid was designated as mission coordinator, and the Coast Guard and other U.S. Naval Commands were queried as to the location of merchant ships or naval vessels (other than those assigned to recovery forces) near the area of interest. Information from these sources was evaluated and communications were established with the following three ships (positions shown in fig. 12): a Coast Guard cutter at St. Thomas, Virgin Islands; a merchant ship located approximately 31 nautical miles north of the calculated landing position; and the U.S.S. Farragut, a destroyer which was located about 75 nautical miles southwest of the calculated landing position. It was determined that the U.S.S. Farragut could arrive in the landing area first, so this ship headed for the landing area immediately. The other two ships were notified that the destroyer had been dispatched and they then continued with their normal operations.

Recovery Aids

All spacecraft recovery aids functioned normally, with the exception that there were no reports of SEASAVE HF/DF beacon reception.

One search aircraft reported contact with the Super SARAH recovery beacon at a range of 250 nautical miles. Another search aircraft reported receiving the SARAH recovery beacon at a range of 50 nautical miles. The aircraft also reported establishing contact with the D/F mode of the UHF transceiver.

The flashing light was reported to be functioning normally and was visible up to 6 miles. The dye marker was sighted by a search aircraft at a range of 15 nautical miles.

TABLE I. - PILOT PREFLIGHT PREPARATION HISTORY

[From March 16, 1962, to May 17, 1962]

Date	Day	Activity[a]
March 16	Friday	Flight plan meeting
March 19	Monday	Systems briefing (ASCS)
March 20	Tuesday	Systems briefing (RCS and Electrical)
March 21	Wednesday	Launch vehicle review
March 22	Thursday	Systems review (ECS and Mechanical)
March 25	Sunday	A. M. - ALFA Trainer P. M. - MPT no. 1
March 28	Wednesday	MPT no. 2
March 31	Saturday	A. M. - MPT no. 1 P. M. - ALFA Trainer
April 2	Monday	MPT no. 1
April 3	Tuesday	MPT no. 1
April 4	Wednesday	Trajectory briefing
April 5	Thursday	MPT no. 1
April 6	Friday	MPT no. 1
April 9	Monday	MPT no. 1
April 10	Tuesday	MPT no. 2
April 13	Friday	Scheduling meeting
April 15	Sunday	Systems test
April 16	Monday	Systems test

[a]Activity code:
MPT no. 1 - (Langley) Mercury Procedures Trainer.
MPT no. 2 - (Cape) Mercury Procedures Trainer.

TABLE I. - PILOT PREFLIGHT PREPARATION HISTORY - Continued

[From March 16, 1962, to May 17, 1962]

Date	Day	Activity[a]
April 17	Tuesday	Systems test
April 19	Thursday	Survival pack training Zero g experiment briefing
April 20	Friday	MPT no. 2
April 21	Saturday	MPT no. 2
April 24	Tuesday	Flight plan meeting
April 26	Thursday	ALFA Trainer
April 27	Friday	MPT no. 1
April 28	Saturday	Morehead Planetarium
April 30	Monday	Simulated flight
May 1	Tuesday	MPT no. 2 MIT[b] photo briefing scheduling
May 2	Wednesday	MPT no. 2
May 3	Thursday	Egress training
May 4	Friday	Egress training MPT no. 2
May 5	Saturday	MPT no. 2 RCS Static fire
May 7	Monday	MPT no. 2

[a]Activity code:
MPT no. 1 - (Langley) Mercury Procedures Trainer.
MPT no. 2 - (Cape) Mercury Procedures Trainer.

[b]MIT - Massachusetts Institute of Technology.

TABLE I. - PILOT PREFLIGHT PREPARATION HISTORY - Continued

[From March 16, 1962, to May 17, 1962]

Date	Day	Activity[a]
May 8	Tuesday	MPT no. 2 Simulated flight no. 2
May 9	Wednesday	Mercury Control Center/Bermuda simulation Mission rules review Flight plan review
May 10	Thursday	Mercury Control Center/Bermuda RCS blip check (launch and egress)
May 11	Friday	WX briefing Scheduling Trajectory, flight plan, and balloon experiment briefings
May 12	Saturday	MPT no. 2 RCS blip test
May 13	Sunday	MPT no. 2
May 14	Monday	MPT no. 2 Flight plan MIT[b] photo briefings Mission review
May 15	Tuesday	Simulated flight no. 3
May 16	Wednesday	Launch vehicle and mission review
May 17	Thursday	Physical examination
May 18	Friday	Mercury Control Center/Bermuda simulation

[a]Activity code:
MPT no. 1 - (Langley) Mercury Procedures Trainer.
MPT no. 2 - (Cape) Mercury Procedures Trainer.

[b]MIT - Massachusetts Institute of Technology.

TABLE I. - PILOT PREFLIGHT PREPARATION HISTORY - Concluded

[From March 16, 1962, to May 17, 1962]

Date	Day	Activity[a]
May 21	Monday	MPT no. 2 Scheduling
May 22	Tuesday	MPT no. 2 Flight plan review
May 23	Wednesday	Pilot briefing Study
May 24	Thursday	Launch

[a]Activity code:
MPT no. 1 - (Langley) Mercury Procedures Trainer.
MPT no. 2 - (Cape) Mercury Procedures Trainer.

TABLE II. - TIME PILOT SPENT IN SPACECRAFT 18

DURING HANGAR AND PAD TESTS

Date, 1962	Spacecraft tests	Approximate duration, hr:min
April 12	Systems test (Hangar S)	6:30
April 15	Systems test (Hangar S)	3:30
April 16	Sequential, sec. 2	7:00
April 17	Sequential, sec. 2	6:00
April 18	Sequential, sec. 2	3:00
April 30	Simulated flight no. 1	4:20
May 4	Simulated flight no. 2 and FACT[a]	0:30
May 5	RCS blip check (special test)	0:40
May 10	Launch simulation and egress	5:00
May 12	RCS blip check (special test)	1:00
May 15	Simulated flight no. 3	7:30
Approximate total time		45 hrs

[a]Flight Acceptance Composite Test.

TABLE III. - SUMMARY OF PILOT TRAINING ON THE AIR LUBRICATED FREE ATTITUDE TRAINER AND PROCEDURES TRAINERS

[Totals: failures, 143; turnaround maneuvers, 114; reentries, 49; retrofire attitude control, 92]

Date, 1962	Trainer (a)	Type of training	Time, hr:min	Number of missions	Number of failures and type						Special training activities (b)
					ECS	RCS	Sequential system	Electrical system	Communication system	Other	
March 25	1	Attitude control	2:15	1			1				1, 3
March 25	3	Attitude control	1:35								2, 4
March 28	2	Attitude control	2:40	2							1, 2
March 29	2	Attitude control	1:45	1							1, 2
March 31	3	Attitude control	1:10								2
March 31	1	Attitude control	2:15	1			1				1, 3
April 2	1	Attitude control	1:00	1							1, 3
April 3	1	Attitude control	1:30	1							1, 3
April 5	1	Attitude control	1:30								1, 3
April 6	1	Attitude control	1:00								1, 3
April 9	1	Systems failures	2:30	10	4	2	6	2	1	3	3, 5, 6
April 10	2	Systems failures Attitude control	1:35	7	2		3	4		4	1, 5
April 20	2	Systems failures Attitude control	3:15	4	2	1	2	3		1	1, 2, 5
April 21	2	Systems failures	3:15	8	2	1	6	5	1	5	5, 6
April 26	3	Attitude control	1:00								2, 4
April 27	1	2-orbit mission	4:00	1			2				2, 3, 6, 7
May 1	2	Systems failures	2:20	4	1		7	1		3	5, 6
May 2	2	3-orbit mission	5:35	1							7

[a]Trainer code:

1 - Langley procedures trainer
2 - Cape procedures trainer
3 - ALFA trainer

[b]Training activities code:

1 - Turnaround maneuvers
2 - Retrofire attitude control
3 - Reentry rate control
4 - Special attitude maneuvers
5 - Launch aborts
6 - Orbital emergencies
7 - Flight plan work

TABLE III. - SUMMARY OF PILOT TRAINING ON THE AIR LUBRICATED FREE ATTITUDE TRAINER AND PROCEDURES TRAINERS - Concluded

[Totals: failures, 143; turnaround maneuvers, 114; reentries, 49; retrofire attitude control, 92]

Date, 1962	Trainer (a)	Type of training	Time, hr:min	Number of missions	Number of failures and type						Special training activities (b)
					ECS	RCS	Sequential system	Electrical system	Communication system	Other	
May 4	2	Systems failures	2:00	3			3	2		1	5
May 5	2	Systems failures Attitude control	3:00	5		1	3	2		4	1, 2, 3, 4, 5
May 7	2	2-orbit mission	3:35	1	1						7
May 8	2	Systems failures	1:15	6	3		5	3	1	6	5, 6
May 9	2	MCC/BDA simulation	2:35	3	1	1	1		2		5
May 10	2	MCC/BDA simulation	1:05	1	2						5
May 12	2	1-orbit mission	1:45	1							7
May 13	2	1-orbit mission	1:45	1		1					7
May 14	2	3-orbit mission	5:40	1							7
May 18	2	MCC/BDA simulation	2:45	4	1	3		1	1	1	5
May 21	2	2-orbit mission	4:15	1	1						7
May 22	2	Systems failures	0:50	4	4	1	3	3	1	4	5, 6
		TOTALS	70:40	73	24	11	43	26	7	32	

[a]Trainer code:

1 - Langley procedures trainer
2 - Cape procedures trainer
3 - ALFA trainer

[b]Training activities code:

1 - Turnaround maneuvers
2 - Retrofire attitude control
3 - Reentry rate control
4 - Special attitude maneuvers
5 - Launch aborts
6 - Orbital emergencies
7 - Flight plan work

TABLE IV. - MODIFICATIONS MADE TO SPACECRAFT 18

Modification	Completion date
The heat shield was X-rayed, and the center-plug dowels were acceptable.	December 7, 1961
The auxiliary battery for the maximum-altitude sensor was added.	December 9, 1961
Gyros with a silicone-base lubricant were installed	December 14, 1961
The cabin-fan inlet duct was equipped with screens to prevent possible cabin-fan fouling by foreign material.	December 18, 1961
The check valve was removed from the inverter cold-plate system.	December 20, 1961
The oxygen partial-pressure indicator was deleted.	January 10, 1962
The suit-compressor check valves were positively oriented and springs were added to assist closing.	January 11, 1962
The semiautomatic blood-pressure measuring system, which included the fill and dump solenoids, was added.	January 24, 1962
The velocity sensor was reset from cap-sep[a] + 5 seconds to cap-sep ± 5 minutes.	January 25, 1962
The suit-circuit constant-bleed orifice was removed.	January 31, 1962
The cabin relative-humidity indicator was removed.	February 14, 1962
The coolant-quantity indicator was deleted.	February 14, 1962
The SOFAR bombs and radar chaff were deleted from the spacecraft.	February 14, 1962
The oxygen partial-pressure transducer was removed from the suit circuit and located in the cabin.	March 2, 1962
The landing-bag limit switches were rewired so that both switches would be required to close for proper indication of bag deployment.	March 3, 1962
The 1/4-g relay circuitry was changed to prevent dropout of this relay during posigrade ignition.	March 6, 1962

[a]Cap-sep: Capsule (spacecraft)/launch vehicle separation.

TABLE IV. - MODIFICATIONS MADE TO SPACECRAFT 18 - Concluded

Modification	Completion date
The oxygen-flow sensor was disabled.	March 14, 1962
The low-frequency telemetry center frequency was raised 500 kc.	March 30, 1962
A maneuver switch was installed that removed roll and yaw slaving of gyros and pitch orbital precession.	April 2, 1962
The hand-controller FBW switch rod was changed to incorporate a step to prevent travel from going over-center.	April 7, 1962
The instrument observer camera was removed.	April 9, 1962
A dual indicator was installed for the suit and cabin steam-vent temperatures.	April 12, 1962
Modified 1- and 6-pound thrust-chamber assemblies were incorporated.	April 18, 1962
A 30-inch balloon was installed in the recovery compartment to obtain visual acuity effects and aerodynamic drag measurements.	April 19, 1962
A low-level commutator and instrumentation for a temperature survey were installed.	April 20, 1962
The oxygen emergency-rate valve and system shut-off valve were mechanically connected.	May 3, 1962
A zero-gravity experimental apparatus was installed in the position formerly occupied by the instrument-panel camera.	May 4, 1962
The yaw manual-proportional valve was replaced at the launch site after a simulated launch, since tests had revealed poor centering from left-yaw position.	May 11, 1962
A third barostat was installed in the cabin and wired into the parachute circuitry to prevent automatic deployment of the drogue parachute and main parachutes at altitudes above 11 200 feet.	May 19, 1962

TABLE V. - SPACECRAFT PREFLIGHT TESTS

Activity	Completion date, 1962
Mechanical mate	April 28
Simulated flight 1 (system)	April 30
Electrical mate and aborts	May 4
Special hydrogen peroxide tests	May 4
Simulated flight 2 (joint FACT)	May 5
Flight configuration and aborts	May 8
Launch simulation	May 10
Simulated flight 3	May 15
Simulated flight 3	May 18
Launch	May 24

TABLE VI. - ATLANTIC MISSILE RANGE OPTICAL COVERAGE

OF LAUNCH AND REENTRY PHASES

Film type	Station	Number of items committed	Number of items obtained	Lost items	Reason for loss
Metric	1	15	15	0	
Engineering sequential	1	46	45	1	Camera jammed upon starting
Engineering sequential	1	1	0	[a]1	Track not acquired
Engineering sequential	3	1	0	[a]1	Track not acquired
Engineering sequential	5	1	0	[a]1	Track not acquired
Documentary	1	50	50	0	

[a]Planned for reentry coverage.

TABLE VII. - CHRONOLOGICAL SUMMARY OF

SIGNIFICANT RECOVERY EVENTS

Elapsed time from launch, hr:min	Elapsed time from landing, hr:min	Event, May 24, 1962
03:33		An Air Rescue Service SC-54 aircraft was launched from Roosevelt Roads, Puerto Rico, and assigned a station on the downrange portion of the third orbital pass recovery area, as shown in figure 12. Deployment of this aircraft, which carried two pararescue personnel, was requested as a precautionary measure after the mission was committed to a third orbital pass.
04:37		Recovery forces were informed that the retro-rockets had been ignited for a landing in Area H.
04:44		Communications to and from the spacecraft were lost as a result of ionization blackout.
04:48		Recovery forces were informed that the new calculated landing position (CALREP) was 19°24' N, 63°53' W. An Air Rescue Service SA-16 amphibian aircraft was launched from Roosevelt Roads to proceed to the calculated landing position.
04:49		Ionization blackout ended.
04:54		A P2V search aircraft made UHF/DF contact on 243 mc with the spacecraft and later reported this contact to Mercury Control at 05:02.
[a]04:56	00:00	The spacecraft landed.
04:59	00:03	The new calculated landing position (19°24' N, 63°53' W) was established as the best estimate of the spacecraft landing position. In the meantime, recovery forces from Area H were proceeding toward the landing position.
05:13	00:17	The destroyer U.S.S. Farragut was proceeding to the calculated landing position.

[a]Actual landing time - 04:55:57 g.e.t.

TABLE VII. - CHRONOLOGICAL SUMMARY OF

SIGNIFICANT RECOVERY EVENTS - Continued

Elapsed time from launch, hr:min	Elapsed time from landing, hr:min	Event, May 24, 1962
05:14	00:18	All search aircraft were executing the search plan, and positive UHF/DF contact was established with the spacecraft.
05:35	00:39	A P2V search aircraft reported visual contact with the spacecraft and that the astronaut was alongside in a liferaft (fig. 13).
05:49	00:53	An Air Rescue Service SC-54 in the landing area prepared to deploy pararescue personnel with survival equipment and a spacecraft auxiliary flotation collar.
05:55	00:59	The pararescue team was deployed.
05:55	00:59	HSS-2 twin-turbine helicopters were launched from the U. S. S. Intrepid with an estimated time of arrival (ETA) at the spacecraft of 07:43 (02:47 after spacecraft landing). These helicopters had the capability of personnel retrieval and return to the Intrepid.
06:05	01:09	The SA-16 arrived on scene.
06:15	01:19	A spacecraft auxiliary flotation collar was deployed from the SC-54. The initial task for pararescue personnel was to contact the astronaut and determine his condition. Since the astronaut required no assistance, they then proceeded to attach the collar to the spacecraft to insure a longer flotation lifetime. The radio equipment that was initially dropped failed to operate properly, and therefore voice communications with the recovery forces were not established at this time. Additional radio equipment was deployed just prior to the time the helicopters arrived on the scene and was not activated.

TABLE VII. - CHRONOLOGICAL SUMMARY OF SIGNIFICANT RECOVERY EVENTS - Continued

Elapsed time from launch, hr:min	Elapsed time from landing, hr:min	Event, May 24, 1962
06:30	01:34	The SA-16 deployed from Roosevelt Roads reported surface conditions in the landing area satisfactory for a safe landing and subsequent takeoff.
06:36	01:40	A situation report from the mission coordinator (downrange recovery commander) indicated the following: (a) At 01:33, the astronaut appeared normal, and waved to the aircraft. (b) Pararescue team had been deployed. (c) Plans were to utilize HSS-2 helicopters for astronaut retrieval rather than the SA-16. These helicopters were deployed with a doctor from the Mercury program aboard. The ETA of the U.S.S. Farragut at the spacecraft landing point was 03:19 and ETA of the U.S.S. Pierce was 06:34. The U.S.S. Pierce was equipped to retrieve the spacecraft and the U.S.S. Farragut was prepared to stand by to provide emergency assistance if required.
06:54	01:58	The P2V search aircraft reported that the flotation collar was attached to the spacecraft and was inflated.
07:07	02:11	The astronaut and pararescue team were in the water. There was no direct communication with the astronaut, but the astronaut appeared to be in good condition.
07:45	02:49	The helicopter arrived over the spacecraft.
07:55	02:59	The astronaut was retrieved by an HSS-2 helicopter (fig. 14). The doctor reported the condition of the astronaut as good.

TABLE VII. - CHRONOLOGICAL SUMMARY OF

SIGNIFICANT RECOVERY EVENTS - Concluded

Elapsed time from launch, hr:min	Elapsed time from landing, hr:min	Event, May 24, 1962
07:57	03:01	A second HSS-2 retrieved the pararescue team. Astronaut Carpenter reported, "Feel fine." Destroyer U.S.S. Farragut was 18 miles from the spacecraft.
08:20	03:24	Helicopters returned to the U.S.S. Intrepid accompanied by the SA-16 and search aircraft.
08:35	03:39	The U.S.S. Farragut arrived in the landing area and maintained visual contact with the spacecraft.
09:10	04:14	The astronaut was delivered to Mercury medical personnel aboard the U.S.S. Intrepid for medical examination and debriefing.
11:07	06:11	The U.S. Pierce recovered the spacecraft and secured it aboard. A "shepherds crook" was used to attach a lifting-line to the spacecraft, which was then hoisted aboard. Photographs of the spacecraft prior to and during retrieval are shown in figures 15 and 16.
15:35	10:39	The astronaut arrived at Grand Turk Island for further debriefing.
30:45	25:49	The spacecraft arrived at Cape Canaveral. (The U.S.S. Pierce delivered the spacecraft to Roosevelt Roads, and it was then airlifted to Cape Canaveral.)

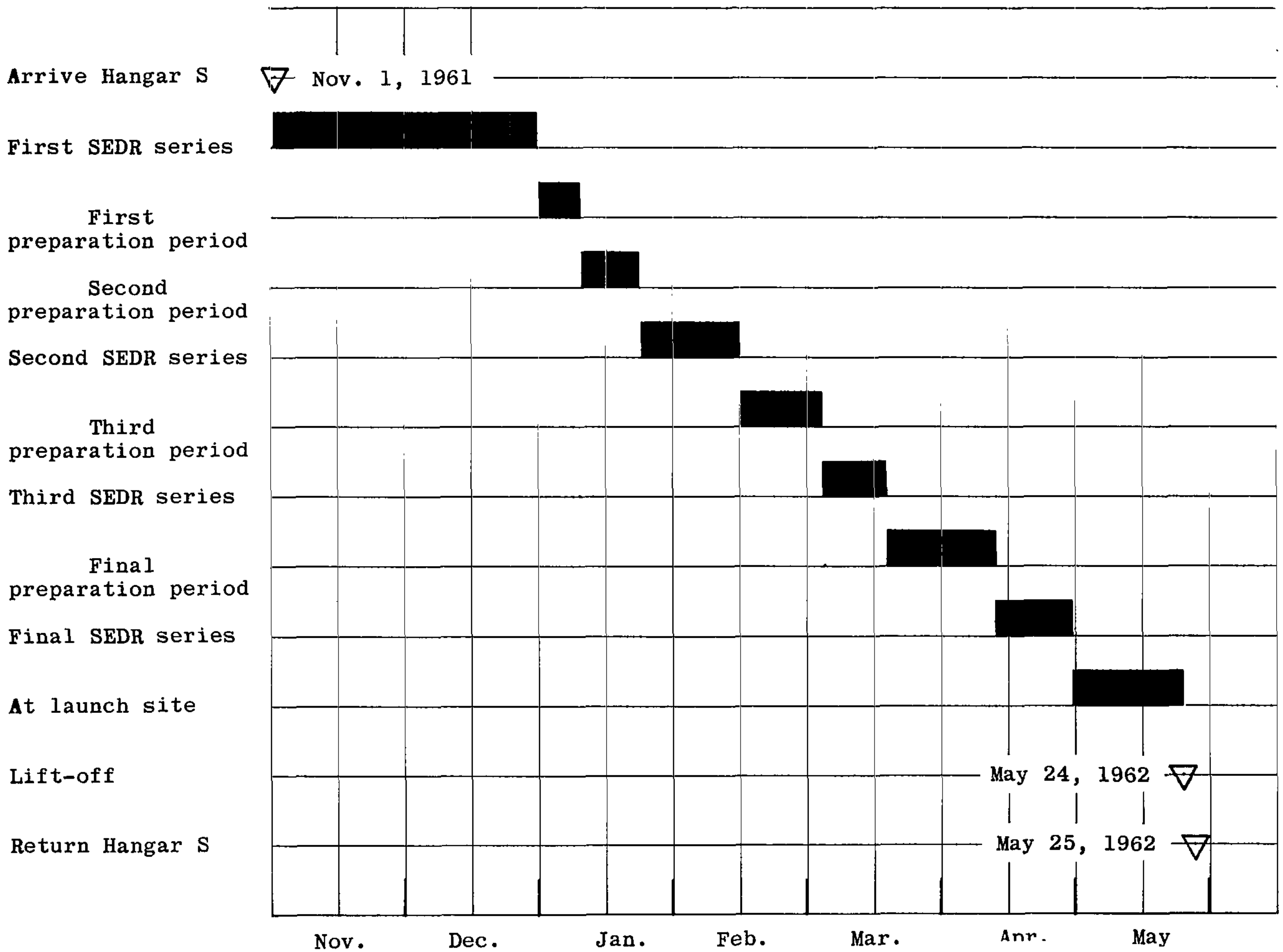


Figure 7.- Spacecraft 18 prelaunch history.

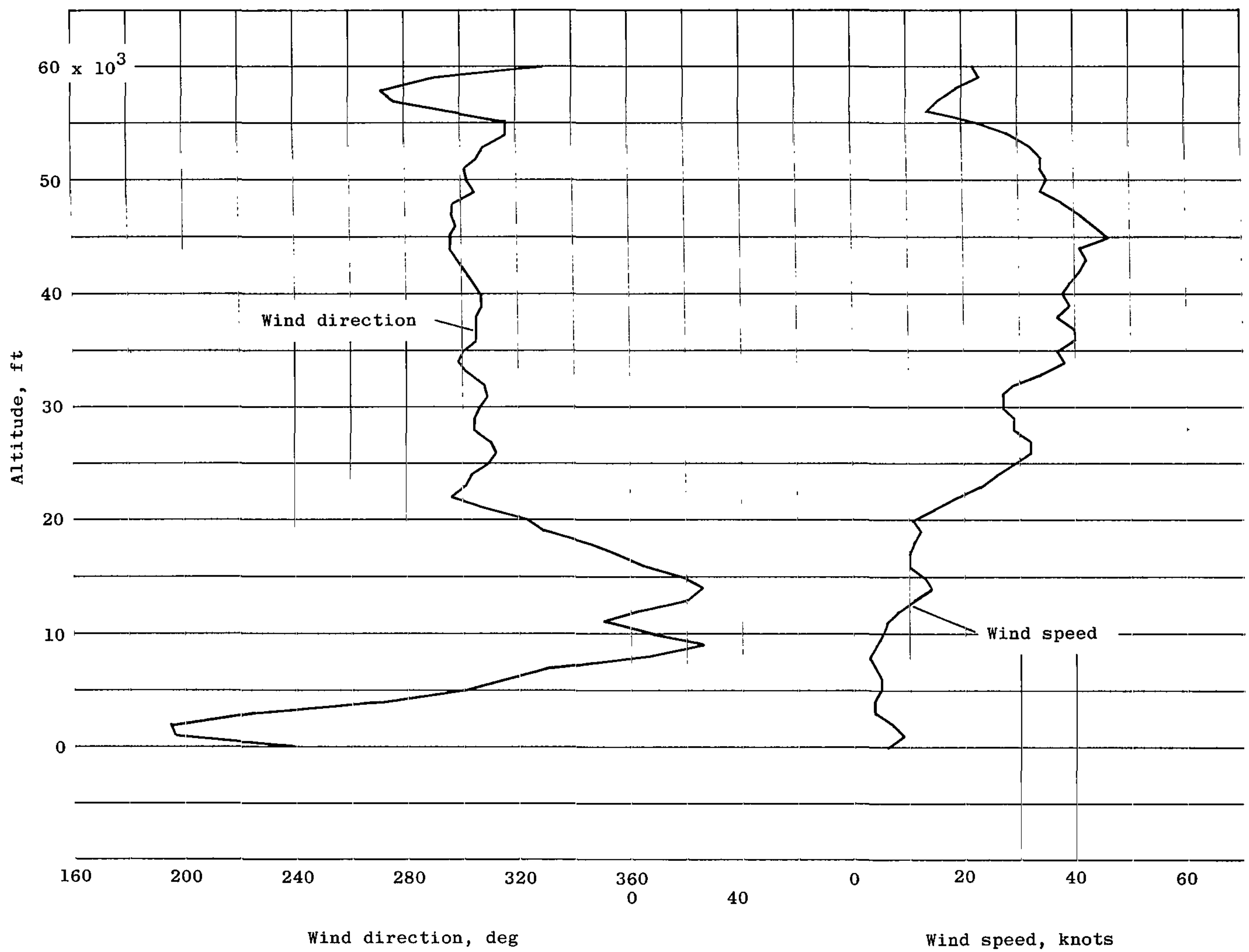


Figure 8.- Launch site wind direction and speed.

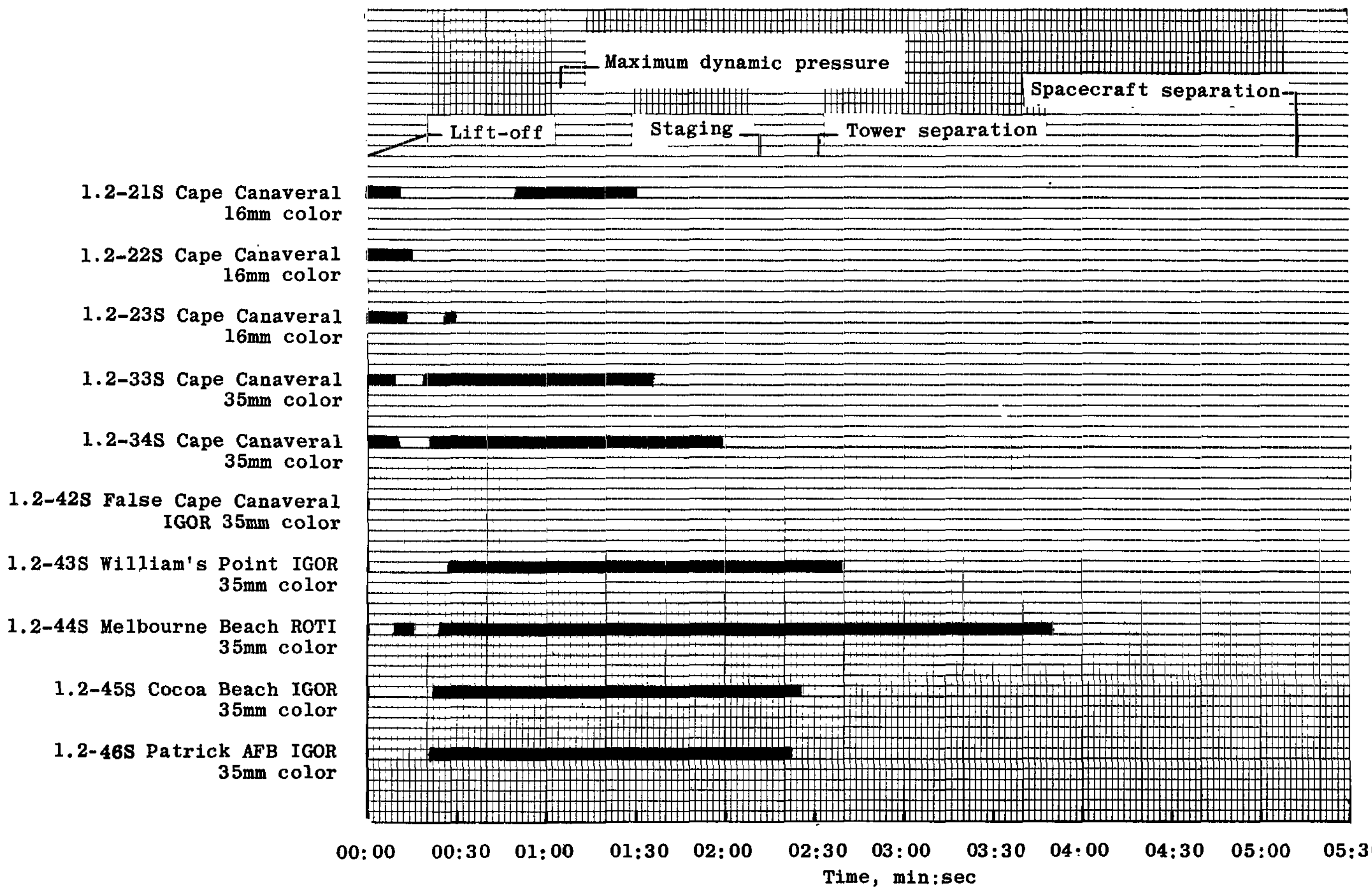


Figure 9.- AMR engineering-sequential tracking-camera coverage.

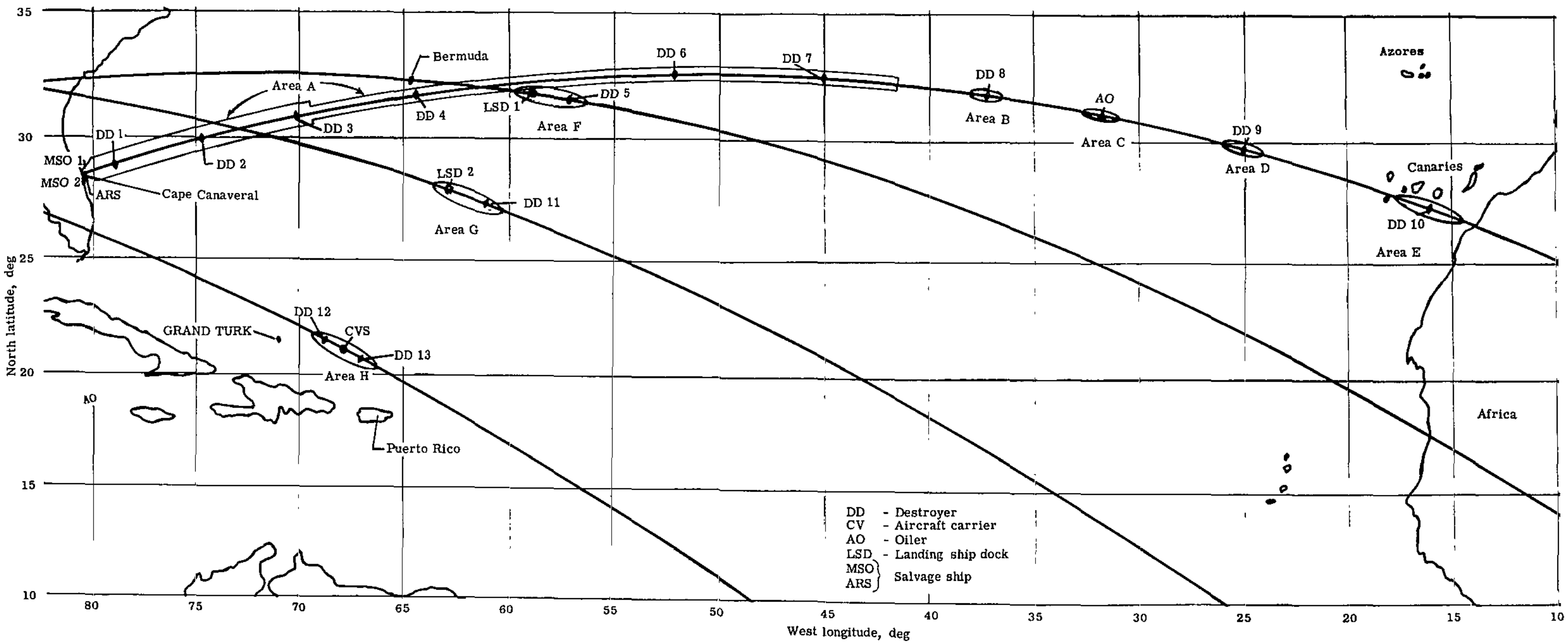


Figure 10.- Recovery areas and ship locations.

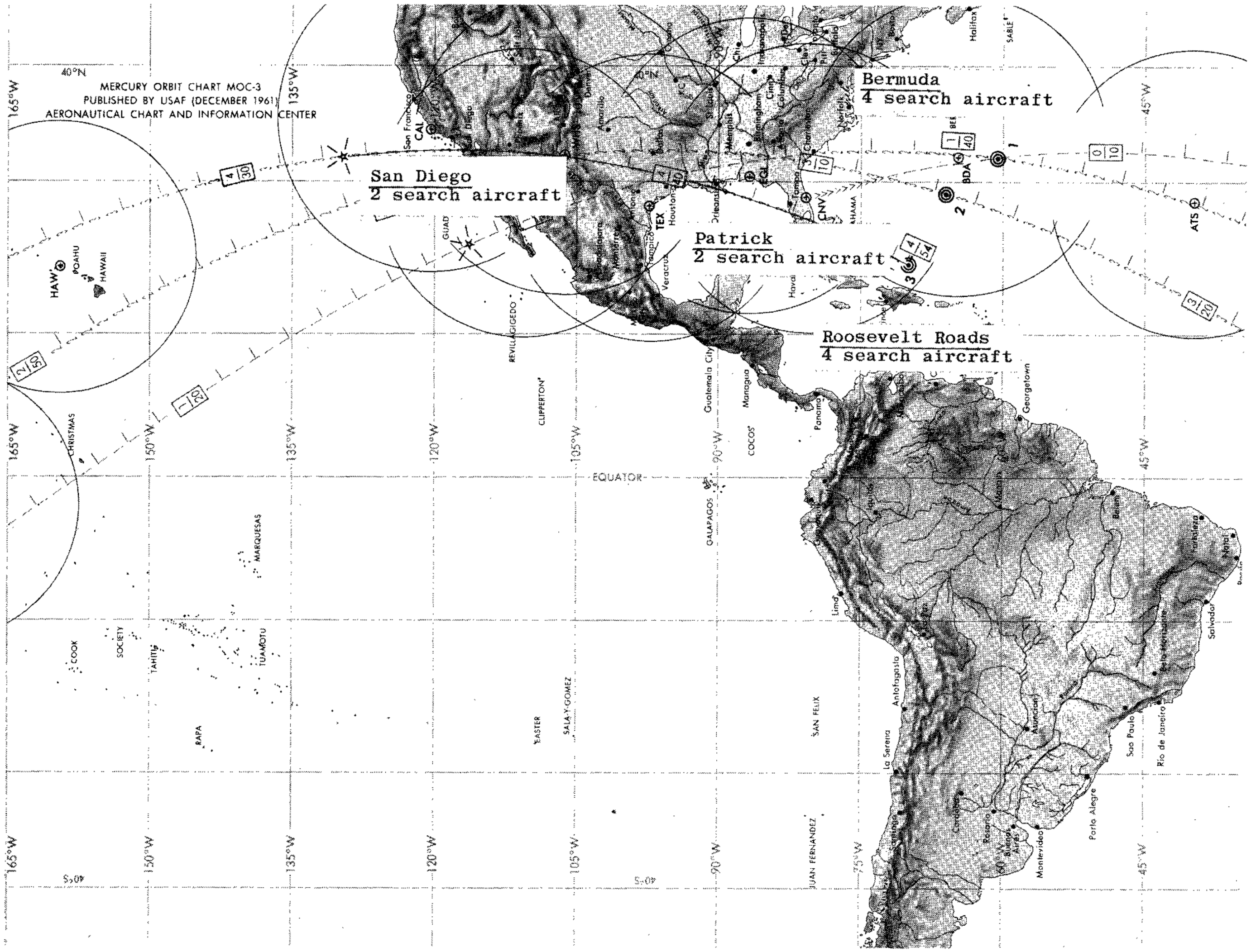


Figure 11.- Contingency recovery support forces.

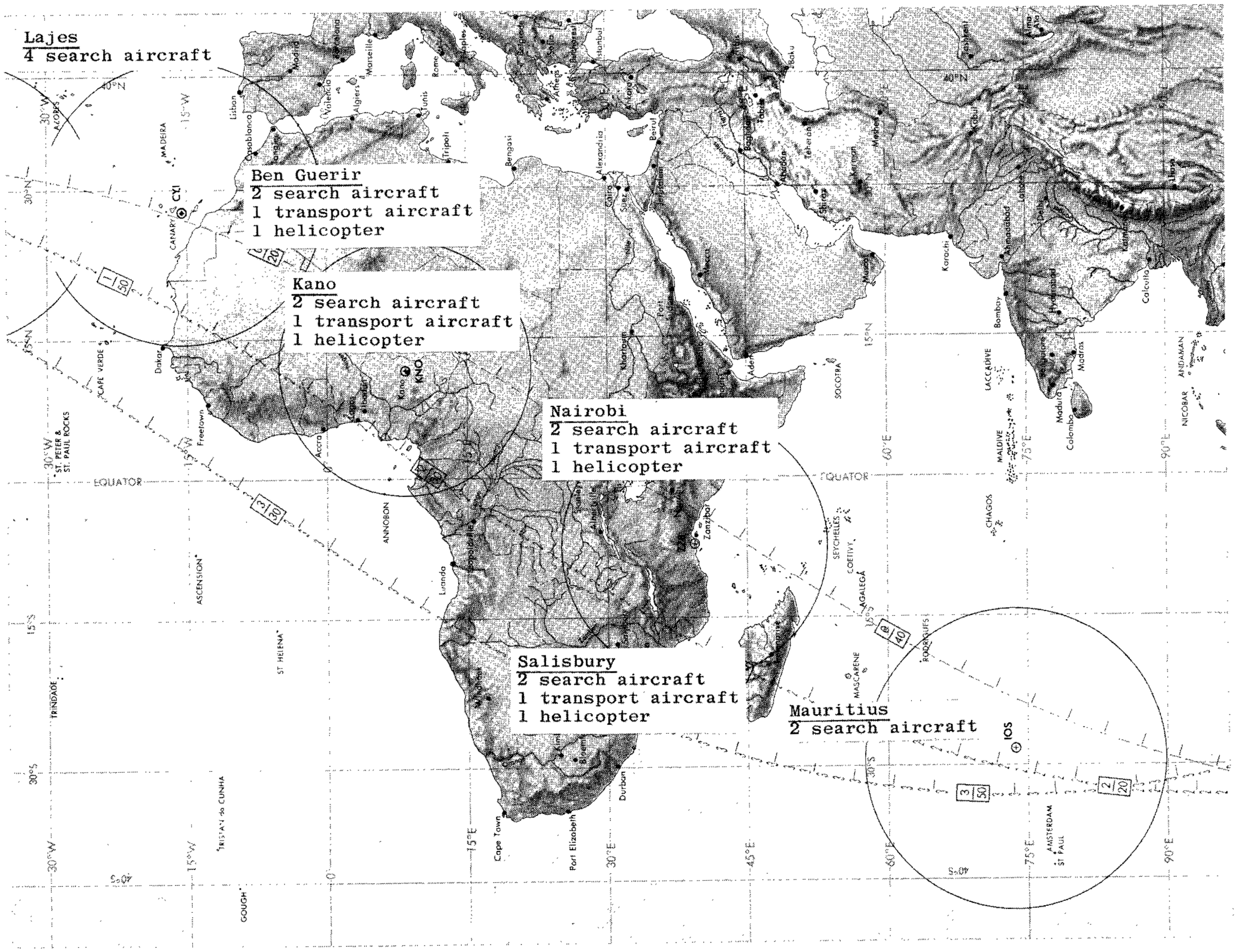


Figure 11.- Continued.

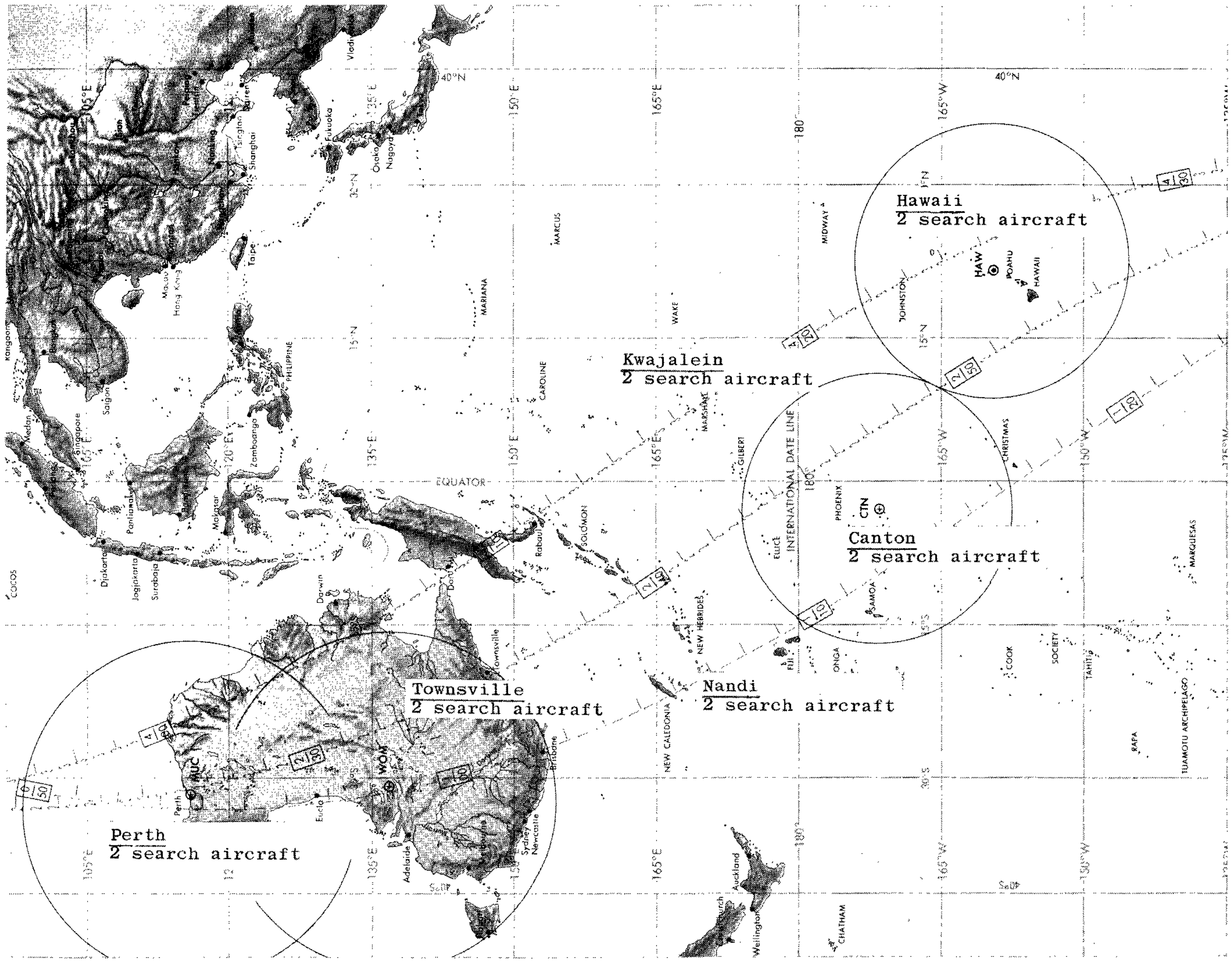


Figure 11.- Concluded.

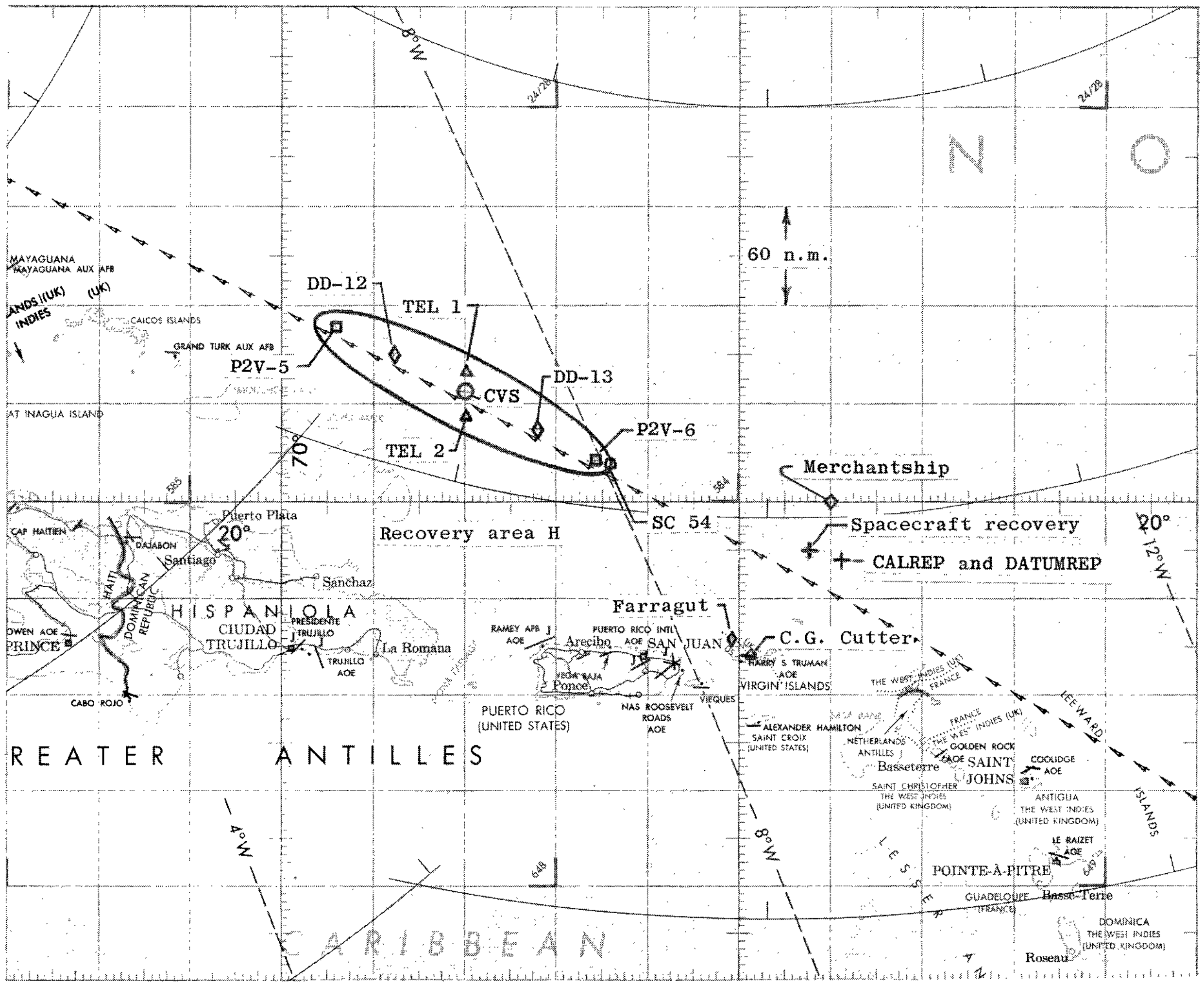


Figure 12.- Details of landing area H.

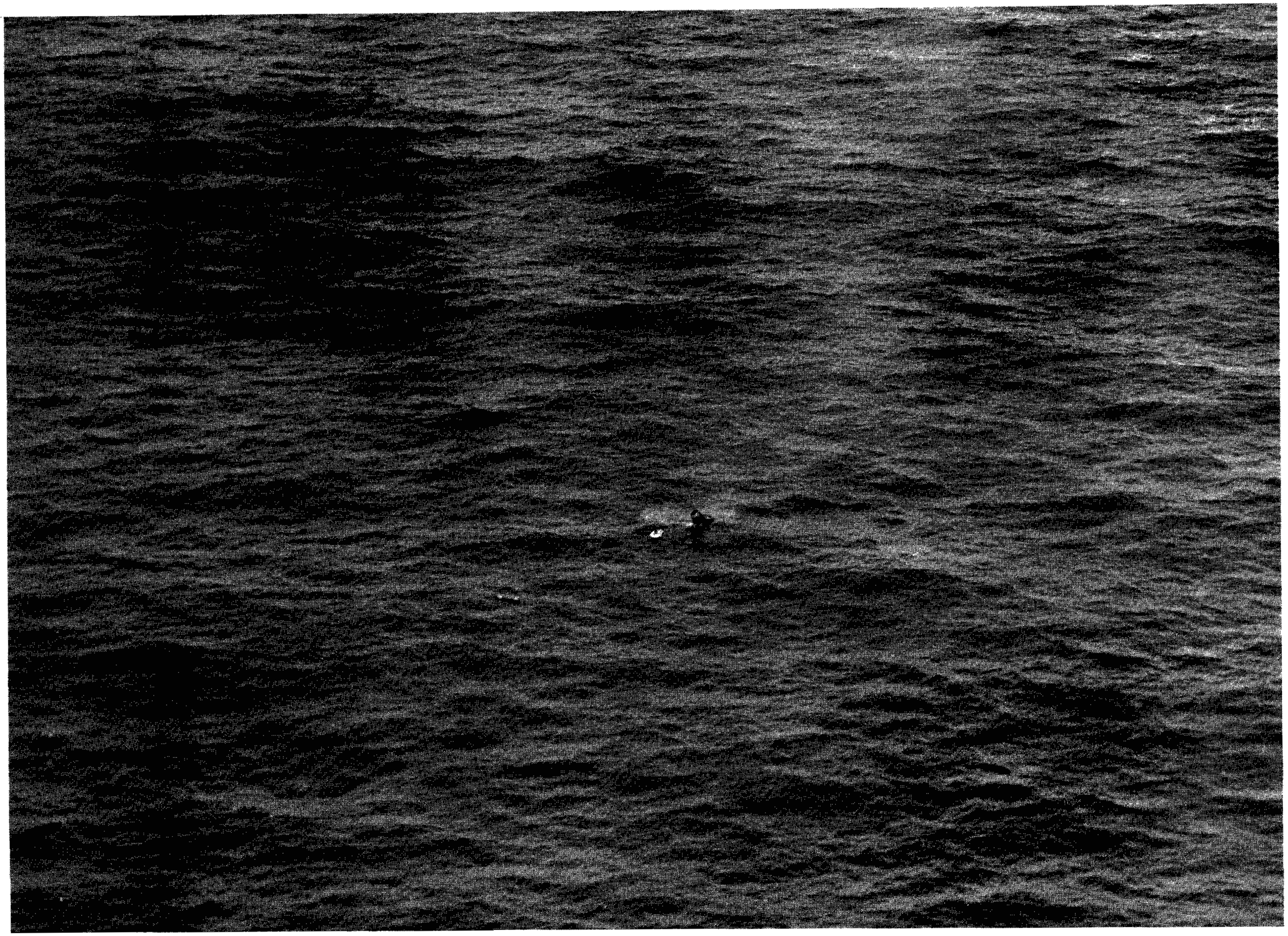


Figure 13. - Spacecraft prior to installation of auxiliary flotation collar.

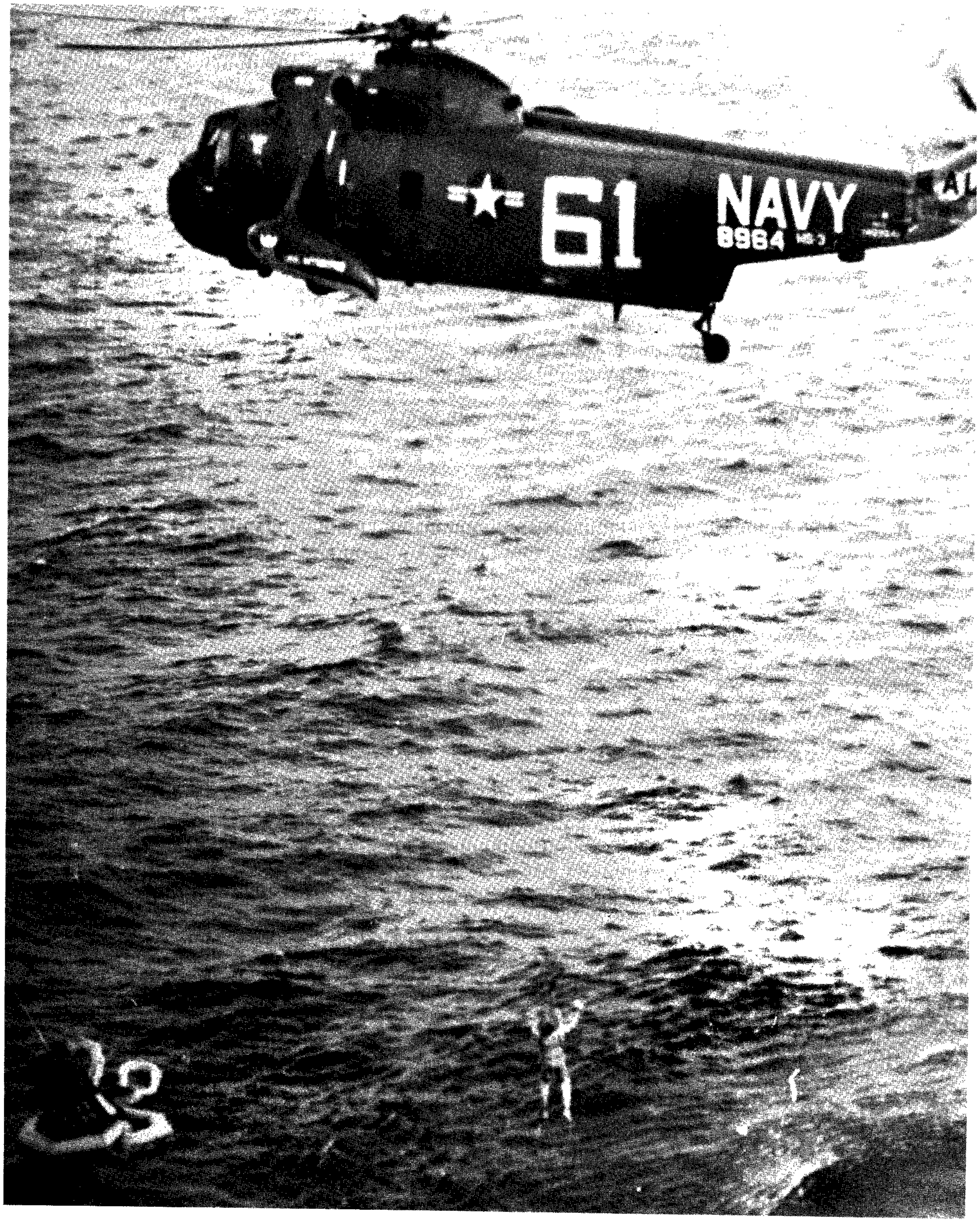


Figure 14. - Astronaut retrieval by HSS-2.

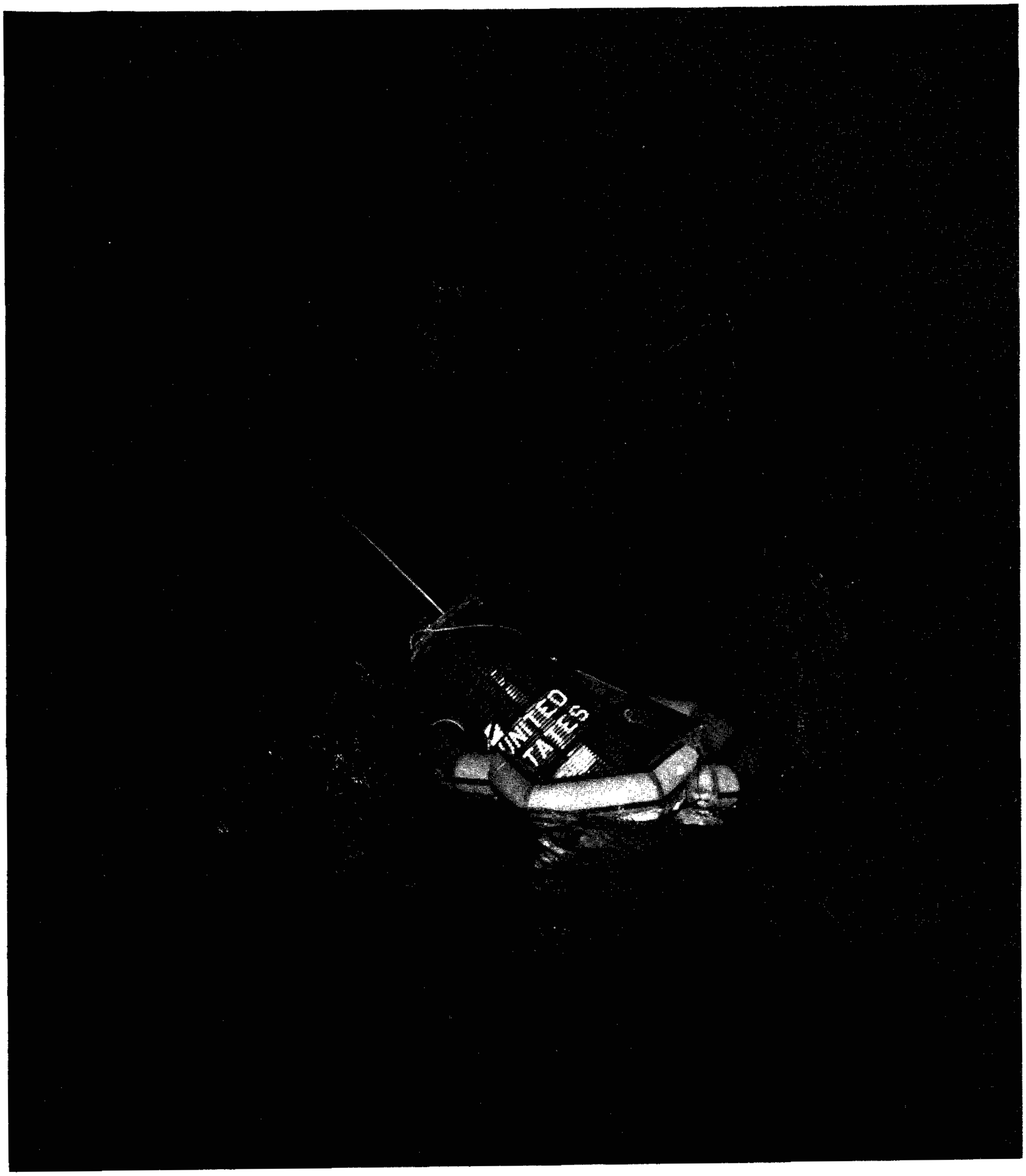


Figure 15.- Spacecraft prior to pickup.

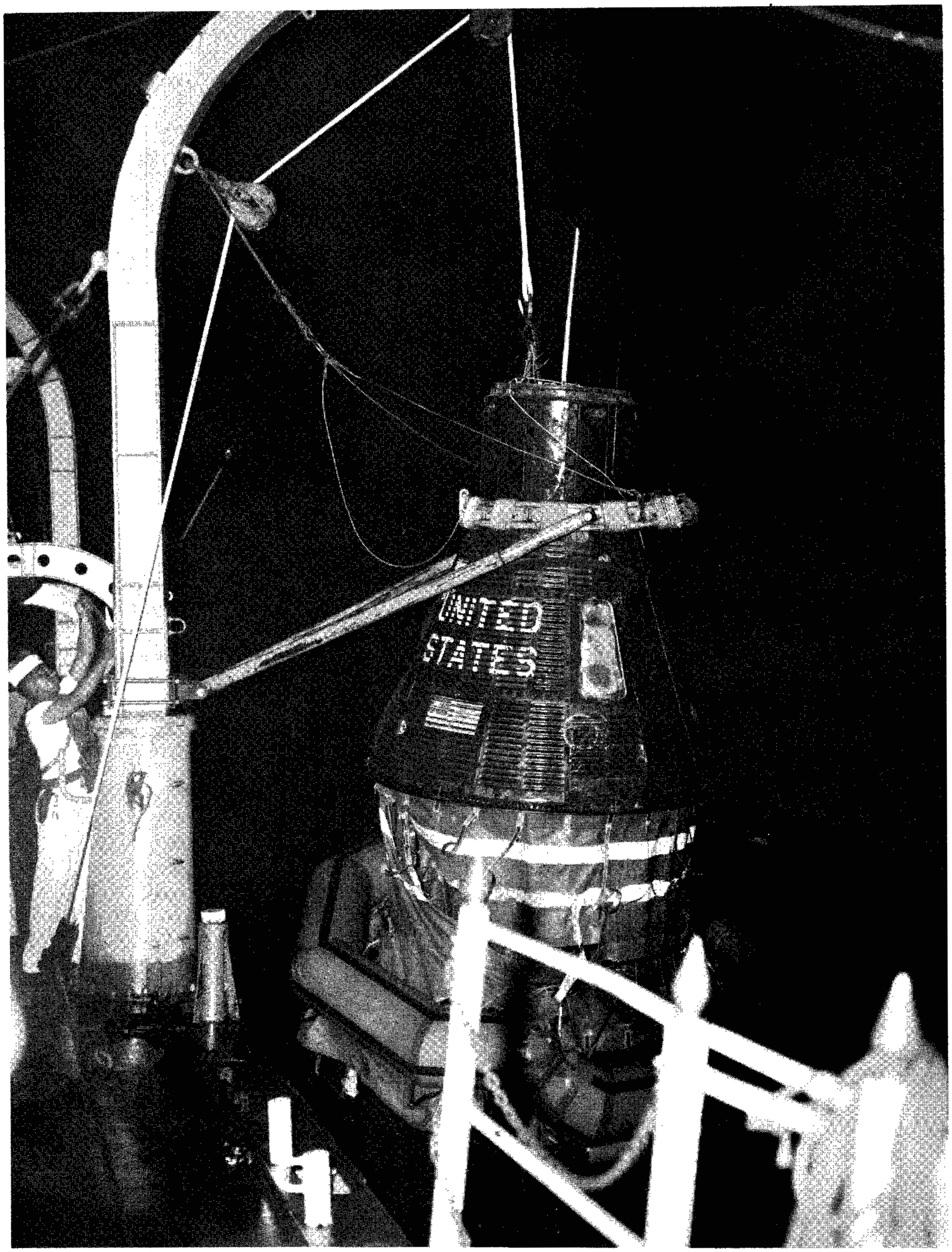


Figure 16. - Spacecraft being hoisted aboard recovery ship.

MISSION PERFORMANCE

The technical results of the MA-7 accompanied by an analysis of the flight data are presented. The performance analyses are grouped into the following major areas: spacecraft performance, aeromedical analysis, astronaut flight activities, astronaut flight report, launch vehicle performance, trajectory and mission events, and Mercury Network performance. The spacecraft performance section of this report includes all the major spacecraft systems. In addition, postflight inspection and scientific experiments are discussed. The aeromedical and astronaut sections deal with the astronaut's well-being, his activities, and his own personal narrative of the flight. The section which presents the launch vehicle performance is a very brief synopsis of Atlas systems operation. The Trajectory and Mission Events section consists largely of a graphical presentation of major trajectory parameters and mission event times. The Mercury Network is analyzed in the areas of trajectory, telemetry, command system, and communications.

SPACECRAFT PERFORMANCE

The spacecraft as an entity performed adequately. Some system anomalies were experienced, and analyses of these anomalies 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. A compilation of unpublished recorded flight data, without analysis, is available for technical referencing. The reader is directed to reference 1 for a more detailed systems description than is contained herein.

Spacecraft Control System

With the single exception of the pitch horizon scanner, spacecraft control system components functioned normally throughout the flight. The horizon scanner problem is discussed in detail in the paragraphs which follow, and the analysis takes into account the astronaut's comments concerning orbit attitude and attitudes prior to retrograde.

System description. - The spacecraft control system is designed to provide attitude and rate control of the spacecraft and is capable of operation in the following modes:

1. Automatic stabilization and control system (ASCS), with secondary choices of orientation, orbit, and auxiliary damping modes

2. Fly-by-wire (FBW)

3. Manual proportional (MP)

4. Rate stabilization control system (RSCS)

Modes 1 and 2 employ the automatic reaction control system (RCS) thrusters, while modes 3 and 4 use the manual RCS thrusters. Each RCS has its own fuel supply and is independent of the other. Combinations of modes 1 and 3, 2 and 3, or 2 and 4 may be used simultaneously. The amplifier-calibrator (amp cal) employed standard A-8 logic circuitry and did not have the single-pulse insurance feature in orbit mode that was employed in spacecraft 13 (MA-6). This insurance feature prevented more than one actuation of a given thruster when the amp cal effected operation of that thruster. The data from the MA-7 flight do not show any double actuations of thrusters in the orbit mode, and therefore the lack of this insurance feature did not affect the control system performance.

A MANEUVER switch was placed in series with the 0.05g switch fuse to remove torquing of the direction-gyro gimbals. This arrangement effectively disables the yaw reference slaving system and pitch orbital precession (4°/min) as the astronaut's discretion. This allows the astronaut to perform spacecraft maneuvers without introducing errors in his attitude displays.

Flight control analysis. - Systems operation was normal during the flight, with the exception of a pitch horizon scanner malfunction which is evident from the data as having been present before spacecraft separation from the launch vehicle. The pitch horizon scanner output read +17° at 40 seconds after tower separation. At this time, the launch vehicle pitch gyro read approximately -0.5°, revealing an 18° error in scanner output. At spacecraft separation the spacecraft pitch gyro was in error by about 20°. This error is shown in figure 17.

At various times during the orbital phase, the pitch horizon scanner output drifted without apparent spacecraft motion, as was found between 00:07:20 and 00:08:30, when an apparent slaving rate of 20° per minute would be required to duplicate the scanner-gyro-reference shift. The nominal gyro slaving rate is 8° per minute. From known astronaut reference positions during the orbital period, the comparable pitch horizon scanner output was observed to be in error by varying amounts between +50° and -20°.

During the retrofire period, a trajectory computation based on radar tracking data yielded a mean pitch attitude of -36.5°, whereas the maximum horizon scanner reading was -17° (fig. 18). This comparison and that which was made during the launch phase are the only independent sources which verify the scanner bias, and these are in excellent agreement.

The ASCS orbit mode performance appeared to be satisfactory, but cannot be evaluated in detail since continuous scanner slaving was employed. The ASCS orbit mode operation can be best analyzed when the gyros have been free for an extended period of time, thereby eliminating the scanner slaving.

The orientation mode displayed a divergent oscillation at 04:26:13 when the astronaut switched to ASCS in order to maintain an accurate retroattitude. This divergent oscillation was caused by the rate-gyro spin motors not having sufficient time to run up, since they were shut down during the previous 2 hours of manual-proportional-control system utilization. The nominal rate gyro run-up time is 2 minutes.

Control system utilization. - Spacecraft turnaround was accomplished manually by the astronaut, according to the flight plan, by using FBW. ASCS control was initiated at 00:07:10. By 00:56:50, maneuvering had been conducted by using all control systems and modes of operation, and the astronaut reported that these operations were satisfactory.

Manual control (FBW and MP) was used extensively during the flight. Approximately 17 minutes of the flight consisted of double authority control. The control system combinations utilized were FBW with MP and ASCS with MP. It should be noted that the high thrusters were actuated inadvertently a number of times by the astronaut while he was using FBW. The repeated use of the high thrusters, together with the use of double authority control, resulted in the unfavorable fuel usage rate, which can be seen in figure 19.

FBW was used to obtain and hold reentry attitude during retrofire. After retrofire, MP was utilized until manual fuel depletion at 04:34:00. Thereafter, FBW was used until spacecraft oscillations began to build up during reentry, at which time the auxiliary damping mode of ASCS was utilized until automatic fuel depletion at 04:49:58.

Since the scanners were lost when the antenna canister was jettisoned during the normal landing sequence, postflight inspection and analysis of these units were impossible. However, postflight tests on the same type units have indicated three possible models of failure: (1) a capacitor anywhere in the circuit short circuited to ground; (2) a failure of the transistors (Q801 and/or Q802) in the flip-flop circuit and subsequent loss of the reference output and the loss of the pulse generating circuit and time reference, and (3) a failure of a transistor in the dc amplifier and subsequent reduction of the data factor by a factor of 10.

Twice during the flight the spacecraft gyros failed to cage properly on the first attempt. However, in both cases, a reattempt resulted in proper caging. The first instance occurred at 02:01:04. The astronaut waited for 40 seconds before recycling the gyro switch, and during this period, the pitch gyro output slowly increased from off-scale negative to nearly zero. After recycling, the gyro maintained the cage position of 0°. The second instance occurred at 04:40:14. The astronaut waited for 9 seconds before recycling the gyro switch; and during this period, the yaw gyro output decreased from an excess of +70° to +65°. After recycling, the yaw gyro caged properly and decreased to zero in about 4 seconds.

Although caging of the gyros is possible at any angle, it is recommended that caging be conducted when spacecraft attitudes are less than 30°. The reason for the recommended maximum attitude stems from the fact that at the higher attitude angles, the pressure which the torquing cams can exert on the gyros is somewhat less than that available at 0°, and, therefore, the rate of response is lower than desired. This slower response at angles greater than 30° is not considered a problem since the caging operation is usually completed successfully after a second attempt.

The spacecraft oscillations began to diverge after automatic fuel depletion and continued until manual drogue-parachute deployment. An analysis of the onboard data revealed that the natural frequency and damping ratios of the MA-7 spacecraft during reentry were approximately the same as those experienced during the MA-6 mission under similar conditions.

Reaction Control System

The reaction control system (RCS) was basically the same as that used for the MA-6 mission, with the exception of modified 1-pound and 6-pound thrust-chamber assemblies. The modification essentially involved replacing the stainless-steel fuel-distribution (Dutch weave) screens with platinum screens and a stainless-steel fuel-distribution plate, reducing the volume of the automatic heat barriers and solenoids, and moving the fuel-metering orifice to the solenoid inlet. All changes were incorporated into the 1-pound thruster assemblies, but only the platinum screens were added to the 6-pound thruster assemblies.

Objectives of the thruster configuration change for the MA-7 mission were to eliminate the possibility of blocking the fuel-metering orifices with particles of Dutch weave screens, as is presumed to have occurred on the MA-6 mission, and also to reduce the total impulse per pulse of low-thruster operation in the ASCS orbit mode. Ground tests conducted on this new configuration indicated an approximate reduction of 50 percent of total impulse per thruster pulse.

Heat sinks were attached to the automatic and manual roll-thruster assemblies in a manner similar to that employed on the MA-6 mission in order to reduce propellant feed-line temperatures.

The astronaut's report that there were no malfunctions in the RCS is substantiated by the onboard recorded data. The high rates of fuel consumption appear to be consistent with the frequency and duration start of thruster activity. There is no evidence, either from flight data or from postflight inspection, of fuel leakage.

Propellant feed-line temperatures were measured during the flight and maximum temperatures recorded are listed in the following table:

Thruster position	Temperature of feed line, °F	Approximate time, hr:min
Automatic roll (clockwise)	104	03:48
Automatic roll (counterclockwise)	105	01:55
Manual roll (clockwise)	108	03:28
Manual roll (counterclockwise)	119	03:00
Automatic pitch (up)	128	03:43
Automatic pitch (down)	139	03:27
Automatic yaw (right)	142	03:34
Automatic yaw (left)	136	03:41

An analysis of the data indicates that thruster impulse of the expected magnitude was delivered whenever a thruster solenoid was actuated. Angular velocity changes imparted to the spacecraft by automatic system thruster operations were nominal. A history of automatic and manual fuel usage is presented in table VIII.

Postflight inspection of all thrust-chamber assemblies revealed that they were in excellent condition with evidence of a normal amount of salt water corrosion and heat discoloration. The results of the postflight RCS inspection are presented in table IX. The only noticeable conditions were the heat markings on the pitch and yaw heat barriers, which varied from 0.25 to 0.45 inch long. These markings were not evident on the 1-pound roll heat barriers; however, a heavier discoloration and slight oxidation of the diffuser plates existed in the pitch and yaw 1-pound thrust chambers. Diffuser plates in the roll chambers were light blue in color.

The platinum screens in all chambers were found to be in excellent condition with no evidence of deterioration.

All automatic system solenoids were inspected and tested for electrical actuation. The 24-pound pitch-down and yaw-right solenoids failed to operate with specification voltage applied. The failure to operate is attributed solely to postflight salt-water corrosion, since these units operated satisfactorily during the flight. All other automatic system solenoids operated satisfactorily. Detailed inspection of the 1-pound and 6-pound solenoids revealed no apparent discrepancy, and the poppet tips were in good condition in all respects. No rust was seen within the valves, but in a number of cases the plating was cracked at the outlet port.

Inspection of the 24-pound solenoids revealed rust in varying degrees within the bore, mainly at the metal insert and poppet bore lip. The inoperative valves had a heavy salt-like substance within the bore. Inlet screens were generally clean, and the few exceptions that were found revealed deposits of minute plastic and crystalline particles.

Environmental Control System

The environmental control system (ECS) is designed to provide a comfortable level of temperature and humidity in the pressure suit and to maintain appropriate suit and cabin pressures. The composition of the suit environment is 100-percent oxygen, and the nominal pressure level is 5.1 psia. Control of this environment is accomplished by removing metabolic heat, carbon dioxide, and water. Replenishment of the atmosphere is provided from two tanks, each containing 4 pounds of gaseous oxygen stored at 7500 psig. In addition to the metabolic requirements of the astronaut, the ECS also removes heat from onboard electrical equipment and supplies gas makeup for cabin overboard leakage.

System description. - The ECS installed in spacecraft 18 represents the specification system in all respects. It differs from the ECS on spacecraft 13 (MA-6) in two respects. First, the constant oxygen bleed, which bypassed the suit pressure regulator and supplied oxygen to the astronaut in excess of metabolic needs, was deleted. Deletion of this oxygen bleed resulted in oxygen being supplied to the astronaut on demand. Secondly, the oxygen partial pressure was measured in the cabin circuit instead of in the suit circuit.

System performance. - Data for the following analysis were obtained from both the commutated data recorded on board and the onboard voice tape. The latter source was utilized for cabin and suit steam-exhaust temperatures, excess coolant-water warning-light actuations, and heat-exchanger coolant-control valve settings, none of which are recorded.

The only ECS measurement known to be inaccurate was the cabin oxygen partial pressure. Difficulty with the oxygen partial-pressure sensor had been encountered during spacecraft preparations, and the final calibration was known to be only approximate.

The flight data deviate from the system's design criteria only in the performance of the cabin and suit-cooling systems.

Higher than desired temperatures in the spacecraft cabin and pressure suit were experienced during the MA-7 flight, and these values are plotted in figures 20 and 21, respectively. In the same figures, heat-exchanger steam-exhaust temperature and coolant-control valve settings are also shown. The steam-exhaust temperature readings are used by the astronaut to monitor performance of the cooling systems and to make the decisions on where to set the control valves manually. The lag inherent in these monitoring points with control valve manipulations resulted in some difficulty in determining the correct settings and was a major contributing factor to the high temperatures experienced. Extensive postflight tests have revealed that the coolant-control valve-setting problem can be minimized by relocating the monitoring point to the metal dome of the heat exchanger where the time lag between a valve setting and a corresponding change in dome temperature has consistently been less than 10 minutes during postflight tests.

A possible contributor to the high suit temperature is the partial freezing of the heat exchanger when high rates of water flow are used. This freezing can result in obstruction of the evaporative surfaces and a slight increase in the evaporation pressure. The design conditions are for evaporation at 0.1 psia pressure and 35° F temperature. An increase of 0.1 psi in this design pressure would raise the corresponding evaporation temperature to 53° F, which, in turn, would significantly reduce the system capability to condense and collect water. Flight data show that suit heat-exchanger exhaust temperature ranged between 65° F and 70° F, instead of the expected 50° F, thus indicating that the evaporation temperature was probably near 55° F and that partial freezing may have been experienced. As an example, figure 21 shows that the suit coolant-control-valve setting was advanced to give a high coolant-water flow rate at 03:27:00. The corresponding temperature decrease resulted in a comfortable suit temperature level until 04:15:00, at which time the temperature began to fluctuate. Ten minutes later, at 04:25:00, there was a sharp increase in the suit temperature. It is suspected that freezing of the suit heat exchanger occurred because of a high coolant-water flow rate for this period of an hour, which resulted in a decreased cooling efficiency just prior to and during the reentry phase.

The possibility of freezing can be reduced by relocating the monitoring point as previously discussed.

Difficulty in achieving high air-flow rates and good circulation of air in the cabin could have contributed to the high cabin-air temperature. Tests are being run on larger cabin-air cooling fans, but the results to date indicate that to obtain improved cooling requires too great an increase in power and water-flow requirements.

The many changes in the cabin coolant-control-valve setting prevent an accurate analysis of the effects of sunlight and darkness on cabin temperatures.

The MA-7 mission was the first orbital flight from which approximate values for astronaut metabolic oxygen requirements could be calculated. Prelaunch oxygen consumption was determined to be 0.0457 lb/hr or 261 scc/min (measured at 14.7 psia and 70° F). During orbital flight, the astronaut metabolic consumption was calculated to be 0.0722 lb/hr (or 408 scc/min). These metabolic consumption rates were calculated from the oxygen-pressure decay rates of the primary oxygen tank after accounting for the flow rate to the cabin through the constant bleed orifice of the suit-pressure regulator valve. The ECS design criteria for the astronaut metabolic rate are 500 scc/min. This rate is based upon oxygen usage data obtained during work of similar difficulty under 1g. The astronaut activity under weighless conditions demonstrated that weightless oxygen-consumption rates are of a similar level as those which occurred under 1g.

Launch phase: The ECS operated properly during the launch phase. The cabin and suit pressures maintained the proper differential of 5.5 to 6.0 psi above ambient pressure during ascent, and held at 5.8 and 5.9 psia, respectively.

Orbital phase: The cabin and suit pressures decreased slowly during the orbital phase because of a cabin-air leakage rate of 1000 cc/min that was established before flight. The pressure decay ceased at approximately 03:00:00, at which time the cabin pressure-control valve began supplying oxygen to compensate for the cabin leakage. The cabin pressure was then maintained at 4.9 psia. The only problems encountered during the orbital phase were the high suit-inlet and cabin-air temperatures previously described.

Coolant quantity indicating system (CQIS) data, which were telemetered to the ground and recorded on the onboard tape, indicated a coolant-water usage of 10.0 pounds when corrected for temperature change. Postflight inspection measured a usage of 10.23 pounds. This agreement represents the most accurate CQIS measurements in flight to date. Coolant usage averaged about 2.1 lb/hr over a period of 4 hours and 50 minutes, compared with a nominal flow rate of 1.6 lb/hr.

The secondary-oxygen-supply pressure increased slightly during the flight. This increase can be attributed to the increase in supply bottle temperature, as measured during flight. Temperatures were identical for both the primary and secondary supplies and indicated 72° F at launch and 86° F at landing. The decay of the secondary oxygen supply experienced during the MA-6 mission did not recur during this flight.

Reentry phase: The performance of the ECS during reentry was normal except for the suit and cabin temperature problems previously discussed. The astronaut opened the inflow and outflow valves manually during descent at 04:51:18, and this action placed the system in the postlanding mode. The emergency oxygen rate commenced at this time.

Communications System

System description. - The spacecraft communications system aboard the MA-7 spacecraft was identical to that in spacecraft 13 (MA-6) with one minor exception. The power switch was modified to provide a mode whereby the astronaut could record voice on the onboard tape recorder without RF transmission to the ground stations. Switching to the transmitting mode could be accomplished without the normal warmup time because the transmitter was maintained in a standby condition with the power switch in the record position.

Voice communications. - The UHF voice communications with the spacecraft were satisfactory. Reception of HF voice in the spacecraft was satisfactory; however, attempts on the part of the astronaut to accomplish HF voice transmissions were unsuccessful. The onboard tape recorder data showed that HF voice transmissions from the spacecraft were attempted three times during the mission as follows:

Time	Spacecraft attitude
01:07:16	Roll: +20° to off scale
	Pitch: Off scale
	Yaw: Undetermined
01:15:54	Roll: -35°
	Pitch: Off scale
	Yaw: Undetermined
03:21:00	Roll: -30° to off scale
	Pitch: -10° to off scale
	Yaw: Undetermined

Postflight tests of all spacecraft HF components, except the antenna which was severed as part of the normal recovery procedure, did not reveal any failures. The poor reception of the spacecraft HF transmission is attributed to spacecraft orientation, atmospheric condition, and the limited number of times utilized.

Radar beacons. - Performance of the C-band and S-band beacons was satisfactory, although slightly inferior to that of the MA-6 mission. Several stations reported some countdown on both beacons and amplitude modulation on the C-band beacon. The amplitude modulation was possibly caused by the modulation presented by the phase shifter (wobulator) and the drifting mode of the spacecraft, which resulted in a less than optimum antenna orientation. In view of these problems, both beacons were rechecked after the mission and found to be essentially unchanged from their preflight status.

Location aids. - Recovery forces reported that the auxiliary beacon (Super SARAH) and UHF/DF signals were received. The Super SARAH beacon was received at a range of approximately 250 miles and the SARAH beacon and UHF/DF were received at a range of 50 miles from the spacecraft. The HF rescue beacon (SEASAVE) was apparently not received by the recovery stations, although the whip antenna used by this SEASAVE beacon was reported by the recovery forces to be fully extended and normal in appearance. The SEASAVE beacon was tested after flight and found to be satisfactory. The reason why the SEASAVE beacon was not received is unknown.

Command receivers. - The command receivers operated satisfactorily. Increasing the low-telemeter frequency by 500 kc eliminated the interference problem which was experienced during the MA-6 reentry blackout period (ref. 1).

Electrical and Sequential Systems

Electrical system. - The spacecraft electrical system was a specification spacecraft system. Voltage and current profiles were similar to those of the MA-6 mission and were as expected. The electrical system in spacecraft 18 differed from that in spacecraft 13 (MA-6) in the following respects.

1. Inverter ac voltages were monitored on the ac voltmeter rather than by monitor lights.

2. The maximum-altitude-sensor battery was used as an auxiliary battery for the velocity sensor after retrofire command.

3. The 24-volt isolated bus was monitored on the number 2 position of the dc voltmeter select switch (position was blank on spacecraft 13).

4. A switch fuse was added to the phase shifter circuit for ON-OFF control during the special radar test.

The 150 and 250 v-amp inverter temperatures, shown in figure 22, increased from 112° F and 128° F, respectively, at launch to 175° F and 186° F, respectively, by 04:00:00. The temperatures appeared to be stable after this time. The rate of temperature increase appeared to decrease after the inverter coolant-control valve was advanced from the number 4 to the number 5 position at 03:00:38. The corresponding change in coolant-water flow is from 0.50 lb/hr to 0.64 lb/hr.

It was found during postflight tests that a number of fuses had blown on this mission that had not blown on previous missions. The blown fuses are attributed to sea water that entered the spacecraft after landing, since there were no indications of any fuses, other than squib-firing fuses, blowing prior to landing. The following is a list of fuses that blew as a result of sea water producing shorting paths to ground within the spacecraft.

1. Emergency hold control
2. Low-frequency telemetry
3. Instrumentation, dc number 6
4. Telemetered sequence, 6-volt isolated
5. Standby inverter
6. Isolated-bus regulator
7. Main inverter fans
8. Automatic H_2O_2 jettison
9. Phase shifter (switch fuse panel)
10. High-frequency telemetry (switch fuse panel)

As expected, squib-circuit fuses were blown as in previous flights. In the retrorocket ignition circuits, 5 of 6 fuses had blown, including the number 1 retrorocket switch fuse which also had a hole in the ceramic portion along the side. Records of current during retrofire led to the deduction that approximately 7 amperes passed through this fuse for 6 or 7 seconds before it blew. This is believed to be the source of smoke reported by the astronaut during retrofire, since this type of fuse commonly produces smoke when blown in this manner. The deduction was confirmed by the astronaut during postflight tests; for he observed two similar fuses blown, which produced a smoke having the same color and smell as that encountered in flight at the time of retrofire.

Postflight inspection revealed that two of the four diodes in the zener diode package were badly corroded. The corroded diodes were 14-volt zeners with their positive terminals connected through fuses to the main and isolated buses, respectively, and their negative terminals connected to the positive side of the other two 14-volt zeners, which have their negative terminals connected to spacecraft ground. The zener diodes exhibit an electrolytic effect when powered under a sea-water environment. Electrolysis occurs between the case, which is at a 14-volt positive potential when the diode electrically adjacent to the bus is conducting, and the spacecraft structure, which is at ground or zero potential. This phenomenon has been demonstrated in the electrical laboratory.

Sequential system. - The sequential system of spacecraft 18 was similar to that employed for spacecraft 13, but the following modifications were incorporated:

1. The spacecraft-separation bolt-fire relay was electrically actuated at spacecraft separation.

2. The landing-bag deployment monitoring circuit was changed. The limit switches were wired so that the actuation of both was required for telelight operation and telemetry indications.

3. The emergency retrosequence relay contacts were electrically bypassed so that the spacecraft was capable of accepting simultaneous retrofire signals from the clock and ground command.

4. The HF transmitter/receiver was automatically turned on at tower separation rather than at spacecraft separation.

5. The O_2-quantity light on the right-hand instrument panel was disconnected.

6. The scanner slaving signal was changed from programed to continuous.

7. A barostat was added inside the cabin and wired so that the automatic recovery system was not armed until the cabin pressure was above 9.62 psia on descent.

8. The emergency drogue-parachute-deployment switch was wired so that the periscope would extend and the snorkel-door blow-off squibs would ignite when the switch was actuated.

The sequential system performed as expected throughout the mission with the following exceptions:

1. Retrofire had to be accomplished manually because there was no attitude permission from ASCS. Had there been attitude permission, the number 1 retrorocket would have fired at approximately 04:33:05, since retrosequence was initiated at 04:32:35. Onboard data show that the manual retrofire circuit was closed at 04:33:08 and that thrust was on at 04:33:08.5. The pilot commented after the flight that retrofire occurred 1 to 2 seconds after he pushed the retrofire switch. Extensive postflight tests of the retrosequence circuitry did not reveal any malfunction which could cause a delay in retrofire. It should be noted that no recorded data indicate when the pilot pushed the manual retrofire switch. The time is known to have been after 04:33:05, when automatic retrofire would have occurred had attitude permission been available, and before 04:33:08, when onboard data show that the manual circuit was closed. The point in doubt is when, in real time, the pilot did push the manual retrofire switch; and this moment can never be definitely determined with any degree of certainty.

2. The main parachute was deployed manually by the astronaut, because automatic deployment did not occur at 10 600 feet. Postflight checks indicated that the

automatic system did function during the descent phase, although it was some time after main parachute deployment. This system is discussed in more detail in the Mechanical and Pyrotechnic Systems section.

3. The onboard tape recorder and other telemetry components apparently did not lose input power at landing plus 10 minutes as planned. Upon initial power-up when the spacecraft was returned to Hangar S, a short circuit was found between the two pre-impact buses, which supply power to telemetry, and the spacecraft main dc bus. After the spacecraft was dried in the altitude chamber, it was found that the short circuit no longer existed. The problem probably resulted from sea water entering one of the fuse blocks which contain the three buses or from sea water entering one of the instrumentation packages. This sea water would have been removed when the spacecraft was dried in the altitude chamber, which explains why the pre-impact buses remained powered.

Instrumentation System

The instrumentation system monitored spacecraft conditions, operational performance of spacecraft systems, and physical conditions and reactions of the astronaut. Most parameters monitored were recorded either on the onboard tape or on the astronaut observer camera to provide a permanent record for subsequent study and interpretation. Significant parameters necessary for the astronaut to perform his tasks were displayed in the cabin, and parameters required by ground personnel for real-time analysis and evaluation were telemeterd to the ground through two transmitters.

System description. - The instrumentation system used in the spacecraft of the MA-7 mission was basically the same as that used in the spacecraft of the MA-6 mission. However, some changes were made to accommodate new experiments and to provide additional data; and some additions, deletions, and substitutions of equipment and parameters were made to improve the system and to reflect knowledge gained on previous missions.

The research experiments requiring instrumentation were the zero-gravity liquid behavior experiment and the tethered inflatable balloon experiment. The zero-gravity experiment utilized a transparent sphere containing liquid, and the sphere was photographed with the astronaut-observer camera throughout the flight. A 30-inch mylar balloon was deployed when the spacecraft was in orbit. The balloon was tethered to the spacecraft with a nylon line which was attached to a strain gage. The resulting tension exerted on the strain gage was measured and recorded on the onboard tape.

A more comprehensive temperature survey was incorporated in the spacecraft of the MA-7 mission. The survey utilized temperature-sensing instrumentation and a low-level commutator. The data were not telemetered, but were recorded on an existing channel of the onboard tape recorder.

Deletions in the spacecraft instrumentation system were the coolant-quantity indicator, O_2 partial-pressure indicator, and the instrument-panel camera. In addition, telemetry high-frequency and low-frequency transmitter temperatures, the backup heat shield temperatures, cross strapping of the X-axis and Y-axis accelerations, and the command receiver signal strengths were also deleted. The telemetry transmitter temperatures and heat shield temperatures were replaced by the "B" nut temperatures on the clockwise and counterclockwise, automatic and manual, roll thrusters. Backup segments for the command-receiver signal strengths and the four thruster "B" nut temperatures were incorporated with the removal of the cross strapping, which also enabled the separation of the horizon-scanner pitch and roll ignore by placing them on separate segments. Four segments were then left unassigned; one was used as a 3-volt reference and the other three were zero references.

Other changes to spacecraft 18 are listed as follows:

1. Suit and cabin steam-vent temperature pickups were installed in the steam-vent overboard ducts and monitored on a dual indicator.

2. A modified integrating accelerometer was installed which reduced the 240-foot-per-second relay to 210 feet per second.

3. A semi-automatic blood pressure measuring system (BPMS) with a manual start button on the instrument panel was installed.

4. The oxygen partial-pressure transducer was relocated from the suit circuit to the cabin.

5. The suit pressure indicator was calibrated from 4 to 6 psia only.

6. The low-frequency-transmitter center frequency was raised 500 kc to eliminate RF interference experienced during the MA-6 flight.

Prelaunch. - The fact that the oxygen partial-pressure transducer began to rise in output the day before the first scheduled launch indicated a drying out of the transducer. A decision was made to remove only the transducer and make calibrations by using another set of amplifiers. The calibration curve did not follow the same curve as the previous calibration, and a decision was made not to rely on the information received.

Approximately 34 minutes prior to lift-off, three cycles of the BPMS resulted in intermittent signals. BPMS cycles near lift-off appeared normal, but the intermittent signals reoccurred during flight. A discussion of the problem is included in the Orbit section.

Launch. - During a period of approximately 20 seconds, starting at T+90 seconds, extraneous signals appearing at the electrocardiograph (ECG) electrodes drove the subcarrier oscillators (SCO) from band-edge to band-edge. These extraneous signals were primarily attributed to rapid body movements of the pilot and possibly excessive perspiration during this period.

At lift-off, the telemetry signals were of good quality, with signal strengths of 8000 microvolts for the low-link telemetry and 10 000 microvolts for the high-link telemetry. A loss of signal for 1 second was evident at staging, which is normal and is caused by flame attenuation. At tower release, the signal strengths increased from 500 microvolts to 700 microvolts on both links. At launch, the transmitter frequencies were -6.0 kc from the center frequency for the low-link and -5.0 kc from the center frequency for the high-link. On the first orbital pass, the high-link was +7.0 kc from the center frequency, and no reading was made on the low-link. Center frequency readings were not made on the telemetry links during the second and third orbital passes. Both telemetry links were modulated for a total of 60 kc deviation throughout the MA-7 mission.

Orbit. - While in orbit, the astronaut reported the zero-gravity experiment as having "Fluid gathered around the standpipe. The standpipe appears to be full and the fluid outside the standpipe is about halfway up." Postflight photographs from the pilot-observer camera confirmed this. The mylar balloon was deployed in orbit, but the test was unsuccessful from an overall standpoint. A more detailed discussion is presented in the Scientific Experiment section of this report.

The temperature survey worked well throughout the flight; however, the low clockwise automatic thruster gave no temperature reading. Postflight inspection revealed a broken thermocouple.

Telemetry data indicated an abrupt increase in the astronaut's body temperature 1 hour after launch. The indicated temperature was erratic from that point until $2\frac{1}{2}$ hours after launch at which time the readout stabilized and appeared normal. During the erratic period an R-calibration was given with no change in body-temperature readout. In addition, the astronaut stated that he was comfortable during the erratic period and that he did not believe the telemetered data. Postflight analysis resulted in the conclusion that the body-temperature data were unreliable during the erratic period. The data at all other times were concluded to be valid. Postflight tests of the instrumentation failed to reveal any malfunction which could have caused the erratic temperature readings.

Intermittency in the BPMS was again evident during flight. The system pressurized when the astronaut activated the start button, but several times during the flight the system did not show any pulses during bleed-down time. Twenty-four blood pressure cycles were obtained during the flight; but the data were very erratic and were not reducible, with any degree of certainty, to the actual blood pressure of the astronaut. The intermittent signals and the unusual inflight data dictated the need for a postflight evaluation of the BPMS. The postflight systems check revealed that the intermittent signals were resulting from a broken cable in the microphone pickup. However, this malfunction could not affect the magnitude of the data transmitted since an intermittent short circuit sends either valid signals or none at all. Additional tests were performed to determine the cause of the erratic inflight data. These tests revealed that the BPMS had not been properly calibrated before the MA-7 flight and that accurate interpretation of the data was not possible.

The astronaut reported that the rate indicator moved during Z-calibration. This movement is normal, since the Z-calibration changes the load on the transducer.

The oxygen partial-pressure transducer appeared to operate normally during flight; however, post-calibration of the system was not possible because of the condition of the transducer.

Reentry. - The manual fuel indicator read 6 percent during reentry, but the astronaut reported that no more fuel was available. This condition can exist because the transducer reads pressure whether or not fuel is present.

After blackout, telemetry signals were received by Cape Canaveral and aircraft. The low-frequency transmitter signal had dropouts and was weak. Because of the corrosion of the transmitters from the salt water, a postflight check of the transmtters' signal quality would not be informative. The spacecraft's excessive landing range caused the telemetry signal received by the aircraft to be of poor quality.

Summary. - The pilot-observer camera film quality from the MA-7 mission was poor because its submersion in both salt water and fresh water made an effective developing process impossible. The film was sufficient, however, to confirm theoretical estimates of the liquid behavior in the zero-g experiment. The onboard tape and the astronaut's hand-held camera film provided excellent flight data. The instrumentation and data system provided satisfactory performance for the mission.

Heat Protection System

Heat shield. - The performance of the heat shield (fig. 23) during reentry was satisfactory. The center plug was lost, but a postflight investigation revealed that this loss occurred after major heating. The area under the plug showed no evidence of charring or excessive heating. Otherwise, the shield suffered only normal cracking and displayed the usual glass droplet streaks. The stagnation point appears to have been approximately in the center of the shield.

Two temperature pickups were recorded. One was located in the center of the shield and the other 27 inches from the center. The maximum temperatures experienced are in agreement with predicted values. Maximum heat-shield temperatures for this and previous flights are presented in figure 24.

The heating appeared to be uniform over the shield, as shown by eight core samples taken at various locations in the shield. Visual char depth varied from 0.3 to 0.35 inch. These measurements compare very closely with those obtained during the MA-5 and MA-6 missions. No reduction in overall thickness was observed.

The measured weight loss of the heat shield, adjusted to compensate for the missing center plug, was 13.1 pounds--slightly more than the expected loss of 11 pounds, but still within the limits of measurement and calculation accuracy. This value is greater than that resulting from previous flights; however, the possibility that previous shields were not completely dry when weighed might have contributed to their lower weight loss. This inconsistency in drying is especially probable for the spacecraft ablation shields of the MA-4 and MA-5 missions. Approximate calculations show that the slightly more shallow reentry for the MA-7 flight would not have resulted in a significant increase in the ablation loss compared to a nominal reentry.

Afterbody. - The shingles on the conical-cylindrical afterbody show no evidence of adverse heating effects. Temperatures measured on these shingles were analyzed, and results were consistent with data of previous orbital flights.

White paint patch. - The greatest heating effects experienced by the white patch (shown in fig. 25, upper left of spacecraft) are when it is oriented toward the Sun; and since the spacecraft was never positioned in this manner for an extended period, only a trend in the data can be derived. Apparently the spacecraft was rolled several times, and thus the patch was placed toward the Sun for brief periods. During these periods, the oxidized shingle was approximately 40° F hotter than the white paint patch.

The effect of differences in emissivity is apparent during exit and reentry. During exit the white patch was apparently 300° F cooler than the oxidizer shingle, and just after 0.05g during reentry the patch was approximately 200° F cooler than the oxidized shingle. Later, in the reentry when the primary heating phase was reached, the white patch temperature increased to approximately 200° F higher than the oxidized shingle. This behavior is explained by the effect of temperature on the emissivity of white paint and the oxidized shingle. At temperatures below approximately 700° F the white paint has higher emissivities than the oxidized shingle, and above this temperature the oxidized shingle has higher emissivities.

Green-glow effect. - The astronaut reported seeing a green glow around the recovery section during reentry. Postflight inspection of the beryllium shingles revealed nothing abnormal in this area, and the appearance was about the same as those of previous spacecraft. The cause for the green glow is unknown.

Mechanical and Pyrotechnic Systems

Some anomalies occurred in the mechanical systems, although no serious or dangerous conditions resulted. These anomalies, along with general systems description and performance, are discussed in the following paragraphs.

Recovery sequence. - A control barostat was installed in the cabin and wired into the parachute circuitry to prevent premature deployment of the drogue and main parachutes. The control barostat was in series with the 21 000-foot drogue parachute and 10 600-foot main barostats, and was supposed to arm the recovery system during descent at a spacecraft altitude of 11 200 feet. Ambient pressure at approximately 11 200 feet is 9.62 psia, and the added barostat was set to this pressure. However, the barostat sensed cabin pressure, which appreciably lags ambient pressure, and the resultant effective spacecraft altitude actually required to actuate the barostat switch was approximately 8 250 feet. The recovery system as flown is shown in figure 26.

The planned recovery sequence called for a manual deployment of the drogue parachute at approximately 21 000 feet and an automatic deployment of the main parachute at approximately 10 600 feet. The astronaut manually deployed the drogue parachute at 25 450 feet when the spacecraft oscillations began to build up. In addition, he manually deployed the main parachute at 8 950 feet, since automatic deployment did not occur at 10 600 feet as planned.

Parachutes. - The performance of the drogue and main parachutes upon deployment was satisfactory. Since neither parachute was recovered, a detailed postflight visual inspection could not be made. Observation by the astronaut verified that both parachutes were deployed cleanly and were undamaged during descent.

Pyrotechnics. - A postflight examination of the spacecraft and an analysis of the pertinent data indicate that all rockets and pyrotechnics apparently functioned normally. During retrorocket firing, the astronaut felt that the deceleration was somewhat less than expected. Detailed trajectory analysis, however, indicates that the retrorocket performance was within specification values.

It cannot be determined whether certain pyrotechnics actually fired (such as redundant clamp ring bolts and tower-jettison rocket ignition), since the available information shows only that the resulting function was satisfactory.

Explosive-actuated hatch. - The spacecraft explosive-actuated side hatch was unbolted after the spacecraft was placed on board the recovery ship. The side hatch was not used for astronaut egress, and postflight visual examination revealed the hatch to be in excellent condition.

Landing shock attenuation system. -

Landing bag: The system was unaltered from the MA-6 configuration, with the exception that the instrumentation limit switches were rewired for improved reliability. The landing-attenuation system performed normally, as evidenced by the astronaut's statements and from postflight examinations. The rescue personnel, who parachuted into the landing area, examined the landing bag in the water and reported the bag to be in good condition. However, when the spacecraft was hoisted aboard ship, all of the straps were found to be broken and the bag was extensively damaged (fig. 27). This damage may have been caused by wave action while the spacecraft was supported by the flotation collar prior to recovery. All restraining cables and the large pressure bulkhead appeared to be intact; however, a cable-restraining spring had been lost.

Ablation shield and main pressure bulkhead: The ablation shield appeared intact, except for a lost center plug; the ablation-shield retaining studs and the bulkhead protective shield showed the usual minor damage. Although a small air leak was found at a thermocouple lead through the main pressure bulkhead, the bulkhead did not experience any visible damage. Small areas of protective honeycomb were slightly crushed and minor deformation of small tubing was experienced, as in previous missions.

Flotation. - The astronaut reported that the spacecraft did not right itself after landing. He also stated that it was listing in the pitch-down, yaw-left quadrant at an angle estimated to be about 60° from vertical. Although no photographs are available of the spacecraft before the astronaut egressed, pictures taken after egress show approximately a 45° to 50° list angle. However, it is not known how much water was in the spacecraft cabin when these photographs were taken. The enter of gravity for the MA-7 flotation configuration was at Z = 120.03 inches, which is a corrected calculation to include the loss of the ablation shield center plug and the measured ablation weight loss. The center of gravity was offset from the axis of symmetry by 0.40 inch; these values are in substantial agreement with those for the MA-6 flotation configuration, which were 119.78 and 0.37 inches, respectively. The list angle for previous missions has been reported as approximately 15° to 25° from the vertical. According to the timing of audible events on the onboard tape, the astronaut apparently initiated his postlanding checklist immediately and had already begun to egress at 4 minutes after landing. Water stability data, obtained from tests conducted by the Recovery Branch of the Flight Operations Division*, indicate that the center of gravity mentioned previously could have caused the spacecraft to take 3 or 4 minutes to stabilize in an upright position if the astronaut had remained in the couch. The astronaut's movements, in preparation for egressing, may have nullified any restoring moment that existed during the stabilization period. The spacecraft erection time can be influenced by many unknown factors, including air trapped in the landing bag, insulation-blanket soaking, and the manner in which the reserve parachute is jettisoned. Considering these unaccountable effects and the fact that they cannot be duplicated in a controlled flotation test, the actual list angle is indeterminate. Therefore, the conclusion must be drawn that, after taking into account the astronaut's immediate egress, the higher center of gravity, and a number of possible minor factors, the spacecraft did not have sufficient time to erect itself before the absence of the astronaut changed the equilibrium angle. This equilibrium angle, based on the unoccupied spacecraft's center of gravity, could well have been close to the astronaut's estimate and is in reasonable agreement with the postflight photograph.

Water in spacecraft cabin. - After spacecraft recovery, approximately 65 gallons of salt water were removed from the cabin and an estimated 10 gallons remained in inaccessible places. The astronaut reported that a few drops of water splashed on the tape recorder at the time of landing. These drops can probably be attributed to water coming in through the cabin pressure-relief valve. Astronaut comments and postflight examinations reveal that this valve was not placed in the locked position. The surge of water which entered the recovery section of the spacecraft upon landing may have had enough velocity head to overcome briefly the valve's negative-pressure-relief setting (approximately 16 inches of water) and spray through onto the recorder. This valve is located almost directly over the tape recorder installation, as shown in figure 28.

The small amount of water that could have come in through the cabin pressure-relief valve, however, would be negligible compared to the total amount found in the spacecraft cabin. Postflight tests show the cabin leak rate to be about 2670 cc of air per minute, which is an increase of 1670 over the prelaunch value of 1000 cc

*Now Landing and Recovery Division, NASA MSC.

per minute. A leak was detected in the large pressure bulkhead around a thermocouple connector; however, this leak is not large enough to account for much over 15 percent of the total. The astronaut stated that he heard some water enter through the opening left by the removal of the small pressure bulkhead, but did not believe that this amounted to much more than a few gallons. Although the spacecraft was listing, it was not listing enough for the recovery section to be in the water. The water probably entered through the small pressure bulkhead opening during the egress and the period when the astronaut was using the spacecraft for support to turn over the liferaft. This water could have entered through the shingles to the recovery section and would not necessarily have been noticed by the astronaut whose attention was otherwise occupied.

Postflight Inspection

Spacecraft 18 underwent the normal postflight conditioning procedure. A photographic record was made of this process after the spacecraft was returned to Hangar S, at Cape Canaveral, Florida. A thorough visual inspection was made of the external and internal areas in the "as-received" condition (fig. 25) and all switch and control positions were noted. The spacecraft was then taken to the pyrotechnic area for external disassembly and inspection; and following this, it was transported to the power area for a postflight systems check.

A desalting washdown, tank drainage, and flushing procedure, as applicable, were accomplished; and deterioration safeguards were taken in general. The immediate postflight inspection procedure included external disassembly of the heat shield and conical shingles in order to inspect the pressure bulkhead and internal skin areas. Samples of insulation were removed and stored for later analysis. A discussion of the individual spacecraft structural systems and the results of a detailed inspection follows.

Structure. - The spacecraft experienced no inflight damage. The conical-section shingles showed the usual bluish and orange tinge, and the cylindrical-section shingles displayed the usual dark yellow-grayish appearance, both of which were caused by aerodynamic heating. Several shingles were slightly dented and scratched, as in previous missions, presumably during the recovery operation.

Ablation shield. - The external surface of the heat shield had the normal, evenly charred, glass-streaked appearance, and some circumferential separation of the edge laminations was evident. The ablation shield center plug was found to be missing, with evidence that the plug remained intact through the reentry heat pulse, as in the MA-5 mission. A number of cracks similar to those experienced in some previous missions were found in the ablation shield exterior; however, these cracks did not compromise mission safety. Considerable recovery-handling dents and cuts were noted. The weight loss of the heat shield during the reentry phase amounted to approximately 13 pounds. A postflight photograph of the ablation shield is shown in figure 23.

Landing bag. - The landing bag had been damaged quite extensively, and all landing bag straps had been broken, primarily because of sea action (fig. 27).

Recovery compartment. - The interior of the compartment was undamaged, and the appearance, except for stains from the recovery dye marker, was normal. The butterfly antenna atop the spacecraft was bent somewhat during postflight handling, and the whip antenna had been severed, as in previous missions, as part of the standard recovery procedure.

Main pressure bulkhead. - Small areas of honeycomb were crushed slightly, and some minor deformation of small tubing was noted. This minor damage was evidently caused by deflection of the fiberglass protective shield which was struck by the edge of the ablation shield during landing. The fiberglass protective shield was gouged in four places by heat-shield retaining studs during landing re-contact. The main pressure bulkhead was intact, except for a small leak noted in the paragraph which follows.

Spacecraft interior. - Nearly the entire interior of the spacecraft was wet from sea water which entered the cabin after landing. About 4 inches of water remained in the astronaut's couch and battery compartments after draining of this sea water aboard ship. Some electrical connectors and internal spacecraft systems were heavily corroded; however, all systems responded well to postflight systems checks. The window was clear, although the usual moisture was present between the two outer panes. A postflight pressure-leak test yielded a leak rate of 2670 cc/min (as compared to about 1000 cc/min preflight) with an audible leak at the thermocouple-lead passage in the large pressure bulkhead. Some of the water found in the spacecraft at recovery undoubtedly came from this source.

Scientific Experiments

Tethered inflatable balloon. - This experiment was designed to provide orbital observations of nearby objects of varying surface finishes and to measure the drag of an object of known aerodynamic characteristics in a region of free molecular flow. Balloon drag could then be related to atmospheric density and thus provide a density profile over the altitude range encompassed during the Mercury orbital pass. The experiment was also intended to obtain qualitative information on the capability of the astronaut to estimate separation distance between the spacecraft and an object of known size and shape in space. The visual portion of the experiment was to evaluate the relative merit of various colors and surface finishes for optimum visibility at varying ranges in a space environment. Additional objectives of this test include observations of the general stability qualities and damping characteristics of the tethered balloon. The appearance, brightness, and behavior of small diffuse reflecting discs were to be observed to provide a compariosn with other foreign particles in space where appropriate.

Description of test: The test device consisted of a 30-inch diameter, inflatable balloon fabricated from a two-ply mylar, aluminum foil material, each ply being $\frac{1}{2}$ mil in thickness. The balloon surface was divided into five equal-sized lunes of different colors and surface finish. These finishes were uncolored aluminum foil, yellow fluorescent Day-Glo, orange fluorescent Day-Glo, flat white finish, and a phosphorescent coating (fig. 29). The balloon and inflating bottle were packaged in a cylindrical container located in the antenna canister under the destabilizer flap.

The balloon and inflation bottle weighed approximately 0.5 pound and the entire installation including instrumentation weighed approximately 5 pounds.

The balloon was deployed in orbit at 01:38:00 by firing an actuating squib. A small compressed spring then ejected the balloon and an inflation bottle from the container, along with two balsa block liners and the mylar discs. The balsa blocks were semi-cylindrical in shape and about 6 inches long and 3 inches wide. They were coated with Day-Glo orange and black and Day-Glo yellow and black, respectively. The mylar discs were coated with aluminum foil on one side and a diffuse reflecting material on the other. The balloon was tethered to the spacecraft by a 6-pound test nylon line measuring 100 feet in length which was deployed from a spinning reel. When the balloon had been fully deployed, the line was entirely stripped from the reel but remained attached to a small strain gage mounted in the bottom of the balloon container. Continuous strain-gage measurements were to be recorded on board the spacecraft until the drag test was completed. The balloon was then to be jettisoned and the rate and distance of separation between the spacecraft and balloon were to be estimated by the astronaut. However, the balloon did not inflate completely and did not jettison. Therefore, drag measurements and rate and distance of separation of the balloon from the spacecraft were not obtained.

Test results: At balloon deployment, the astronaut reported seeing the mylar discs spread out and quickly disappear. His first impression was that the balloon had broken free from the spacecraft; however, the object he was tracking was one of the balsa blocks. He observed this block for about 20 seconds, at which time the partially inflated balloon came into view. These observations were verified by pictures taken by the astronaut.

During the towed phase, the following results were obtained from astronaut observations, photographs, and the onboard data tape:

1. Pilot comments indicated that deployment occurred with the spacecraft near $0°$-$0°$-$0°$ attitude. These attitudes cannot be confirmed by onboard instrumentation, since the gyros were caged at the time. Attitude rates were noted in all three axes during and after deployment, but the effect of these rates cannot be conclusively determined.

2. The strain-gage instrumentation and the squib-firing system appeared to work well. Strain-gage calibrations also checked well with previous ground checks.

3. The onboard tape indicated that in-and-out oscillations occurred following deployment and spacecraft attitude changes. These oscillations developed because of the inherent elasticity of the balloon and nylon line. However, an annealed aluminum-foil shock absorber was included in the ejected balloon (fig. 29). Ground simulation tests showed that about 90 percent of the energy imparted to the balloon during deployment was absorbed by the shock absorber.

4. Pilot comments and flight photographs showed that the balloon shape tended to be irregular and oblong, and appeared to be about 6 to 8 inches in cross section.

5. The astronaut described the balloon motion as being completely random in nature. These random motions may have been caused by large changes in spacecraft attitude which occurred after deployment. However, uneven aerodynamic loads which likely existed on the irregular balloon shape would also be expected to contribute to this random motion. Onboard comments by the astronaut did indicate, however, that during the portion of both the second and third orbital passes when dynamic pressure was increasing, balloon motions tended to become more stable.

6. Approximately 35 minutes after balloon deployment, the astronaut initiated a series of control maneuvers to check the spacecraft control system. The strain-gage measurements indicated that fouling of the tethering line occurred during this period. This conclusion is further substantiated by the fact that subsequent spacecraft maneuvers were not registered on the strain-gage system.

7. At approximately 03:14:00, the astronaut attempted balloon jettison, but the balloon did not release from the spacecraft. However, the onboard strain-gage recording indicated a drop in gage output from the level it had held since probable fouling to the output level of the unloaded gage. This drop, which constituted a change of only 2 to 3 percent in gage output, does provide a positive indication that the jettison squib fired and that the tethering line was severed.

8. Only the Day-Glo orange and the uncoated aluminum foil were visible to the astronaut, and these are the only colors that appear in the photographs. Therefore, an effective evaluation of the colors could not be made on this flight.

Summary: Analysis of the experimental results indicates that the balloon deployment, jettison, and instrumentation systems functioned satisfactorily during flight. Since the balloon failed to inflate properly at deployment, no useful drag and visual observation data were obtained. High rates of change in spacecraft attitude after balloon deployment, as well as the irregular shape of the partially inflated balloon, probably accounted for the random motion of the balloon observed during flight. Effective evaluation of the various colors was not possible since only part of the balloon was exposed.

Zero-gravity liquid behavior. - This experiment was a joint effort of two NASA Centers, the Lewis Research Center and the Manned Spacecraft Center. The design and development of the experiment were based on information obtained in the Lewis Research Center drop-tower test program. Lewis Research Center's primary interest in the experiment involved a desire to control liquid ullage in the orbital-rendezvous fuel transfer and long-term propellant storage operations. Manned Spacecraft Center's interest stemmed from a desire to utilize this same phenomenon to eliminate the need for propulsion-stage ullage rockets and bladders in attitude control tankage of manned spacecraft.

Objectives: The main purpose of the zero-gravity experiment is two-fold:

1. To determine the ability of the ullage control surface to maintain a stable liquid-vapor interface during acceleration disturbances experienced by a spacecraft during propulsive and reentry maneuvers.

2. To determine the steady-state interface configuration and to measure the time required for the capillary control surface to position the interface at the start of zero gravity and after being disturbed by the ignition of the retrorockets.

Description of the experiment: The apparatus consisted of a glass sphere (fig. 30) approximately $3\frac{3}{8}$ inches in diameter containing a capillary tube, 2 inches in length and $1\frac{1}{4}$ inches in diameter. Three semicircular holes measuring $\frac{5}{16}$ inch in diameter were cut into the base of the circumference of the capillary. The sphere was encased in an aluminum and a plexiglass half section and suspended by four plexiglass tabs cemented to the glass sphere. The sphere contained 60 milliliters of fluid, which was 20 percent of the actual volume of the sphere. The fluid consisted of a mixture of distilled water, green dye, aerosol solution, and silicone, with a resultant surface tension of 32 dyne/cm.

Discussion: The pilot-observer camera film used to photograph the experiment was subjected to salt-water contact for approximately 36 hours after landing and prior to its reaching Rochester, New York, for developing. The effect of salt water made the film difficult to read for accurate data purposes. However, the film data are sufficient as a rough approximation and confirm the drop-tower test results.

Spacecraft separation occurred at 00:05:12.2 after lift-off. The liquid in the sphere was first observed to move at 00:05:14, and the capillary appeared to be completely filled at 00:05:26. During the spacecraft turnaround maneuver, the liquid remained in the capillary. Reading the clock on the film is difficult, although the meniscus can be seen in the capillary during the daylight portions of the flight. At no time did it appear that the capillary meniscus was lost because of attitude control operations.

Retrofire was conducted from approximately 4:33:10 to 4:33:32, with the capillary emptying at 4:33:13 under 0.35g acceleration. The liquid began to refill the capillary at 4:33:39 and this operation appeared to have been completed at 4:33:51. The capillary emptied at 4:45:53 during the reentry phase, which was after the 0.5g point. The accuracy of the onboard accelerometer is not enough to obtain the g loading that caused the collapse of the meniscus.

Maximum angular acceleration of 0.011g in pitch, 0.0055g in yaw, and 0.0033g in roll during utilization of the reaction control system was experienced during the flight. Although the meniscus appeared to move slightly under these angular accelerations, the level of the meniscus to the standpipe appeared to remain unchanged.

The astronaut visually observed the experiment at 3:19:43 hours, and he confirmed that the meniscus completely filled the standpipe and that no oscillations of the meniscus or bubbles in the liquid were evident.

Results and conclusions: The results of the experiment fully confirm classical capillary-action theory and serve to complement the results of the Lewis Research Center drop-tower tests.

The ability of the capillary to maintain a stable fluid position during angular accelerations imposed by the reaction control system indicates that this method of ullage control is valid within the loading range involved. The results obtained during this experiment will be extrapolated to other liquids, particularly propellants, in accordance with the general laws governing each specific fluid: namely, the surface tension, fluid temperature, and the capillary tube diameter. Although the film data were of poor quality, due to salt-water effects, the results of the zero-gravity experiment have enhanced and extended the knowledge of liquid behavior in a weightless environment.

Photographic studies. -

Horizon definition: Dr. Maxwell Peterson at the Massachusetts Institute of Technology requested that photographs be taken of the daylight horizon through a dual blue and red filter. It was desired to obtain definition of the earth-horizon limb for application to spacecraft navigation system design. Eastman SO130 film was used for this purpose. This film was intended to provide a measure of the intensity of light scattering as a function of wavelength and altitude. The pilot exposed 26 frames of usable quality, with some losses during film change. One of these photographs is illustrated in figure 31.

Meteorological: The Meteorological Satellite Laboratory of the U.S. Weather Bureau requested that the pilot take photographs using Tri-X and infrared sensitive film through a five-filter unit. The purpose of this experiment was to obtain information on the best wavelengths for meteorological satellite photography. The film and filter were taken aboard the spacecraft by the pilot, but time did not permit completion of the experiment.

General color photography: Thirty feet of Eastman color negative film were provided for the pilot to take color films of the sunlit Earth with a 35mm hand-held camera.

Photographs of the launch vehicle and balloon were taken to verify the astronaut's observations and provide information for simulation studies. Fourteen pictures were taken of the partially inflated balloon, and fifteen pictures were taken of the launch vehicle.

Photographs of African and North American land masses were requested by the Theoretical Division of Goddard Space Flight Center (GSFC). These photographs were requested to build up a catalog of photographs of various physiographic features of the earth to be used as reference material for studies of other planetary surfaces and for detection of meteorite impact features on the Earth. The pilot took 13 frames showing the African land mass, and these exposures were forwarded to GSFC.

Photographs of cloud formations are to be used by scientists of the U.S. Weather Bureau Meteorological Satellite Laboratory in studies of weather formations and for comparison with Tiros data. Ninety-six photographs showing cloud formations were obtained, and these exposures were forwarded to the U.S. Weather Bureau.

The color layers at the horizon at sunset may provide information as to the light transfusion characteristics of the upper layer of the atmosphere.

The Theoretical Physics Division of GSFC requested photographs for this purpose, and the pilot obtained 18 photographs of the sunset horizon.

Theoretical calculations indicate that the Sun should appear flattened just before setting and just after rising. Photographs of the Sun at these times were requested by the Theoretical Physics Division of the GSFC. The pilot made two excellent photographs of the Sun at the horizon, and these were forwarded to GSFC for evaluation. The results of this evaluation are discussed in reference 2.

Photographs were requested in order to derive information on the size, brightness, and speed of motion of the particles which Astronaut John H. Glenn, Jr., reported seeing during the MA-6 mission. The pilot exposed 19 frames in an attempt to photograph these particles, and an analysis of the photographs is presented in reference 2.

Airglow layer observations. - During the third orbital pass the pilot made a series of observations on a luminous band, visible around the horizon at night, which was also reported by Astronaut Glenn. The most decisive observation was made with an airglow filter supplied by GSFC. The filter transmits a narrow band of wavelengths, approximately 11 Angstrom units wide at the half-power point and centered at the wavelength of the strongest radiation of the night airglow (5577 Angstrom). A detailed evaluation and discussion of the observations are presented in reference 2.

Ground-flare visibility experiment. - The major objectives of this experiment were: to determine the capability of the astronaut while in orbit, to observe a ground light of high intensity, and to evaluate visibility from the spacecraft at various ranges and slant angles through the atmosphere. This experiment was also intended to provide a quantitative measure of atmospheric attenuation of light.

Description of the experiment: The experiment was conducted by using two items of equipment. The first of these items was a group of one-million-candlepower flares located near the Woomera tracking station. A total of ten flares was to be used, four during the first orbital pass and three during each succeeding pass. Each flare had a burning time of approximately $1\frac{1}{2}$ minutes. These flares were scheduled to be ignited in series approximately 60 seconds apart, with the first flare ignition occurring near the point of closest approach of the spacecraft to the station. The second item of equipment to be used in flight consisted of a photometer which was 4 inches in diameter, $\frac{1}{4}$ inch thick, and 4.3 ounces in weight. The photometer filter varied from 0.1 neutral density (20.4 percent light reduction) to 3.8 neutral density (99.98 percent light reduction).

Results: On the first orbital pass over Australia, four flares were ignited simultaneously. However, because of the extensive cloud cover (approximately $\frac{8}{10}$ at 3000 feet), the flares were not visible to the astronaut. Therefore, the experiment was discontinued for the remainder of the mission and no results were obtained.

AEROMEDICAL ANALYSIS

The aeromedical studies of the MA-7 mission continued the basic program outline in previous manned mission reports. The studies are separated into three groups: clinical examinations, physiological observations, and mission observations.

1. Clinical examinations consist of standard medical procedures, including repeated examinations by physicians; routine and special laboratory tests; X-rays; and special tests, such as retinal photography and tests of the body's balancing mechanism. The preflight and postflight clinical examinations are performed as close together in time as is permitted by recovery operations to detect any physical changes resulting from the space-flight experience.

2. Physiological observations consist of data gathered by the sensor systems adapted to both the spacecraft and the pilot. Since the pilot's physiological responses cannot be completely separated from his environment, the discussion in the Environmental Control System section of this report complements the aeromedical studies.

3. Mission observations are a report of the aeromedical experiments and other pertinent observations that relate to body functions in the space environment.

The preflight aeromedical studies were conducted in order to ascertain the astronaut's state of health and his medical fitness as related to his capability for orbital flight. The accumulation of such data before the flight familiarized the aeromedical monitors with the astronaut's normal physiological responses. Following recovery, the biomedical data were analyzed and compared to the preflight data to disclose any effects which may have resulted from the flight.

Clinical Examinations

Clinical observations were accomplished through several medical examinations and before most of the preflight activities listed in table X. Previous annual physical examinations and the pilot's medical records were reviewed.

Clinical history. - The aeromedical history of the MA-7 mission began on April 30, 1962, with the astronaut's arrival at Cape Canaveral for preflight preparations. A summary of his activities from this date until his return to Cape Canaveral following the flight is presented in table X. Throughout this period, his physical and mental health remained excellent. A special diet was used for 19 days before the flight. Re-scheduling of the launch date caused two starts on the low-residue diet before the final diet began. The pilot maintained his physical condition through distance running and daily workouts on a trampoline.

On the morning of the flight, the pilot was free of medical complaints, mentally composed, and ready for the mission. Breakfast consisted of filet mignon, poached eggs, strained orange juice, toast, and coffee. The events of the aeromedical countdown are presented in table XI. The preflight fluid intake consisted of 1050 cc of water and sweetened ice tea. He voided three times before launch.

After landing, the astronaut stated, "My status was very good, but I was tired." The fatigue at landing is normal and attributable to the heat load associated with the elevated suit temperature and humidity, the activity required to carry out the flight plan, and the emotional stress associated with a flight. Several postlanding events also contributed to his fatigue. After he entered the liferaft, he realized that it was upside down. He left the liferaft, held to the spacecraft, righted the raft, and once again climbed aboard. His neck dam was still stowed, and he deployed it with difficulty after his second entry into the raft. An undetermined, but moderate, quantity of water had entered his pressure suit.

Astronaut Carpenter drank water and ate food from his survival kit during the 3-hour period awaiting helicopter pickup.

Throughout the debriefing period he talked logically about his space-flight experiences and remained alert.

Physical examinations. - Abbreviated physical examinations were accomplished prior to most of the planned activities in the prelaunch period. No variations from previous examinations were revealed. Later the aeromedical debriefing team conducted comprehensive medical examinations in internal medicine, neurology, opthalmology, aviation medicine, psychiatry, and radiology and made clinical laboratory studies. These examinations included the special labyrinthine studies (a modified caloric test and the balance test on successively more narrow rails), electrocardiogram, electroencephalogram, and audiogram. The astronaut was in excellent health and showed no significant change from previous examinations.

On the night prior to flight, the pilot obtained approximately 3 hours of sound sleep. No sedative was required. He was given the preflight examination by the same specialists in aviation medicine, internal medicine, and neuropsychiatry. He had an entirely normal mental status.

The prelaunch and postlaunch physical findings are shown in table XII.

After a 3-hour period in the liferaft, the astronaut was examined in the helicopter. The physician reported as follows: "He pulled the tight rubber collar from his neck and cut a hole in his rubber pressure suit sock (left) to drain out sea water. He was anxious to talk and to discuss his experiences, and cooperative and well controlled. He talked with the helicopter pilot, paced about a bit, and finally relaxed as one normally would after an extended mental and physical exercise." The physical examination aboard the aircraft carrier revealed that he was in good health. Concerning his arrival at Grand Turk Island, the internist member of the debriefing team stated, "He entered the dispensary with the air and the greeting of a man who had been away from his friends for a long time. He was alert, desiring to tell of his adventure and seemed very fit. . . his appearance and movements suggested strength and excellent neuromuscular coordination." A brief medical examination was undertaken about an hour after the pilot's arrival. The following morning, the comprehensive examination was made by the same group of specialists who had examined him on May 17, 1962. The postflight modified caloric test on May 25 revealed an approximate 1.4° C rise in threshold temperature in the right ear and 1.8° C in the left. The rail tests of dynamic and static equilibrium showed a moderate postflight increase of the pilot's ability to stand with his eyes closed. The significance of these preflight and postflight differences is unknown. The aeromedical debriefing was completed on the second morning following the flight. The results of these examinations are presented in tables XII and XIII. A mild asymptomatic urethritis was present during both preflight and postflight periods. Treatment was withheld until after the flight. The small postflight rise in hematocrit, coupled with a 6-pound weight loss, suggests mild dehydration; however, this did not jeopardize the pilot's health.

Aside from moderate fatigue, based upon the long hours of work and a few hours of sleep, the astronaut remained in excellent health throughout the debriefing period. He returned to Cape Canaveral on May 27, 1962, ready to "do it again."

Physiological Data

Physiological data sources for the MA-7 mission were the same as those reported in previous Mercury manned flights. Data from the Mercury-Atlas three-orbit centrifuge simulation, from preflight pad activities (when spacecraft power was available), and from the countdown all serve for comparison with flight data. The reports from the range medical monitors, the onboard continuous biosensor records, the voice transmissions, and the pilot-observer camera are essential sources. Results of special inflight tests and the debriefing provided additional information.

Biosensor system. - The biosensor system consists of two sets of electrocardiographic leads, ECG I (axillary) and ECG II (sternal); a rectal temperature thermistor; a respiration rate thermistor; and the BPMS.

The only biosensor change from the MA-6 mission was the replacement of the manual BPMS with a semiautomatic system. The BPMS is a device for indirect measurement of arterial pressure that utilizes the same principle as in clinical sphygmomanometry. In the BPMS, a similar inflatable cuff is employed, with the stethoscope of the clinical method replaced by a microphone positioned under the cuff. The microphone signal exits from the suit through the bioconnector and enters the amplifier in the blood-pressure unit. The BPMS amplifier consists of a shielded preamplifier and two high-gain amplifiers which determine the response characteristics. Each amplifier is designed to have greatly attenuated response outside the 32 to 40 cps pass band by means of resistor-capacitor filtering circuits in each feedback loop. The amplifier output is gated so that there is no output signal unless a signal of sufficient amplitude is present; and this gating results in a marked reduction in the output noise level for improved readability of the signal. The amplifier is contained in the BPMS controller unit, which also includes the pressure transducer and its batteries, the voltage regulator, and associated mixing and limiting circuits. This system is actuated by manually depressing a switch on the spacecraft instrument panel which initiates the complete 118-second cycle. The cycle includes switching the telemetry channel from ECG II to the BPMS, cuff pressurization and bleed down over a 30-second period, and return of the telemetry to ECG II. The system contains a pressurized oxygen source, with regulator, for cuff inflation and an orifice which relieves the cuff pressure into the suit circuit. The blood-pressure transmitting and recording procedure was the same as that in the MA-6 mission. In order to find the arterial pressure, the points of inception and cessation of the microphone signal on the cuff pressure signal, the systolic and diastolic pressures, must be identified.

All sensors operated normally during the countdown except for intermittent signals from the BPMS, 34 minutes prior to lift-off. These intermittent signals reoccurred several times during the flight. Since the blood-pressure data obtained during flight were also very erratic, the conclusion was that the data were not reducible to the actual blood pressure of the astronaut. A discussion of the BPMS problems and postflight tests are contained in the Instrumentation section of this report.

During the flight, body movements and profuse perspiration caused a large number of ECG artifacts, and the record was interpretable throughout.

The telemetered body temperature data were erratic from approximately 1 hour to $2\frac{1}{2}$ hours after launch. However, other medical data available indicated that the body temperature readout was erroneous. The erratic period is shown as a shaded area in figure 32. The values at all other times are considered valid.

The respiration rate sensor provided useful preflight information, but inflight coverage was minimal.

The pilot-observer camera film was of poor technical quality as a result of its postlanding immersion in sea water, and was therefore of limited usefulness. One of the better quality frames is reproduced in figure 30.

Preflight physiological data. - The preflight activities monitored for the MA-7 mission, together with time durations, are shown in the following table:

Event	Duration
Simulated launch, MA-6, January 17, 1962	5 hours 12 minutes
Simulated flight no. 2, April 30, 1962	4 hours 0 minutes
Simulated launch, MA-7, May 10, 1962	3 hours 15 minutes
Simulated flight no. 3, May 15, 1962	4 hours 50 minutes
Launch countdown, MA-7, May 24, 1962	3 hours 1 minute
Total	20 hours 18 minutes

In figure 33 are shown the values of respiration rate, heart rate, blood pressure, body temperature, and suit-inlet temperature recorded during the MA-7 launch countdown. Figure 34 is a sample of actual preflight data recorded during the countdown at T-68 minutes. Values for the same physiological functions obtained from simulated launches are also plotted in figure 33 at points coincident with significant events. Heart and respiration minute rates were obtained by counting for 30 seconds every 3 minutes until 10 minutes before lift-off, at which time counts were made for 30 seconds every minute. All values recorded are within physiologically acceptable ranges.

Examination of the ECG wave form from all preflight data revealed normal sinus arrhythmia (variation in rate), occasional premature atrial contractions (early beats from normal excitation area), and rare premature ventricular contractions (early beats from an excitation area lower in the cardiac musculature). These variations are normal. A summary of blood-pressure data is shown in table XIV.

During approximately 50 minutes in the transfer van on launch day, the astronaut's heart rate varied from 56 to 70 beats per minute, with a mean of 65. The respiration rate varied from 8 to 20 cycles per minute, with a mean of 14. The ECG reading was normal. Additional physiological values were not obtained.

Flight physiological data. - Figure 32 shows the respiration rate, heart rate, body temperature, and suit-inlet temperature during the flight, with values from the Mercury-Atlas, three-orbit centrifuge simulation presented and correlated with flight events.

Heart rate, respiration rate, and body temperature data are summarized in the following table:

Data sources	Heart rate			Respiration			Body temperature		
	No. of values	Mean	Range	No. of values	Mean	Range	No. of values	Mean	Range
All pre-flight data	408	57	42-84	354	15	5-32	128	99.3	98.3-101.5
Countdown	92	62	50-84	75	15	6-26	57	97.8	96.8-98.2
Flight									
Launch	7	87	82-96	5	16	10-20	4	98	98
Orbital	94	70	60-94	(a)	(a)	(a)	60	99.9	98-100.6
Entry	115	84	72-104	(a)	(a)	(a)	15	100.4	100.2-100.5

[a]Not obtained.

The heart rate increased from 84 beats per minute to the maximum of 96 beats per minute between lift-off and T+30 seconds. This increase was not associated with maximum acceleration. The orbital phase of the mission resulted in a weightless period of 4 hours 30 minutes. The highest heart rate recorded during the entry phase was 104 beats per minute, which occurred immediately following the highly oscillatory period just after reentry. All heart rates were within accepted ranges.

Examination of the ECG wave form recorded during the flight showed an entirely normal record except for the following variations: A single premature atrial contraction (PAC) occurred 13 seconds after SECO, followed by a beat showing suppression of the sinus pacemaker. A second PAC took place 1 minute 15 seconds before retrofire. At 04:48:19, 21 seconds prior to maximum reentry acceleration, a number of cardiac events occurred during a 43-second period. These events began with a PAC, followed by an aberrant QRS, a compensatory pause, and then a normal beat. Twelve seconds later there was a third PAC with aberrant conduction followed by a normal cycle. A fourth PAC occurred 5 seconds later with a less aberrant complex. An atrial fusion beat followed. After three normal beats, there were two sets of nodal beats. The first set contained four nodal beats followed by three normal beats. The second set contained five nodal beats. The remainder of the record was entirely normal. During the period of maximum entry acceleration, the astronaut made a special effort to continue talking. The increased respiratory effort associated with continued speech could have produced these changes. These irregularities did not compromise effective performance. Figure 34 illustrates the appearance of physiological data from the onboard tape after 1 minute of weightlessness. Figure 35 shows the physiological data with the premature atrial contraction at 04:32:06 mission elapsed time.

The preceding data summary shows a 2.6° F overall increase in body temperature. This increase is physiologically tolerable and is believed to have resulted in part from an increased suit-inlet temperature. The trend of gradually increasing body temperature has been observed in previous manned flights. The summary does not include telemetered body temperature readings taken from approximately 1 hour to $2\frac{1}{2}$ hours after launch. The readings were erratic during this period and considered to be unreliable. It should be noted that the astronaut stated during this erratic period that he was comfortable and could not believe the telemetry data. This onboard assessment was helpful in determining the significance of the readings.

Mission Observations

The MA-7 mission differed from the MA-6 mission in the following respects:

1. Bite-size food cubes carried in a non-rigid container were included, instead of semi-solid foods in collapsible tubes.

2. The 5.0 gram xylose tablet was taken orally after 2 hours 36 minutes of exposure to zero g, rather than at the beginning of flight.

3. Water was consumed several times during the flight.

4. Moderate overheating was a factor during the flight, whereas postflight environmental heat stress was present in the MA-6 mission.

5. Food and water were consumed during the 3-hour postflight survival experience.

Overall, the astronaut stated that he had anticipated greater physical stress during the flight than was experienced. Weightlessness was a pleasant experience and reminded him of his sensations while skin diving. He oriented rapidly to his new environment. To test vestibular sensitivity, he performed rather violent head maneuvers on several occasions while weightless. These movements caused no disorientation or vertigo. He also moved his head during roll maneuvers and noted no coriolis effect. Often he had no positional reference, but lack of such reference did not confuse him.

The pilot experienced a momentary illusion involving his position in relation to the special equipment storage kit. At one time when he was sitting upright in orbit attitude, he was surprised to see that the equipment kit was vertical with respect to the horizon. During mission simulations in the procedures trainer, the equipment kit had always been parallel to the horizon. This illusion was very brief and caused the pilot no subsequent difficulty in the operation of the spacecraft.

Vision and hearing were normal. He readily estimated distances by the relative size of objects. Colors and brightness of objects were normal. Tactile approximation, with his eyes closed, was unchanged from that experienced in the ground environment. He reported no tendency to overshoot or undershoot in reaching spacecraft controls.

He felt that bladder sensation was normal while he was weightless, although he is not certain that he urinated during the flight. He had no urge to defecate. The pilot did not feel tired or sleepy during the flight. He stated that he was frustrated by the stress of time and his inability to control suit temperature. He reported that he was hot from the end of the first orbital pass until the middle of the third orbital pass. ECS readouts confirm this subjective evaluation. He experienced no other heat stress. He used no medications at any time during the mission.

During the flight, the pilot consumed solid food, water, and a xylose tablet without difficulty. Once the food was in his mouth, chewing and swallowing were normal. Taste and smell were normal. The solid food was in the form of $\frac{3}{4}$-inch cubes with a special coating, packed in a plastic bag, and stored in the equipment kit. Some of the food cubes had crumbled, and the pilot reported that the resulting particles were an aspiration hazard (the crumbing of food probably occurred prior to or during launch). The elevated cabin temperature caused the chocolate to melt. The amount of water consumed from the mission water supply was 1213 cc, of which approximately 60 percent was consumed in flight, and the remainder was drunk by the astronaut after landing. The xylose experiment was unsuccessful on this flight because of the indefinite time of urination.

Calibrated exercise was performed without difficulty at 03:59:29 ground elapsed time. Because of the overheated condition of the pilot, an earlier scheduled exercise was omitted. A bungee cord with a 16-pound pull through a distance of 6 inches was used as an exerciser. Use of this exerciser caused an increase in heart rate of 12 beats per minute, with a return to previous values within 1 minute. The blood-pressure readings taken at this time could not be interpreted. This response demonstrated the ability of nominal exercise to elevate the pilot's heart rate. This pulse response to exercise was evidence of a reactive cardiovascular system.

Attempts to produce autokinesis (illusion of vision due to involuntary eye muscle movements) were made on two occasions. Autokinesis was not produced, but the tests were inconclusive.

Conclusions

1. The postflight clinical examinations of Astronaut M. Scott Carpenter revealed no significant change from the preflight findings.

2. Aspiration of the crumbled food presents a danger to the astronaut.

3. The inflight pilot responses were within acceptable physiological ranges. No compromise of pilot performance was noted.

4. The information from the two ECG leads provided invaluable correlation data for blood pressure analysis. The evaluation of any ECG abnormality or artifact requires crosschecking of the two leads.

5. The aberrant ECG tracing during entry was most probably the result of a respiratory maneuver and talking during maximum acceleration.

6. An immediate postlanding pilot-status report is necessary for intelligent use of medical personnel in the recovery forces.

7. Sensory perceptions during the flight, as reported by the astronaut, were normal and equivalent to those under 1g.

8. Additional time for remote-site postflight examination and debriefing would be beneficial.

ASTRONAUT FLIGHT ACTIVITIES

Pilot activities during orbital flight consisted of observations, experiments, and flight maneuvers. The activities were planned to provide the maximum information in the time available. The observations included pilot recorded comments, photographs, and in-flight studies of the earth's surface and atmosphere and celestial phenomena. Experiments in which the pilot actively participated consisted of measurements with a tethered balloon and tests to evaluate the physiological functions of a man in a space environment. Flight maneuvers were devised to determine the astronaut's ability to control the spacecraft under varying conditions of attitudes and to recover from a nonstandard attitude maneuver. The construction of the flight plan was based on an 08:00 a.m. e.s.t. launch, which determined the timing of tasks to be done during daylight and to be done at night. A nominal trajectory was assumed with regard to station passage and the apogee-perigee points, which also affected the timing of certain in-flight observations and experiments.

The mission produced successful measurements of the altitude and thickness of the haze layer and proved its origin to be an expected airglow phenomenon. The extensive drifting flight in the third orbital pass to conserve fuel, the ingestion of water and bite-size food, and the horizon-definition photographs required for the design of the Apollo navigation and guidance system--all provided additional usable results applicable to future space flight. Extensive cloud cover over Australia prevented the observation of flares or the lights from cities and Darwin airport. Partial inflation compromised the success of the tethered balloon experiment, and instrumentation problems in the blood-pressure system precluded complete results of calibrated work at zero g.

The scientific experiments specified in the flight plan are discussed in detail in the Scientific Experiments section of this report. Spacecraft attitude control activities specified in the flight plan and the scientific equipment on board the spacecraft are discussed in the following paragraphs.

Spacecraft Attitude Control and Flight Procedures

The major portion of the pilot's performance in controlling the spacecraft attitudes could not be quantitatively analyzed because:

1. The horizon scanners appear to have malfunctioned.

2. There was a considerable period of time in which the spacecraft attitudes were either beyond the horizon scanner field of view and/or the gyros were in the caged position.

3. The pilot deviated slightly from procedures rehearsed prior to and during the pilot preflight preparation period.

The pilot's attitude control activities are summarized in table XV. The function and operation of the RCS are discussed in the Spacecraft Control System section. The attitude control tasks are discussed in the following paragraphs.

Turnaround maneuver. - The purpose of accomplishing the turnaround maneuver, by using the FBW control mode, was to conserve fuel and still complete the turnaround within approximately the nominal time period required by the ASCS system.

Approximately 1.60 pounds of H_2O_2 was used during the MA-7 FBW turnaround, whereas over 5 pounds of control fuel was used during the MA-6 ASCS turnaround. Generally, the turnaround maneuver was accomplished satisfactorily except that the pilot was slow in assuming proper retroattitude (fig. 36). Since he had a "go" condition, he had no immediate need to assume the proper retroattitude quickly; and he therefore positioned the spacecraft to track and photograph the sustainer stage of the launch vehicle.

Sustainer tracking. - This task was designed to determine the limits of the pilot-spacecraft combination in tracking a moving object at varying separation distances and to investigate the visual limitation associated with a receding object in space. The pilot, by using FBW mode, was to aline the window reticle with the sustainer and pitch down slowly, staying on target, until he was required to return to orbit attitude during contact with the Canary Islands. This maneuver would normally allow approximately $2\frac{1}{2}$ minutes of tracking. Results of the mission show that the task of taking photographs extended for a period of longer duration than had been expected. Although the pilot did not perform the tracking maneuver as planned, he commented that precision tracking of objects with small relative motions with respect to the spacecraft could best be done on FBW by using low thrusters only or, possibly, the lowest deflections on manual proportional control.

Gyro caging and uncaging procedure. - A procedure for alining the gyro indicators to the window reference was formulated and rehearsed during the preflight preparation period. According to the procedure, the pilot was to use the window and not the periscope, because of the assumption that the periscope would not be available for future Mercury flights. The pilot's ability to realine the gyro indicators to the window reference cannot be determined precisely because of the pitch-horizon-scanner malfunction. However, the data indicate that the pilot generally followed the planned gyro realinement procedure on the first two occasions. Thereafter he simply maneuvered to a true vehicle attitude by using the periscope orbital attitude reference scribe mark, and caged and uncaged the gyros at this point. The method of alining the gyros by using the periscope was more economical in both time and fuel expenditure than by using the window.

Yaw maneuvering. - The pilot accomplished two 180° yaw turnarounds and several 90° yaw maneuvers during flight. Since these maneuvers were accomplished only for the purposes of photography and observation, and not as precision maneuvers, no attempt was made to analyze them quantitatively. The preferred method of yaw-attitude control on the daylight side was by reference to ground terrain drift. At night this type of reference is available only when the Moon is sufficiently bright to illuminate the clouds. The preferred method of yaw determination available at all times on the night side is by orientation to known stars that lie close to the orbital plane. Star charts were provided for this purpose. The pilot reported difficulty in finding cues for determining yaw. However, his general comments during debriefing indicated that moonlight or ground lights are necessary for the terrestrial yaw check.

An attempt was made to establish that star patterns can be recognized in both the day and night sectors of an orbit. Through knowledge of constellation patterns, the pilot was able to use the stars for yaw reference. The pilot was able to identify successfully several constellations on the dark side of the Earth. Star navigation was not attempted during the day sectors. Constellations Corvus and Cassiopeia were noted during the first orbital pass at about 19 and 35 minutes after sunset, respectively. Scorpio was noted during the third orbital pass at about 27 minutes after sunset. The brightest star in each of these constellations is approximately 2.5 magnitude. Ursa Major (Big Dipper) was also identified prior to the haze-layer experiment. The pilot reported that the star navigation device was very useful. However, he did have difficulty in reading the charts because of their reflective surface and the cabin lighting arrangement. The pilot stated that he saw fewer stars than he had expected while in orbit because of the reduced light transmission characteristics of the window and internal lighting reflections.

Drifting flight, inverted flight. - These maneuvers cannot be quantitatively analyzed because the gyros were caged and the horizon scanner outputs were usually questionable. During the flight, the pilot allowed the spacecraft to drift for a total of 1 hour 17 minutes, 1 hour 6 minutes of which was continuous drifting during the third orbital pass to conserve fuel. The pilot reported that drifting flight was not disturbing and that he was not concerned when no external reference was available. He stated that the forward inverted attitude was desirable for orbital flight.

Retrofire attitude control. - The pilot decided to control attitude during the retrorocket ignition event by using the FBW control mode, primarily because of an undetermined problem with the automatic stabilization control system (ASCS).

Because of the apparent attitude control problem leading to the deviation in impact point, a review of the pilot's activities prior to and during the retrofire period is presented.

At approximately 11 minutes prior to retrosequence, the pilot discovered a source of the glowing particles reported during the MA-6 mission. Observing and photographing these particles delayed the accomplishment of equipment stowage and completion of the pre-retrofire checklists. At this time, the pilot was reminded to pull his manual fuel handle out, thereby enabling the manual control system to serve as a backup to the automatic control system. At 5 minutes prior to retrofire, he determined that his gyro indications were wrong and quickly rechecked his FBW and MP control modes. At 2 minutes prior to retrofire, he again checked his automatic control system and decided to use the window and periscope in conjunction with FBW to control retrofire. At 30 seconds prior to retrofire, he again checked his ASCS orientation mode upon ground request. This mode drove him down in pitch and he quickly switched back to FBW and repositioned the spacecraft to retrofire attitude by using external reference. Because the MP control mode was also enabled, he used double authority during this maneuver and the subsequent retrofire maneuver. At 12 seconds prior to retrofire, he was told by the ground crew to maneuver to bypass position and use manual override. The pilot had to initiate retrofire manually which occurred approximately 3 seconds late, with respect to when it would have occurred with an automatic retrofire signal.

Apparently, as a result of these control activities just prior to retrofire, the pilot began the period of retrofire with an indicated 25° error in yaw which he gradually reduced during the course of the 22-second period of retrorocket firing (fig. 18).

Fuel management. - The pilot frequently departed from recommended operational procedures concerning control mode switching, which resulted in a greater than normal fuel expenditure rate (fig. 19). The high rate of fuel usage can be attributed to the following:

1. The pilot inadvertently used the high FBW thrusters.

2. Double authority control was used on six occasions, including the retrofiring sequence, for a total of approximately 17 minutes.

3. The ASCS oriented the spacecraft seven times (approximately 1.5 lb of fuel was used during each maneuver). On three of these seven occasions, the manfunctioning attitude reference system may possibly have caused inadvertent use of the orientation mode of control. On three occasions the pilot switched to ASCS "normal" with the gyros caged, and in one case the ground crew requested that he check his ASCS orientation mode just prior to retrosequence. About 1.5 pounds of fuel was used each time the ASCS went into orientation mode.

Scientific Equipment

The equipment aboard the spacecraft of the MA-7 mission and the pilot's comments regarding their operation are discussed in the following paragraphs.

Hand-held camera. - (See fig. 37.) A 35mm Robot Recorder 36 was provided. Its weight was reduced, a pistol-grip handle was provided along with other modifications to permit ease of operation, and a clip was provided for attachment to the chart holder during orbit. It was equipped with a standard back assembly and a 30-foot film capacity magazine. Additional equipment included two interchangeable lenses, one a 75mm, f3.5 lens, and the other a 45mm, f2.8 lens. Each lens system was provided with an ultraviolet (UV-17) filter. The camera functioned well throughout the flight. Although the large capacity back reduced film changes to a minimum, changing films was still necessary to accomplish specialized photography. The results are contained in the Scientific Experiments section of this report.

Film. - The 30-foot magazine was preloaded with Eastman Color Negative film (Eastman stock number 5250) and attached to the camera prior to insertion into the spacecraft. This film load represented a 250-exposure capability. The Massachusetts Institute of Technology provided a preloaded magazine containing a special film (Eastman stock number SO-130) to be used for the horizon-definition photographs. This film load provided approximately 70 exposures. The Weather Bureau experiment required a 36-exposure film load that was alternately spliced from Tri-X and infrared film stocks. Also included was one 36-exposure roll of Ansco Super Hypan film to provide an alternate to the Eastman Color Negative film for photographing the particles. The results obtained by the use of these films are given in the Scientific Experiments section of this report.

Filter mosaics. - (See fig. 38.) Two filter mosaics were provided. These mosaics were mounted in holders designed to be inserted into the camera at the film plane. One was to be used with the MIT film and the other with the Weather Bureau film. The MIT mosaic consisted of two equal sections of Wratten filter, numbers 29 and 47B. The Weather Bureau mosaic contained five equal sections of Wratten filter, numbers 0.8 neutral density, 25, 47, 58, and 87. Of these, only the MIT mosaic was used and it performed satisfactorily.

Photometer. - (See fig. 39.) This device was the same type as that used during the MA-6 mission to view sunrise and sunset, to evaluate the pilot's capability to orient to the horizontal, and to serve as a high- and low-level light meter. This instrument was used by the pilot with satisfactory results.

Binoculars. - (See fig. 40.) The pilot was provided with a miniature pair of 8 × 20 binoculars. Clips were provided to permit attachment to the chart holder during orbit. The pilot reported that utilization of the binoculars during flight was difficult because of the viewing angle of the window.

Extinction photometer. - (See fig. 41.) This device consisted of a calibrated, circular, varying density filter in a suitable mount. It was used on several occasions during the flight with satisfactory results.

Air glow filter. - (See fig. 42.) This is the same device, with a modified mount, as that used on the MA-6 flight. It selectively passes light at the 5577Å wave length. The device was used to view the airglow layer on the night side of the Earth.

Night adaption eye cover. - (See fig. 43.) This device fitted the eye socket in such a manner as to eliminate any direct light from reaching the eye. It was provided with a red lens to allow the pilot to use his left eye during the adaption period. The device functioned properly during the flight although complete dark adaption was prohibited by stray light within the spacecraft.

Map booklet, star navigation device and inserts, and flight plan cards. - The pilot reported that the glare from the star navigation device made it difficult to use. The remainder of this equipment and its stowage were adequate.

Equipment stowage. - All equipment had female velcro applied to strategic points, whereas male velcro was applied to the stowage areas. Four equipment areas were provided within the spacecraft. During the launch, retrofire, and reentry phases, the equipment was stowed in three locations. The equipment container located to the pilot's right, below the hatch, contained the 35mm hand-held camera and associated accessories, the photometer, binoculars, and extinction photometer. The instrument-panel storage compartment located in the main instrument panel contained the exercise device, film, filter mosaics, airglow filter, and the night adaption eye cover. The chart holder, located below the periscope, contained the map booklet, star navigation device and inserts, and the flight-plan cards. During the orbital phase, the equipment was stowed either in these locations or on the velcro applied to the hatch for this purpose. The pilot reported no difficulties with stowage of any of the equipment.

ASTRONAUT'S FLIGHT REPORT

[A first-person account of the major events and personal observations during the MA-7 flight is presented by the pilot. Before and during powered flight, launch-vehicle noise and vibration were less than expected. As in the MA-6 mission, the astronaut quickly adapted to weightless flight and remarked that it was more comfortable and provided greater mobility than under normal gravity. Astronaut Carpenter also observed the space particles and the bright horizon band, previously reported by Astronaut John H. Glenn, Jr., and obtained new information on both phenomena. The final phases of the flight, including retrosequence, reentry, landing, and egress, are covered in detail.]

Launch Phase

Insertion into the spacecraft was accomplished without incident, except for a minor problem with the tiedown of the visor-seal-bottle hose to the helmet. The countdown went perfectly until the 45-minute weather hold. At T-10 minutes it was picked up again and proceeded perfectly once more until lift-off. During the prelaunch period I had no problems. The couch was comfortable, and I had no pressure points. The length of the prelaunch period was not a problem. I believe I could have gone at least twice as long. Throughout this period, the launch vehicle was much more dormant than I had expected it to be. I did not hear the clatter that John Glenn had reported. Once I felt the engine gimbaling. I do not recall hearing the lox venting.

When the ignition signal was given, everything became quiet. I had expected to feel the launch vehicle shake, some machinery start, the vernier engines light off, or to hear the lox valve make some noise, but I did not. Nothing happened until main engine ignition; then I began to feel the vibration. There was a little bit of shaking. Lift-off was unmistakable.

About a minute and a half after lift-off, the sky changed in brightness rather suddenly. It was not black, but it was no longer a light blue. The noise and vibration increased so little during maximum dynamic pressure that it would not be noticed unless you were looking for it. The booster engine cutoff (BECO) was very gentle. Three seconds later, staging occurred. There was no mistaking staging. Two very definite noise cues could be heard: one was the decrease in noise level that accompanied the drop in acceleration; the other was associated with staging. At staging there was a change in the light outside the window, and I saw a wisp of smoke.

At tower jettison, I felt a bigger jolt than at staging; and it was gone in a second. Out the window, the tower could be seen way off in the distance, heading straight for the horizon. It was rotating slowly, with smoke still trailing out of the three nozzles. Just prior to BECO, I noticed a low-frequency oscillation in yaw. This oscillation picked up again after BECO and increased very gradually until sustainer engine cutoff (SECO).

At SECO, the dropoff in acceleration was not disturbing. Two separate bangs could be heard: first, the clamp ring explosive bolts, and then the louder noise of the posigrade rockets. The best cues to the end of powered flight were weightlessness and absolute silence.

Orbital Flight Phase

General flight observations. - I began the turnaround and wondered why I felt nothing. At this time, the angular accelerations of the spacecraft were not perceptible, and only the blackness of space could be seen through the window. The instruments provided the only reference. The turnaround proceeded just as in the trainer except that I was somewhat distracted initially by the new sensation of weightlessness. I followed the needles around and soon there was the horizon.

Following the turnaround, I watched the expended launch vehicle through the window as it fell behind me, tumbling slowly. It was bright and easily visible. I could see what looked like little ice crystals emanating from the sustainer engine nozzle. They seemed to extend for two or three times the length of the launch vehicle in a gradually broadening fan pattern.

After the initial sensation of weightlessness, it was exactly what I had expected from my brief experience with it in training. It was very pleasant, a great freedom, and I adapted to it quickly. Movement in the pressure suit was easier and the couch was more comfortable.

Later, when I tried to eat the solid food provided for the flight, I found it crumbled in its plastic bag. Every time I opened the bag, some crumbs would come floating out; but once a bite-sized piece of food was in my mouth, there was no problem. It was just like eating here on Earth.

Orientation. - My only cues to motion were the instruments and the views through the window and periscope. At times during the flight, the spacecraft angular rates were greater than 6° per second, but aside from vision, I had no sense of movement.

I was never disoriented. I always knew where the controls and other objects within the cabin were relative to myself. I could reach anything I needed. I did not have one unusual experience. After looking out the window for some time, I noticed that when I turned my head to the right to look at the special equipment storage kit, I would get the impression that it was oriented vertically, or 90° from where I felt it should be. This impression was because of my training in the procedures trainer where I was always horizontal and lasted only temporarily.

At times when the gyros were caged and nothing was visible out the window, I had no idea where the Earth was in relation to the spacecraft. However, it did not seem important to me. I knew at all times that I had only to wait and the Earth would again appear in the window. The periscope was particularly useful in this respect, because it had such a wide field of view. Even without it, however, the window would have been adequate.

Unusual flight attitudes. - During the flight I had an opportunity to investigate a number of unusual flight attitudes. One of these was forward inverted flight. When I was pitched down close to -90°, I think I could pick out the nadir point, that is, the ground directly below me, very easily without reference to the horizon. I could determine whether I was looking straight down or off at an angle. During portions of the second and third orbits, I allowed the spacecraft to drift. Drifting flight was effortless and created no problems.

Alining the gyros consumed fuel or time. The horizon provided a good roll and pitch reference as long as it was visible in the window. On the dark side of the Earth, the horizon or the airglow layer is visible at all times even before moonrise. Yaw reference was a problem. The best yaw reference was obtained by pitching down -50° to -70° and looking through the window. The periscope provided another good yaw reference at nearly any attitude. The zero-pitch mark on the periscope was also a valuable reference for alining the gyros since at zero pitch, the horizon could not be seen through the window. Yaw attitude is difficult to determine at night, and the periscope is of little help in determining yaw on the night side. The best reference is a known star.

Control system operation. - For normal maneuvering in orbit, FBW, low thrusters only, was the best system. However, I believe for a tracking task, manual proportional control might be more desirable, although I did not actually try it for this purpose. The FBW high thrusters and the rate command and auxiliary damping systems were not needed for the tasks that I had to perform in orbit prior to preparing for retrofire.

In orbit, the operation of the solenoids of both the high and low thrusters of the FBW system could be heard. I could hear and feel the rate command system, both the solenoids and the thrusters. When using the MP mode, I did not hear the control linkages, but again I heard the thrusters. Through the window, the exhaust from the pitch-down thrusters could be seen. There was no movement, just a little "V" of white steam in front of the window. It was visible even at night.

Balloon observations. - At balloon deployment, I saw the confetti as it was jettisoned, but it disappeared rapidly. I saw one of the balsa blocks and mistook it for the balloon. Finally, the balloon came into view; it looked to me as if it were a wrinkled sphere about 8 to 10 inches thick. It had small protrusions coming out each side. The balloon motion following deployment was completely random.

Terrestrial observations. - There was no difference between the appearance and color of land, water areas, or clouds from orbit and the view from a high-flying aircraft. The view looked to me exactly like the photographs from other Mercury flights. The South Atlantic had a cloud coverage of 90 percent, but all of western Africa was clear. I had a beautiful view of Lake Chad. Other parts of Africa were green, and it was easy to tell that these areas were jungle. There were clouds over the Indian Ocean. Farther west in the Pacific, it was not heavily clouded, but the western half of Baja California, Mexico, was covered with clouds along its entire length. The eastern half was clear. Over the United States on the second orbital pass, I noticed a good amount of cloudiness, but after retrofire I could see the area around El Centro, California, quite clearly. I saw a dirt road and had the impression that had there been a truck on it, I could have picked it out. I did not see Florida or the Cape Canaveral area.

Celestial observations. - Because of the small source of light around the time correlation clock, I was not fully dark adapted, nor was the cabin completely dark; therefore, I did not see any more stars than I could have seen from the Earth. After having seen the star, Corvus, during the flight and later in the recovery airplane, I am convinced that a lot more stars can be seen from the ground than I could see through the spacecraft window. I could, nevertheless, readily see and identify the major constellations and use them for heading information. I could not see stars on the daylight side when the Earth was in the field of view of the window. However, I do remember seeing stars at the western horizon when the Sun was just up in the east but the terminator had not yet reached the western horizon. The sunrises and sunsets were the most beautiful and spectacular events of the flight. Unlike those on Earth, the sunrises and sunsets in orbit were all the same. The sharply defined bands of color at the horizon were brilliant.

On the dark side of the Earth, I saw the same bright band of light just above the horizon which John Glenn reported. I measured the width of this band in a number of ways, and I also observed it through a special "airglow" filter. A description and analysis of my observations are discussed in reference 2.

A number of times during the flight, I observed the particles reported by John Glenn. They appeared to be like snowflakes. I believe that they reflected sunlight and were not truly luminous. The particles traveled at different speeds, but they did not move away from the vehicle as rapidly as the confetti that was deployed upon balloon release. At dawn on the third orbital pass as I reached for the densiometer, I inadvertently hit the spacecraft hatch and a cloud of particles flew by the window. Since I was yawed to the right, the particles traveled across the front of the window from the right to the left. I continued to knock on the hatch and on other portions of the spacecraft walls, and each time a cloud of particles came past the window. The particles varied in size, brightness, and color. Some were gray and others were white. The largest were 4 to 5 times the size of the smaller ones. One that I saw was $\frac{1}{2}$-inch long. It was shaped like a curlicue and looked like a lathe turning.

Retrograde and Reentry Phase

Retrosequence. - I think that one reason that I was unable to maintain my schedule at retrofire was because, just at dawn during the third orbital pass, I discovered the source of the space particles. I felt that I had time to investigate the particles and still prepare properly for retrofire, but time slipped away. The Hawaii Cap Com was trying very hard to get me to do the preretrograde checklist. After observing the particles, I was busy trying to get alined in orbit attitude. Then I had to evaluate the problem in the automatic control system. I was unable to maintain my schedule and had to stow things haphazardly.

Just prior to retrofire, I had a problem in pitch attitude and lost all confidence in the automatic control system. By this time, I had gone through the part of the preretrograde checklist which called for the manual fuel handle to be out as a backup for the automatic control system. When I selected the FBW mode, I did not shut off the manual system. As a result, attitude control during retrofire was accomplished on both the FBW and the manual control modes.

At the time, I felt that my control of spacecraft attitude during retrofire was good. My reference was divided between the periscope, the window, and the attitude indicators. When the retroattitude of -34° was properly indicated by the window and the periscope, the pitch attitude indicator read -10°. I tried to hold this attitude on the instruments throughout retrofire, but I cross-checked attitude in the window and the periscope. I have commented many times that on the trainer you cannot divide your attention between one attitude reference system and another and still do a good job in retrofire. But that was the way I controlled attitude during retrofire on this flight.

Although retrosequence came on time, the initiation of retrofire was slightly late. After receiving a countdown to retrofire from the California Cap Com, I waited 2 seconds and then punched the manual retrofire button. About 1 second after that I felt the first retrorocket fire.

If the California Cap Com had not mentioned the retroattitude bypass switch, I would have forgotten it, and retrofire would have been delayed considerably longer. Later, the California Cap Com also mentioned an auxiliary damping reentry which I think I would have chosen in any case, but it was a good suggestion to have.

I had expected a big "boot" from the retrorockets, but the deceleration was just a very gentle nudge. The ignition of the rockets was just audible. Retrofire gave me a sensation, not of being pushed back toward Hawaii as John Glenn had reported, but of being slowed down in three increments. By the time the retrofire was over, I felt that there had been just enough deceleration to bring the spacecraft to a stop; but of course, it had not stopped.

Reentry. - Retropack jettison and the retraction of the periscope occurred on time. At this time, I noticed my appalling fuel state and realized that I had controlled retrofire on both the manual and FBW systems. I tried both the manual and the rate-command control modes and got no response. The fuel gage was reading about 6 percent, but the fuel tank was empty. This left me with 15 percent of the automatic fuel to last out the 10 minutes to 0.05g and to control the reentry. I used it sparingly, trying to keep the horizon in the window so that I would have a correct attitude reference. I stayed on FBW until 0.05g. At 0.05g I think I still had a reading of about 15 percent on the automatic fuel gage. I used the window for attitude reference during reentry because of the difficulty I had experienced with the attitude displays prior to retrofire.

I began to hear the hissing outside the spacecraft that John Glenn had described. The spacecraft was alined within 3° or 4° in pitch and yaw at the start of the reentry period. I feel that it would have reentered properly without any attitude control. The gradual increase of aerodynamic forces during the reentry appeared to be sufficient to aline the spacecraft properly. Very shortly after 0.05g, I began to pick up oscillations on the pitch and yaw rate needles. These oscillations seemed about the same as those experienced in some of the trainer runs. Because of this similarity, I decided that the spacecraft was in good reentry latitude, and I selected the auxiliary damping control mode.

I watched both the rate indicator and the window during this period, because I was beginning to see the reentry glow. I could see a few flaming pieces falling off the spacecraft. I also saw a long rectangular strap going off in the distance. The window did not light up to the extent that John Glenn reported. I did not see a fiery glow prior to peak acceleration.

I noticed one unexpected thing during the heat pulse. I was looking for the orange glow and noticed instead a light green glow that seemed to be coming from the cylindrical section of the spacecraft. It made me feel that the trim angle was not right and that some of the surface of the recovery compartment might be overheating. However, the fact that the rates were oscillating evenly strengthened my conviction that the spacecraft was at a good trim angle. The green glow was brighter than the orange glow around the window.

I heard the Cape Cap Com up to the blackout. He told me that blackout was expected momentarily. I listened at first for his command transmission, but it did not get through; so I just talked the rest of the way down.

At peak acceleration, oscillations in rate were nearly imperceptible, since the auxiliary damping was going very well. The period of peak acceleration was much longer than I had expected. I noticed that I had to breath a little more forcefully in order to say normal sentences.

Landing

At around 70 000 feet, I may have run out of automatic fuel. I do not remember looking at the fuel gage, but the rates began to oscillate pretty badly, although the rate needles were still on scale. My best indication of the oscillation amplitude was to watch the Sun cross the window and try to determine the angle through which the spacecraft was oscillating. I could feel the change in deceleration as the spacecraft went to one side in yaw or pitch. I switched the drogue parachute fuse switch on at 45 000 feet. At about 40 000 feet, spacecraft oscillations were increasing. At about 25 000 feet, I deployed the drogue parachute manually when the oscillations became severe. I could see the drogue parachute pulsing and vibrating more than I had expected. It was visible against a cloudy sky. After the drogue parachute was deployed, I operated the snorkel manually.

I switched the main parachute fuse switch on at 15 000 feet and waited for the main parachute to deploy. At about 9500 feet, I manually activated the main parachute deployment switch without waiting for automatic deployment. It came out and was reefed for a little while. I could see the parachute working as the material was stretched taut and then as it undulated after the peak load. The parachute disreefed and it was beautiful. I could see no damage whatsoever, and rate of descent was right on 30 feet per second.

I was convinced that the main parachute was good, selected the automatic position on the landing bag switch, and the bag went out immediately. I went through the postreentry and 10 000-foot checklists and got everything pretty well taken care of.

The landing was much less severe than I had expected. It was more noticeable by the noise than by the g-load, and I thought I had a heat-shield recontact problem of some kind. I was somewhat dismayed to see water splashed on the face of the tape recorder box immediately after impact. My fears that there might be a leak in the spacecraft appeared to be confirmed by the fact that the spacecraft did not immediately right itself.

Egress

The spacecraft listed halfway between pitch down and yaw left. I got the proper items disconnected and waited for the spacecraft to right itself. However, the list angle did not appreciably change.

I knew that I was way beyond my intended landing point, because I had heard earlier the Cape Cap Com transmitting blind that there would be about an hour for recovery. I decided to get out at that time and started to egress from the spacecraft.

Egress is a tough job. The space is tight, and the small pressure bulkhead stuck slightly. I easily pushed out the canister, and I had the liferaft and the camera with me. I disconnected the hose after I had the canister nearly out.

I forgot to seal the suit and deploy the neck dam. I think one of the reasons was that it was so hot. After landing I read 105° on the cabin temperature gage. I felt much hotter in orbit than after landing; and although it was humid, I still felt fine.

I climbed out through the small pressure bulkhead with the liferaft attached to me. I placed the camera on top of the recovery compartment so that I could get it in case the spacecraft sank. I left the spacecraft, pulled the liferaft out after me, and inflated it, still holding onto the spacecraft. I climbed aboard and assessed the situation. Then I realized that the raft was upside down! I climbed back onto the spacecraft, turned the liferaft over, and got back in.

Recovery

The sea was quite calm except for periodic swells, but it was not choppy. The time on the ocean was very pleasant. I drank a lot of water from my survival kit while I was in the raft, but as far as temperature was concerned I was comfortable.

The first thing I saw in the water was some seaweed. Than a black fish appeared, and he was quite friendly. Later, I heard some planes. The first one I saw was a P2V, so I took out the signaling mirror from my survival kit. Since it was hazy, I had some difficulty in aiming the mirror, which is done by centering the small bright spot produced by the sun in the center of the mirror. However, I knew the planes had spotted me because they kept circling the area. Another aid to the planes in locating me was the dye marker which was automatically ejected by the spacecraft. There must have been a stream of dye in the water 10 miles long.

Soon there were a lot of airplanes around, but I just sat there minding my own business. Suddenly, I heard a voice calling from behind me. I turned around and there was someone swimming up to me. I did not even know that he had been parachuted into the water. He inflated his raft, climbed in, and attached his raft to mine. He told me he had parachuted from 1100 feet and had to swim quite a way to reach me. Later, another swimmer joined us. I broke out the food and asked them if they wanted any; but they had finished lunch recently, and they did not take any.

More aircraft kept circling over us. From time to time, one would drop a smoke bomb marker. A 20-man liferaft was dropped, but the parachute failed to open and it hit the water with a tremendous impact. Attached to the raft was another package, containing the Stullken collar, a flotation device much like a life preserver which can be wrapped around the spacecraft to keep it floating. It also hit with a terrific force which, as we learned later, broke one of the CO_2 bottles used to inflate the collar. The divers started out to get the collar and it took them some time to bring it back. They finally got back, wrapped the collar around the spacecraft, and inflated it.

When the HSS-2 helicopter appeared, it made a beautiful approach. One of the divers helped me put on the sling, and I picked up my camera which I had previously placed in the recovery compartment. I motioned to the helicopter pilot to take up the slack in the line and I let go of the spacecraft expecting to be lifted up. Instead, I went down! The helicopter must have settled slightly, because I am sure that there was a moment when nobody saw anything of me but a hand holding a camera clear of the water.

A moment later, however, I began to rise. It was a lift of some 50 to 60 feet. I got into the helicopter with no difficulty and took off my gloves and boots. I poked a hole in the toe of my left sock and stuck my leg out the window to let the water drain out of the suit. When the helicopter landed aboard the carrier, I was in good shape. Although, I had already had a long day, I was not excessively tired and I was looking forward to describing my experiences to those at the debriefing site.

Concluding Remarks

Overall, I believe the MA-7 flight can be considered another successful step on the road to the development of a useful and reliable manned spacecraft system. The good performance of most of the spacecraft systems gave me confidence in the vehicle itself, while the spectacular novelty of the view from space challenged me to make the most of my opportunity and lured me into an unwise expenditure of fuel early in flight. As a result, it became necessary to go to extended drifting flight, and I was able to demonstrate that there was no problem associated with prolonged drifting flight, a procedure we shall have to make use of on the longer duration Mercury flights. I was able to detect and overcome the one significant systems malfunction that might have affected the flight: the malfunction of the pitch horizon scanner circuit. I understand that many were concerned while waiting without word from me during reentry and after landing. However, from my position, there was no major cause for concern. The spacecraft was stable during the critical portions of reentry and the parachute worked perfectly. The recovery was effected expeditiously, despite the significant position error at landing. The flight was truly a wonderful experience.

LAUNCH VEHICLE PERFORMANCE

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

Hydraulics

The launch vehicle hydraulic system operated satisfactorily throughout the MA-7 powered flight phase. The sustainer hydraulic system maintained 3080 psi, as indicated by transducer H310P (see fig. 44 for the location of this transducer). Sustainer hydraulic accumulator pressure, measured with transducer H52P, began decreasing at 00:03:10 and reached zero at SECO (see fig. 45). The cause of the indicated dropoff in the sustainer hydraulic accumulator pressure is discussed in the section that follows.

Abort Sensing and Implementation System

At T-3.33 seconds the abort sensing and implementation system (ASIS) went to a ready condition, that is, all ASIS parameter monitors were enabled and both spacecraft fail-detect relays were energized. The additional holddown time for propulsion system verification was 2.95 seconds.

The ASIS performed satisfactorily during the flight. However, the sustainer hydraulic pressure switch no. 2 actuated to the abort position at 00:04:25.1. This switch and the sustainer hydraulic accumulator pressure transducer (H52P) are connected to a common pressure-sensing line. The transducer indicated a gradual decrease in pressure from 2940 psia to zero between 00:03:10 and 00:05:12. Switch no. 2, which was preset to activate at 2015 ± 100 psia, activated when the transducer indicated a pressure of 1050 psia. The sustainer-control hydraulic-pressure transducer indicated that hydraulic pressure remained constant at a normal level throughout the flight; and as a result of this, the ASIS sustainer hydraulic pressure switch no. 1 did not activate until normal time after SECO. Both ASIS sustainer hydraulic pressure switches must be actuated to initiate abort command; therefore, this command was not given. Postflight tests have indicated that the problem was caused by a lox leak which resulted in lox impingement on the sensing line tee, and caused freezing in the line and erroneous pressure sensing by both the no. 2 switch and the transducer, H52P.

Airframe

The performance of the airframe was satisfactory, and structural integrity was maintained through powered flight and spacecraft separation. The maximum activity in airframe external dynamic pressure, measured at the spacecraft adapter, occurred in the vicinity of Mach 1 and at maximum dynamic pressure. This activity decreased with the lessening of ambient pressure.

Noise during tower jettison and posigrade ignition was measured with a microphone located inside the spacecraft adapter. The behavior noted was similar to that of previous Mercury-Atlas flights. Spacecraft to lox dome clearance and spacecraft separation were normal as indicated by extensiometer measurement.

Guidance

The performance of the launch vehicle guidance system was satisfactory. The guidance system locked on the vehicle in both track and range at 00:73 seconds, approximately as planned, and lost lock at 05:38 (28.1 seconds after SECO).

In figures 46 to 48, the velocity and flight-path angle are shown in the region of SECO. Launch vehicle guidance data are shown in figure 46, and the Range Safety Impact Predictor Computer (IP 7090) data are shown in figure 47 to illustrate the noise level during the time of the "go--no-go" computation. The data from both the launch vehicle guidance system and the IP 7090 computer are considered very good, except for three IP 7090 points immediately after SECO. The reason for these three points with such large errors is not known. The points are obviously in error but are included in the figures, since these points were generated by the IP 7090 computer and received by the GFSC computers as shown in the figures.

The guidance system data indicated a cutoff condition which was about 2 ft/sec high in velocity and about 0.0002° high in flight-path angle. These values are well within the expected accuracy range for the system. In figure 48, these data are shown as flight-path angle plotted against 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. Data from both the launch vehicle and IP 7090 indicated a "go" condition.

The primary auxiliary sustainer cutoff (ASCO) signal based on the launch vehicle guidance system computations was sent to the launch vehicle simultaneously with SECO. However, the backup ASCO signal was generated at the 7090 computer 0.44 second before the guidance SECO discrete was sent. The enable switch in the Mercury Control Center was in the "normal" position, which prevented transmission of this improper ASCO signal. Had this signal been sent, a cutoff velocity error of approximately 110 ft/sec, and possible marginal "go--no-go" insertion conditions, would have resulted. The cause for the early backup ASCO signal is attributed to the accuracy limits (tolerance band) within which the computer was to initiate the signal. The limits were established prior to the flight, but they were not narrow enough to insure that the backup signal would not be sent too early.

TRAJECTORY AND MISSION EVENTS

Sequence of Events

The times at which the major events of the MA-7 mission occurred are given in table XVI.

Flight Trajectory

The ground track of the flight is shown in figure 49, and the altitude-longitude profile is shown in figure 50.

The launch trajectory data, shown in figure 51, are based on the real time output of the Range Safety Impact Predicator Computer (which used Azusa MK II and Cape Canaveral FPS-16 radars) and the General Electric-Burroughs guidance computer. The data from these tracking facilities were used during the time periods listed in the table which follows.

Facility	Time, min:sec
Cape Canaveral FPS-16	0 to 00:39
Azusa MK II	00:39 to 01:13
General Electric-Burroughs	01:13 to 05:10

The parameters shown for the "planned" launch trajectory in table XVII were computed by 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 ARDC model atmosphere in the region of maximum dynamic pressure (about a 37 000-foot altitude). As a result, the maximum dynamic pressure expected would be about 10 percent higher than that shown as "planned."

The orbital portion of the trajectory, shown in figure 52, was derived by starting with the spacecraft position and velocity vector obtained during the second orbital pass near Bermuda as determined by the GSFC computer using Mercury Network tracking data. By integrating backward along the flight trajectory to orbital insertion and forward to the start of retrofire at the end of the third orbital pass the calculated orbit was obtained. These integrated values were in excellent agreement with the guidance-system measured values at orbital insertion. The values were also in accord with the position and velocity vectors determined by the GSFC computer for orbital passes near the Canary Islands (first orbital pass) and Muchea (second and third orbital passes), thus the validity of the integrated orbital portion of the flight trajectory was established.

The reentry portion of the trajectory, shown in figure 53, was obtained by starting with the spacecraft position and velocity vector near Cape Canaveral, Florida, as determined by the GSFC computer. By integrating backward along the flight to the end of retrofire and forward to landing, the reentry trajectory was obtained. This computed trajectory reflected the assumptions that the drogue parachute deployed at 04:50:54 and the main parachute deployed at 04:51:48.2, as indicated by onboard measurement of the times of these events.

The spacecraft decelerations from the integrated reentry trajectory agree within reading accuracy with the decelerations measured by the onboard accelerometer. In addition, the time of 0.05g from the integrated reentry trajectory and from spacecraft onboard measurements agree within 1 second. This agreement verifies the validity of the integrated reentry position of the trajectory.

The fact that the spacecraft landed approximately 250 nautical miles downrange of the nominal impact point and 15 nautical miles north of the nominal ground track can be attributed to improper spacecraft attitude, late retrofire, and a slightly lower (approximately 3 percent) than nominal retrorocket performance.

Use of measured spacecraft attitudes, which were given by both scanner and gyro data in integrated trajectory calculations resulted in landing points approximately 400 nautical miles downrange of the actual landing point. Therefore, these attitude data are clearly erroneous. In order to obtain a reasonably accurate estimate of the actual spacecraft attitudes and retrorocket performance which are uniquely related to the measured trajectory and, consequently, the actual landing point, an extensive trajectory analysis was conducted. This study made use of: actual radar tracking data immediately prior to and after retrofire; the measured retrofire time; and a calculated spacecraft pre-retrograde weight. The following estimated accuracies of space-fixed position and velocity vectors were obtained from radar tracking immediately prior to and after retrofire.

Parameters	Values
Velocity, ft/sec	±2
Flight-path angle, deg . . .	±0.002
Altitude, ft	±400
Heading angle, deg	±0.002

Results of the comparison of the preretrofire and postretrofire vectors yielded spacecraft attitudes of 36.5° ± 0.5° in pitch and 27° ± 0.5° in yaw and a retrorocket total impulse which is 3 ± 0.5 percent lower than the nominal value of 38 943 lb/sec expected for this particular group of rocket motors. This impulse is within the specification value of 38 880 lb/sec ± 5 percent. These values can be used to generate the measured reentry trajectory and the actual landing point. The roll attitude was neglected, since the roll values of ±20° result in only 1-nautical-mile variation in the landing point.

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

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

A comparison of the planned and actual trajectory parameters is given in table XVII. The difference between these parameters was a primary result of the actual cutoff velocity and flight-path angle at insertion being slightly higher than planned.

MERCURY NETWORK PERFORMANCE

The Mercury Network consists of the Mercury Control Center at Cape Canaveral; stations at the Atlantic Missile Range, Bermuda, and at thirteen other locations along the orbital ground track; and communications and computing centers at the Goddard Space Flight Center. For the MA-7 mission the Atlantic Ocean Ship was located at 17°45' S., 39°24' E. The Indian Ocean Ship was not deployed because of modification commitments necessary for the support of later missions.

Generally, Mercury Network performance was excellent. The few minor malfunctions 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 for postflight analysis. The relaying of air/ground voice to the Mercury Control Center from all voice sites contributed substantially in enabling Mercury Control Center to maintain close real-time monitoring of the mission.

Trajectory

Details of tracking, data transmission, computing, and trajectory displays are discussed in the paragraphs which follow.

Tracking. - The radar tracking system provided satisfactory data from both C- and S-band systems for all requirements. The quantity and quality of the data were more than adequate. All sites provided high quality data to the computer on all orbital passes where the spacecraft was above their horizon (figs. 54 and 55). Some sites reported amplitude modulation, lobing, and countdown of both radar beacons, and Bermuda reported local interference on the C-band radar. In spite of these difficulties, the overall tracking was very good. At White Sands Missile Range, tracking was lost very shortly after the modulator was turned off, but this was undoubtedly caused by extreme range and low-elevation angle. During the "blackout" period on reentry, the S-band radars tracked for a maximum of about $1\frac{1}{2}$ minutes. The C-band radars tracked well into the "blackout" condition with the San Salvador FPS-16 losing tracking 45 seconds before the end, at which time the elevation angle was about 1 degree and the range almost 400 miles.

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

Computing and trajectory displays. - A modified computer program at the Goddard Space Flight Center (GSFC) was utilized in support of the MA-7 mission. This program had the capability of receiving high-speed radar data from Bermuda and provided the Mercury Control Center with an additional source for determining satisfactory orbital insertion (go--no-go). The computing and trajectory display facilities at Bermuda were retained and operated in parallel with the high speed radar data transmitted to GSFC since this was the first opportunity to obtain operational experience with the new system. The system performed satisfactorily, and no problems were encountered. With the introduction of high-speed data from Bermuda, the capability of transmitting raw FPS-16 radar data from the Atlantic Missile Range radars to GSFC has been deleted.

Confidence checks during the countdown indicated that the launch monitor system was in a "go" condition. According to reports, however, high refractive indices were being measured through a fog bank in the local Cape Canaveral area by a test aircraft. These indications caused some concern among the guidance personnel who believed that this condition could create noisy data at cutoff similar to that experienced on the MA-4 mission. Further evaluation indicated that this noise would probably be of a high-frequency nature and would therefore not cause any significant difficulty. Therefore, the guidance complex considered this a "go" condition. This was the first Mercury flight in which the 6000-foot legs of the tracking antenna configuration were actively utilized for guidance.

The selected source for display at the MCC was the output of the IP 7090 from lift-off until approximately 00:01:13 at which time the launch vehicle guidance system was selected and displayed throughout the powered flight. The quality of the launch vehicle guidance system data was excellent up to SECO and during the "go--no-go-" computation. No difficulty was experienced in making the "go--no-go" decision, and it was not necessary to select either the IP 7090 or Bermuda data to verify the launch vehicle guidance system solution. The cutoff conditions are given in table XVIII.

The programed phase of the flight showed a minor deviation of plus 1.2° in flight-path angle and plus 1.5 nautical miles in altitude at BECO.

After staging, steering corrected these deviations in both flight-path angle and altitude. The yaw velocity error was zero at cutoff.

Low-speed tracking data from the remote sites were excellent, such that the orbit was well defined after Canary Island tracking was received. Subsequent tracking resulted in no change in the orbit and increased confidence in the values obtained. Table XIX shows the tracking data obtained.

The retrosequence time set in the spacecraft at launch was 04:32:25. At insertion, the computed retrosequence time was 04:32:39. This time was reduced to 04:32:28 after updating the computed trajectory based on the Bermuda (BDA) data. During the remainder of the mission, the computed time varied only ±1 second at about 04:32:28. This small variance indicates that the orbit was fixed very early in the flight.

The spacecraft clock was set to 04:32:34 over Muchea during the third orbital pass. This setting included a -1 second clock error and a +6 second correction because of a decrease in spacecraft weight which was caused by more fuel usage than had been accounted for in the computer programs. A countdown to retrosequence at a ground elapsed time of 04:32:35 was given from Mercury Control Center (MCC).

During the reentry, tracking data accurately established the landing location. Table XX shows the minor variations in landing latitude and longitude obtained from tracking data across the United States. Cape Canaveral, Grand Bahama Island, and San Salvador FPS-16's tracked through blackout, reports of which in real time at the MCC were extremely comforting in verifying the integrity of the spacecraft during reentry.

The performance of the computing system and the tracking facilities was excellent throughout the mission and no malfunctions occurred. It is felt that the performance of the BDA to GSFC high-speed data transmission system during this mission was such that the computing facilities and trajectory displays at Bermuda are no longer necessary in support of the Mercury program.

Telemetry

The data provided by the telemetry system were generally adequate and of good quality. Coverage was excellent, and data were acquired throughout each orbital pass at every site. Coverage is shown graphically in figure 56 and in tabular form, with decommutator figures, ranges, and elevation angles in table XXI. Signal strengths were satisfactory, ranging up to more than 400 microvolts. The usual ionization blackout of telemetry, expected to begin at approximately 04:43:10, did not begin until 04:43:56 because of the landing point overshoot. Grand Turk had acquired the signal briefly (6 seconds for the commutated channel, 29 seconds for the continuous channels) at approximately 04:48:44. If Grand Turk had acquired the signal at the end of the blackout, this would indicate an ionization time of 04:48:00. Loss of signal at Grand Turk was apparently caused by the range and elevation angle.

No serious problems were experienced in the instrumentation systems, other than apparent difficulties with onboard physiological instrumentation which is discussed in the Instrumentation and Aeromedical Analysis sections of this report.

Trend charts plotted from the telemetry summary messages showed fairly good consistency except for automatic and manual fuel quantity. The reason for the obvious scatter in the fuel quantity data is unknown, but it is in part caused by the fact that the full sensor range represents only 54 percent of full-scale indicator reading which reduces resolution by almost 2 to 1.

Performance of the acquisition-aid system was satisfactory, with the usual multipath errors at elevation angles less than 18°.

Command System

The command system for the MA-7 mission operated in a satisfactory manner during the mission. A summary of the command handover exercises is shown in table XXII, and a summary of command transmissions is shown in table XXIII.

Ground system. - All command sites had command coverage beginning at slant ranges equal to that of the MA-6 mission. The 10-kw command sites using the quadhelix antennas had an average of approximately 35 percent better coverage above the 10-microvolt level than that of the 600-watt command sites.

A total of sixteen functions were transmitted from the command sites. All of the functions were received successfully with the exception of one telemetry "R" calibration from Muchea. This function was not received because the signal strength was below receiver threshold. In addition, the emergency voice via command carrier was used by Muchea during the first orbital pass, and by Cape Canaveral during reentry. Muchea's transmission was successful. Cape Canaveral's transmission was not successful because of ionization blackout and excessive slant range.

More ground system malfunctions occurred than have previously been noted during mission time. The following malfunctions were experienced.

1. The rotary joint on the quadhelix antenna located at Cape Canaveral burned out at T-135 minutes. The Atlantic Missile Range unipole antenna along with Grand Bahama Island was used for the first orbital pass coverage. The unipole was used with a change in the handover plan for the second and third orbital coverage. The unipole coverage was less than expected with an average of only 26-percent coverage above the 10-microvolt level.

2. The master FRW-2 at Bermuda was inoperative during the mission. An attempt to repair the transmitter prior to the mission was unsuccessful because of numerous teflon ring failures in the power amplifier section of the transmitter. The station satisfactorily supported the mission with the standby FRW-2 and the 10-kw power amplifier.

3. A failover[1] from the master to the standby FRW-2 transmitter occurred at Guaymas during the third orbital pass. This failover was caused by an open fuse in the transmitter power supply. The standby transmitter operated satisfactorily.

4. Although the California command site was not used during the first orbital pass, a failover to the standby transmitter occurred during this time. The cause was an open 310-volt fuse. The fuse was replaced and the mission was completed in a normal manner.

Spacecraft system. - Command receiver "A" operating from the 18-volt isolated bus had a threshold value of 3.6 microvolts and a saturation value of between 20 to 40 microvolts. Commander receiver "B" operating from the 18-volt standby bus had a threshold value of 3.8 microvolts and a saturation value of between 40 to 80 microvolts.

The command system appeared to operate normally. The antenna pattern effects on the MA-7 mission were as noticeable as on previous missions.

Communications

Air/ground voice. - The performance of the primary air/ground voice system (UHF) was generally good throughout the mission, with the exception of the first 1 to 2 minutes of launch, and the period from the onset of "blackout" during reentry to the end of the mission. During the early phase of powered flight the voice transmissions received from the vehicle were very noisy, although readable. The loss of signal after blackout was undoubtedly caused by horizon effect. The range to Grand Turk was over 400 miles and to the nearest relay aircraft approximately 200 miles.

In spite of these ranges several Cape Canaveral transmissions were received by the astronaut and one spacecraft transmission was received by Cape Canaveral, all apparently through the two relay aircraft flying at approximately 25 000 feet.

Signal strengths were adequate to provide very good signal-to-noise ratios for essentially all times the spacecraft was above the local visual horizon at the network sites. UHF in-range times averaged about 6 minutes per orbital pass. (See fig. 57.)

Since the UHF system provided adequate communications, the HF system was seldom used. On the first orbital pass, the astronaut heard Canton calling, responded on UHF, then HF, but was not received until within UHF range. Two other instances of spacecraft HF transmission not being received occurred during the flight. A discussion of the HF problem is presented in the Communication System section of this report.

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[1]Failover - Failure of primary system, accompanied by automatic switching to standby system.

Emergency voice checks, which were made by using the command transmitters, resulted in loud and clear reception by the astronaut.

Ground communications. - All the ground communication networks provided good support for the mission. A few isolated instances of outages occurred, but communications were accomplished by alternate circuits. Single-sideband HF communication from the Indian Ocean Ship direct to Cape Canaveral or relayed via Ascension or Pretoria, was excellent and aided materially in mission monitoring.

TABLE VIII. - SPACECRAFT FUEL CONSUMPTION

Time, hr:min:sec	Mission phase	Automatic system		Manual system	
		Fuel used, lb	Fuel remaining, lb	Fuel used, lb	Fuel remaining, lb
00:00:00	Launch	0	35.0	0	24.9
00:08:00	Turnaround and damping	1.6	33.4	0	24.9
01:33:32	First orbital pass	15.8	17.6	8.5	16.4
03:07:04	Second orbital pass to retro-sequence	5.8	11.8	5.1	11.3
04:33:21	Retrosequence to 0.05g	5.4	6.4	10.3	1.0
04:44:44	0.05g to drogue parachute	5.0	1.4	[a]1.0	0
04:50:54	Drogue to main parachute	[a]1.4	0	--	--

[a]Fuel depletion occurred during this period.

TABLE IX. - RESULTS OF POSTFLIGHT INSPECTION OF SPACECRAFT 18 THRUST CHAMBERS

Thruster	Serial number[a]	Inspection results
Yaw right (1-lb)	136	Orifice spacer clean; rust stains evident on the bottom side of orifice and diffuser plate. Platinum screens in good condition.
Yaw left (1-lb)	133	Orifice spacer clean; diffuser plate clear. Platinum screens in good condition.
Pitch up (1-lb)	73	Orifice spacer clean; rust stains evident on both sides of diffuser plate and top side of first screen. Platinum screens in good condition.
Pitch down (1-lb)	135	Orifice spacer clean; diffuser plate clear. Screens appeared in excellent condition.
CCW automatic roll (6-lb)	28	Heavy rust stains on all parts; diffuser plate and orifice clear; platinum screens in good condition.
CCW automatic roll (1-lb)	28	Rust stains evident on orifice spacer and diffuser plate; diffuser plate blue in color. Platinum screens in satisfactory condition.
CW automatic roll (6-lb)	18	Very wet; orifice clean; diffuser plate blue in color; screens in very good condition.
CW automatic roll (1-lb)	18	Orifice spacer clean; no rust; diffuser plate lightly blued on top surface. Screens in excellent condition.
CCW manual (1- to 6-lb)	21	Orifice and diffuser plate clean; light rust stain on platinum screen. Light corrosion on check valve nose piece.
CW manual (1- to 6-lb)	28	Corrosion on check valve nose piece; salt-like substance found in valve and heat barrier screen. Orifice, diffuser plate, and platinum screens in good condition.

[a]The serial number refers to a thrust-chamber assembly, which may contain more than one thruster.

TABLE X. - GENERAL ACTIVITIES OF THE ASTRONAUT OF THE MA-7 MISSION

Date, 1962	Activity
April 30	Arrived at Cape Canaveral Simulated flight, suited
May 2	Procedures trainer, suited
May 5	Began special diet, aeromedical feeding facility
May 7	Procedures trainer, suited
May 9	Procedures trainer, not suited
May 10	Simulated launch, suited
May 15	Simulated flight no. 3, suited
May 17	Comprehensive medical examinations, Patrick Air Force Base hospital
May 21	Preflight low-residue diet began for third time
May 23	MA-7 meetings Asleep at 8:00 p.m.
May 24	Awakened 1:15 a.m. Began aeromedical countdown Launch 7:45 a.m. Recovery physicians examination 3:30 p.m. and 5:15 p.m. Brief examination, Grand Turk Island 11:00 p.m.
May 25	Asleep 2:30 a.m. Awoke 9:15 a.m. for aeromedical debriefing Engineering debriefing
May 26	Asleep 12:45 a.m. Awoke 6:45 a.m. Aeromedical and engineering debriefing Skin diving (3 hours)
May 27	Asleep 2:30 a.m. Awoke 9:15 a.m. Arrived Patrick AFB 2:00 p.m.
May 28	Departed from Cape Canaveral 2:15 p.m.

TABLE XI. - MA-7 AEROMEDICAL COUNTDOWN EVENTS

[May 24, 1962]

Time, a.m. e.s.t.	Activity
1:15	Awaken the pilot
1:46	Breakfast
2:05	Preflight physical examination
2:41	Biosensor placement
3:04	Don Mercury pressure suit
3:25	Pressure suit and biosensor checkout
3:40	Hangar S Aeromedical Facility to transfer van
4:03	Transfer van to launch pad
4:36	Ascend gantry
4:43	Astronaut insertion into spacecraft
7:45	Lift-off

TABLE XII. - PREFLIGHT AND POSTFLIGHT MEDICAL FINDINGS

[Electrocardiograms on May 17 and May 24, 1962, aboard the recovery vessel were normal and unchanged in all respects.]

	Preflight				Postflight			
	May 17, 1962 (Patrick Air Force Base)		May 24, 1962 (Cape Canaveral, 2:05 a. m.)		May 24, 1962 (Recovery Vessel 5:15 p. m.)		May 25 and 26, 1962 (Grand Turk Island)	
Temperature (oral), °F	97.9		97.4		97.6		97.5	
Pulse rate, beats/min	60		60		76-80		--	
Blood pressure, mm Hg	[a]126/84 RAS		[b]120/78 LAS		116/78 LAS		124/80 LAS	
Respiration, breaths/min . . .	14		12		--		--	
Body weight (nude), lb[c]	$151\frac{1}{2}$		154		148		$151\frac{3}{4}$	
Extremity measurements[d], in.	Left	Right	Left	Right	Left	Right	Left	Right
Forearm, maximum	9	$8\frac{3}{4}$	$10\frac{7}{8}$	11	$10\frac{3}{4}$	$10\frac{3}{4}$	$10\frac{1}{4}$	$10\frac{5}{8}$
Forearm, minimum	7	$6\frac{7}{8}$	$6\frac{3}{4}$	$6\frac{5}{8}$	$6\frac{5}{8}$	$6\frac{1}{2}$	$6\frac{3}{4}$	$6\frac{3}{4}$
Calf, maximum	$12\frac{7}{8}$	$13\frac{1}{4}$	$13\frac{3}{4}$	13	13	$13\frac{1}{4}$	$13\frac{3}{8}$	$13\frac{3}{4}$
Calf, minimum	8	$8\frac{3}{8}$	8	$7\frac{7}{8}$	$7\frac{3}{4}$	$7\frac{3}{4}$	$8\frac{1}{8}$	8
Comments:	Complete examination was negative; skin clear except for 2 clusters of inclusion cysts at left axillary ECG site; chest X-ray normal.		Fit for flight; alert with appropriate mental status.		Modern erythema at left chest ECG and blood-pressure cuff site; normal mental status; chest X-ray fogged - no interpretation.		Minimal erythema as at postflight sites; examination unchanged from May 17th findings, including ECG, EEC, audiogram and chest X-ray.	

[a]Right arm, sitting.

[b]Left arm, sitting.

[c]All body weights on different scales.

[d]Extremity measurements made by same individual on May 17 and 24 (preflight), and May 25 and 26, 1962. On May 17, 1962, measurements were made 6 and 10 inches below olecranon on forearms and 6 and 11 inches below patella on legs. All other measurements are maximums and minimums.

TABLE XIII. - PREFLIGHT AND POSTFLIGHT LABORATORY ANALYSES

Determination	Peripheral blood			
	Preflight		Postflight	
	-7 days	-2 days	May 25, 1962 (12:15 a.m.)	May 26, 1962 (12 m.)
Hemoglobin, g (Cyanmethemoglobin method)	15.0	13.8	16.0	14.8
Hematocrit, percent	47	42	50	46
White blood cells, per mm^3	12 700	11 600	12 500	11 900
Red blood cells, millions per mm^3	5.2	--	5.6	5.2
Differential blood count, percent				
Lymphocytes	25	19	27	37
Neutrophiles	71	79	65	58
Monocytes	2	1	3	2
Eosinophiles	2	1	4	2
Basophiles	0	0	1	1

TABLE XIII. - PREFLIGHT AND POSTFLIGHT LABORATORY ANALYSES - Concluded

Urine summary[a]					
Sample date, 1962	Volume, cc	Specific gravity	pH	Albumin	Microscopic examination
12:15 p.m., May 17	250	1.024	5.0	Trace	20-30 WBC/hpf, occasional hyaline casts, occasional RBC/hpf, squamous epithelial cells
1:40 p.m., May 22	-	1.015	6.0	Negative	Occasional WBC, occasional epithelial cells, rare RBC
Inflight Final urination on water. Exact time unknown, but after egress from spacecraft.	2 360	1.003	5.0	Trace	20-25 WBC/hpf, no RBC, no casts
5:00 p.m., May 24	155	1.013	5.0	30 mg	Some clumps of WBC/lpf, 20-25 WBC/hpf, no RBC, no casts
6:05 a.m.[b], May 25	140	1.016	5.0	Trace	15-20 WBC/hpf, no RBC, no casts
9:25 a.m., May 25	140	1.016	5.0	Trace	10-15 WBC/hpf, no RBC, no casts
2:35 p.m., May 25	215	1.024	5.0	Trace	3-5 WBC/hpf, no clumps in lpf, no RBC, no casts
6:30 p.m., May 25	305	1.021	5.0	Trace	15-20 WBC/lpf, few mucous threads, 1-3 WBC/hpf
12:30 a.m., May 26	890	1.005	5.0	Negative	8-12 WBC/hpf, occasional small WBC clusters
2:20 a.m., May 26	310	1.019	6.0	Trace	Large amount of amorphous urates
7:00 a.m., May 26	550	1.009	5.0	Negative	10-15 WBC/hpf, small amount of mucous, occasional small cluster of WBC
9:45 a.m., May 26	310	1.014	5.0	Negative	4-8 WBC/hpf, occasional small WBC cluster, small amount of mucous

[a]All samples are negative for glucose, ketons, and bile.

[b]This sample was divided into three fractions at collection. Microscopic examination was immediately done. Only the first fraction showed the presence of appreciable WBC/hpf. Samples 2 and 3 showed 2-3 WBC/hpf. No other formed bodies were noted.

TABLE XIV. - SUMMARY OF BLOOD-PRESSURE DATA

Data sources	Number of values	Mean blood pressure, mm Hg	Standard deviation, 2σ		Systolic range, mm Hg	Diastolic range, mm Hg	Mean pulse pressure, mm Hg
			Systolic	Diastolic			
Preflight physical examinations	18	119/73	14	15	98-128	58-84	46
Three-orbit Mercury-Atlas centrifuge simulation	30	130/83	22	15	104-155	72-106	47
Launch-pad tests	45	127/64	31	18	101-149	44-84	63
MA-7 countdown	13	116/63	18	12	105-139	56-70	53
Totals (preflight)	106	125/71	24	14	98-155	44-106	54
Postflight physical examinations	3	115/76	2	9	114-116	70-80	39

TABLE XV. - SUMMARY OF CONTROL SYSTEM USAGE

Control mode[a]	Time from launch		Gyro switch position			Maneuvering, flight activities
	From	To	Position	From	To	
Auxiliary damping	00:05:12	00:05:22	Normal	Prelaunch	00:12:38	Five second rate damping at spacecraft separation.
FBW	00:05:22	00:07:10				Turnaround maneuver.
ASCS	00:07:10	00:12:55	Free	00:12:38	00:14:46	Photographed launch vehicle while the pilot maintained attitude for radar track.
FBW	00:12:55	00:16:31	Normal	00:14:46	00:30:53	Used high FBW thrusters.
ASCS	00:16:31	00:17:29				Astronaut reported a window-instrument disagreement.
MP	00:17:29	00:17:48				MP control check.
ASCS	00:17:48	00:17:56				Dropped into orientation mode.
FBW and MP	00:17:56	00:21:28				
ASCS	00:21:28	00:30:52				Dropped into orientation mode. Photographed horizon.
FBW	00:30:52	00:39:12	Caged	00:30:53	00:32:10	Used high FBW thrusters.
			Normal	00:32:10	00:33:13	
			Caged	00:33:13	00:33:17	To aline window and gyro indicators.
			Normal	00:33:17	00:33:48	

[a]See key at end of table.

TABLE XV. - SUMMARY OF CONTROL SYSTEM USAGE - Continued

Control mode[a]	Time from launch		Gyro switch position			Maneuvering, flight activities
	From	To	Position	From	To	
			Caged	00:33:48	00:33:51	
			Normal	00:33:51	00:36:45	
			Free	00:36:45	00:38:35	Used airglow filter, horizon definition photography.
ASCS	00:39:12	00:39 :13	Caged	00:38:35	00:39:13	Went to ASCS normal with gyros caged.
RSCS	00:39:13	00:39:14	Normal	00:39:13	00:56:19	
ASCS	00:39:14	00:45:46				Photographed sunset; yawed 90° left and right.
FBW	00:45:46	00:48:33				Used high FBW thrusters.
ASCS	00:48:33	00:56:30	Free	00:56:19	01:02:55	Dropped into orientation mode. Observed occluded Venus; emergency voice check.
RSCS	00:56:30	00:56:53				Re-checked RSCS.
MP	00:56:53	00:58:20				
FBW	00:58:20	01:13:06	Caged	01:02:55	01:43:00	Flare observation (-80° pitch, +80° yaw). Used high FBW thrusters. Started drifting flight at 01:01:00. Varied spacecraft rates slightly, by rocking arms back and forth (0.1°/sec). Ate food at 01:08:52. Stopped drifting flight at 01:12:30.
RSCS	01:13:06	01:14:09				

[a]See key at end of table.

TABLE XV. - SUMMARY OF CONTROL SYSTEM USAGE - Continued

Control mode[a]	Time from launch		Gyro switch position			Maneuvering, flight activities
	From	To	Position	From	To	
FBW and MP	01:14:09	01:24:50				Yawed 180° to take photographs of sunrise. Observed particles.
FBW	01:24:50	01:37:43				Photographed clouds.
ASCS	01:37:43	01:37:47				Went to ASCS normal with gyros caged.
FBW	01:37:47	01:43:01	Normal	01:43:00	02:01:03	Deployed the balloon at 01:38:00.
ASCS	01:43:01	02:01:07	Caged	02:01:03	02:01:23	Dropped into orientation mode. Observed and took photographs of balloon.
FBW	02:01:07	02:04:20	Free	02:01:23	02:01:43	
			Caged	02:01:43	02:02:29	
ASCS	02:04:20	02:09:00	Normal	02:02:29	02:14:12	Dropped into orientation mode. Observed sunset.
FBW	02:09:00	02:28:53	Caged	02:14:12	02:14:17	Used high FBW thrusters.
			Normal	02:14:17	02:30:09	Checked stability of spacecraft. Extended maneuver beyond repeater stop limits with gyros normal and with balloon attached to spacecraft. Haze layer extincted.
MP	02:28:53	04:26:10	Free	02:30:09	02:38:01	
			Caged	02:38:01	02:55:02	Took xylose pill. Took photographs of sunrise, observed particles.

[a]See key at end of table.

TABLE XV. - SUMMARY OF CONTROL SYSTEM USAGE - Continued

Control mode[a]	Time from launch		Gyro switch position			Maneuvering, flight activities
	From	To	Position	From	To	
			Normal	02:55:02	02:55:24	
			Caged	02:55:24	02:57:38	
			Normal	02:57:38	03:11:39	Drank water; yaw gyro at 250 repeater stop (03:06:00); wobulator check.
			Caged	03:11:39	04:25:53	Started drifting flight at 03:12:00; attempted to jettison balloon. Performed zero-g and auto-kinesis experiments; observed particles; photographed the horizon; observed sunset; drank water; made photometer readings of the stars; performed calibration exercises. Observed occluded stars in haze layer. Held attitude on Moon at 04:12:30. Observed and photographed sunrise and particles. Dropped into orientation mode. Observed and took photographs of balloon.
MP	02:28:53	04:26:10	Normal	04:25:53	04:27:53	
ASCS	04:26:10	04:26:26				ASCS gyros run down (RSCS - ASCS switch in Rate Command position) dropped into orientation mode for 16 seconds. Reported ASCS problem.
FBW and MP	04:26:26	04:27:10				Used FBW high thrusters.
Auxiliary damping	04:27:10	04:27:51				Reported window and gyro indications not in agreement and rate of descent indication at 10 to 12 ft/sec.

[a]See key at end of table.

TABLE XV. - SUMMARY OF CONTROL SYSTEM USAGE - Continued

Control mode[a]	Time from launch		Gyro switch position			Maneuvering, flight activities
	From	To	Position	From	To	
FBW and MP	04:27:51	04:28:37	Caged	04:27:53	04:30:33	Retrograde checklist
FBW	04:28:37	04:29:41				Used high FBW thrusters
ASCS	04:29:41	04:29:45				Went to ASCS normal with gyros caged. Stowed equipment
FBW	04:29:45	04:29:57				Astronaut decided to control retrofire by using FBW control mode. Checked FBW and MP control modes.
MP	04:29:57	04:31:23	Normal	04:30:33	04:32:06	
ASCS	04:31:23	04:32:02				Rechecked ASCS control mode.
FBW and MP	04:32:02	04:32:43	Free	04:32:06	04:34:09	Retroattitude command - 04:32:06
ASCS	04:32:43	04:32:50				Checked orientation mode per ground request. Disliked orientation attitudes.
FBW	04:32:50	04:33:53	Normal	04:34:09	04:37:56	Pitched to a -15° gyro attitude and held during the retrofire period. Retroattitude switch in bypass. Yaw and roll gyro indications held at approximately +20° each axis. Retrofire time - 04:33:21.03 (initiated manually by astronaut, retrofire 3 seconds late).
			Caged	04:37:56	04:38:00	Used high FBW thrusters. On 250° yaw repeater stop at 04:35:00. Out of manual fuel. Terrain observations. Off yaw repeater stop at 04:40:55. Inserted 4.5°/sec counterclockwise roll at 04:44:55.
			Normal	04:38:00	04:40:14	
			Caged	04:40:14	Landing	

TABLE XV. - SUMMARY OF CONTROL SYSTEM USAGE - Concluded

Control mode[a]	Time from launch		Gyro switch position			Maneuvering, flight activities
	From	To	Position	From	To	
Auxiliary Damping (ASCS)	04:45:04	04:51:48				Auxiliary damping counterclockwise roll to 12°/sec. Auxiliary damping held rates to $\pm\frac{1}{2}$ degree until automatic fuel depletion at 04:50:00. Yaw rates pegged at 10°/sec at 04:50:21. Pitch rates pegged at 10°/sec at 04:50:31. Drogue parachute deployed at 04:50:54. Astronaut deployed drogue parachute manually at about 25 000 ft during third small-end-down spacecraft oscillation. Main parachute deployed manually 04:51:48. Landing at approximately 04:56:00.

[a]Key: ASCS - Automatic stabilization and contol system.
RSCS - Rate stabilization and control system.
FBW - Fly-by-wire control system.
MP - Manual proportional control system.

TABLE XVI. - SEQUENCE OF EVENTS

Event	Planned time,[a] hr:min:sec	Actual time, hr:min:sec	Difference, sec
		Launch phase	
Booster-engine cutoff (BECO)	00:02:10.1	00:02:08.6	-1.5
Tower release	00:02:32.2	00:02:32.2	0
Escape-rocket ignition	00:02:32.2	00:02:32.2	0
Sustainer-engine cutoff (SECO) discrete		00:05:09.9	
Tail-off complete	00:05:05.3	00:05:10.2	4.9
Spacecraft separation	00:05:06.3	00:05:12.2	5.9
		Orbital Phase	
Retrofire sequence initiation	04:32:25.6	04:32:36.5	10.9
Retrorocket No. 1 (left)	04:32:55.6	04:33:10.3	14.7
Retrorocket No. 2 (bottom)	04:33:00.6	04:33:15.3	14.7
Retrorocket No. 3 (right)	04:33:05.6	04:33:20.3	14.7
Retro assembly jettison	04:33:55.6	04:34:10.8	15.2
		Reentry phase	
0.05g relay	04:43:55.6	04:44:44	48.4 [b](1.0)
Drogue parachute deployment	04:50:00.6	04:50:54	53.4
Main parachute deployment	04:50:37.6	04:51:48.2	70.6
Landing (accelerometer measurement)	04:55:22.6	04:55:57	34.4 [b](25.6)
Main parachute jettison	04:55:22.6	04:56:04.8	42.2 [b](33.4)

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

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

TABLE XVII. - COMPARISON OF PLANNED AND ACTUAL

TRAJECTORY PARAMETERS

Condition and quality	Planned	Actual	Difference
Cutoff conditions (including tail-off)			
Range time, sec	305.3	310.2	4.9
Range time, min:sec	05:05.3	05:10.2	
Geodetic latitude, deg North	30.4308	30.5035	0.0727
Longitude, deg West	72.5076	72.4111	-.0965
Altitude, ft	528 367	527 859	-508
Altitude, nautical miles	86.96	86.87	-.09
Range, nautical miles	437.4	443.3	5.9
Space-fixed velocity, ft/sec	25 715	25 717	2.0
Space-fixed flight-path angle, deg	-.0006	-.0004	.0002
Space-fixed heading angle, deg East of North	77.4886	77.6008	.1122
Post-posigrade ignition conditions			
Range time, sec	307.3	312.2	4.9
Range time, min:sec	05:07.3	05:12.2	
Geodetic latitude, deg North	30.4606	30.5374	.0768
Longitude, deg West	72.3605	72.2416	-.1189
Altitude, ft	528 397	527 894	-503
Altitude, nautical miles	86.96	86.88	-.08
Range, nautical miles	445.2	452.3	7.1
Space-fixed velocity, ft/sec	25 736	25 738	2.0
Space-fixed flight-path angle, deg	-.0035	-.0031	.0004
Space-fixed heading angle, deg East of North	77.5672	77.6915	.1243
Orbit parameters			
Perigee altitude, statute miles	100.1	99.97	-.13
Perigee altitude, nautical miles	86.96	86.87	-.09
Apogee altitude, statute miles	166.2	166.82	.62
Apogee altitude, nautical miles	144.4	144.96	.56
Period, min:sec	88:32	88:32	0
Inclination angle, deg	32.52	32.55	.03

TABLE XVII. - COMPARISON OF PLANNED AND ACTUAL

TRAJECTORY PARAMETERS - Concluded

Condition and quality	Planned	Actual	Difference
Maximum conditions			
Altitude, statute miles	166.2	166.82	.62
Altitude, nautical miles	144.4	144.96	.56
Space-fixed velocity, ft/sec	25 737.0	25 738.0	1.0
Earth-fixed velocity, ft/sec	24 420.0	24 422.1	2.1
Exit acceleration, g	7.7	7.8	.10
Exit dynamic pressure, lb/ft^2	[a]966 [b]878	967	1.0
Entry acceleration, g.	7.6	7.5	-.1
Entry dynamic pressure, lb/ft^2	450	429	-21.0
Landing point			
Latitude	21°07'N	[c]19°27'N	-1°40'N
Longitude	68°00'W	[c]63°59'W	4°01'W

[a]Based on Cape Canaveral atmosphere.

[b]Based on 1959 ARDC model atmosphere.

[c]"Actual" landing coordinates shown in the table were those resulting from the trajectory integration. The retrieval point after landing was reported as 19°30'N and 64°15'W by the recovery ship.

TABLE XVIII. - ORBITAL INSERTION CONDITIONS AVAILABLE AT MERCURY CONTROL CENTER

Insertion conditions	Nominal	General Electric	Impact plotter	Bermuda	Back from Muchea
Velocity with posigrades, fps (average of go--no-go)	25 736	25 735	25 750	25 740	25 739
Inertial flight path angle, deg (average of go--no-go)	-0.0035	-0.0314	-0.114	+0.010	-0.00051
Insertion altitude, nautical miles	87.0	86.7			86.7
Inclination angle, deg	32.52	32.5			32.5
Orbit capability		[a]7			
Apogee, nautical miles	145	143			145

[a]Minimum number required for go--no-go decision in the Mercury Control Center. Actual orbit capability can exceed this value by a significant amount.

TABLE XIX. - RADAR TRACKING DATA

Station	Radar	Total points	Standard deviations		
			Range, yd	Azimuth, mils	Elevation, mils
First orbital pass					
Bermuda	FPS-16	74	31.0	0.11	0.54
Bermuda	Verlort	74	62.8	1.28	2.15
Canaries	Verlort	68	18.5	1.18	.67
Muchea	Verlort	84	17.8	1.05	1.15
Woomera	FPS-16	79	4.5	.17	.14
Guaymas	Verlort	52	11.0	1.44	1.58
White Sands	FPS-16	29	4.9	.23	.41
Texas	Verlort	72	31.9	2.55	2.20
Eglin	FPS-16	82	10.0	.35	.24
Eglin	Verlort	81	40.1	1.67	1.78
Cape Canaveral	FPS-16	61	7.6	.12	.56
Second orbital pass					
Bermuda	FPS-16	76	10.1	0.16	0.57
Bermuda	Verlort	71	62.2	1.65	2.71
Canaries	Verlort	61	12.0	2.31	1.80
Muchea	Verlort	82	22.9	1.28	1.34
Woomera	FPS-16	74	2.5	.10	.22
Hawaii	FPS-16	53	5.4	.24	.21
Hawaii	Verlort	52	16.7	1.33	1.23
California	FPS-16	45	10.1	.30	.40
California	Verlort	45	12.0	1.42	1.56

TABLE XIX. - RADAR TRACKING DATA - Concluded

Station	Radar	Total points	Standard deviations		
			Range, yd	Azimuth, mils	Elevation, mils
Second orbital pass - Concluded					
White Sands	FPS-16	38	17.7	.14	.39
Texas	Verlort	70	76.7	2.50	2.44
Eglin	FPS-16	88	7.0	.54	.29
Eglin	FPS-16	89	89.1	1.82	2.53
Cape Canaveral	FPS-16	59	6.6	.16	.73
Third orbital pass					
Bermuda	FPS-16	66	8.2	0.30	0.50
Bermuda	Verlort	66	34.7	1.84	2.09
Muchea	Verlort	64	8.8	.74	.60
Hawaii	FPS-16	62	11.5	.19	.34
Hawaii	Verlort	64	21.8	1.83	1.71
Reentry					
California	FPS-16	61	11.6	0.84	0.66
California	Verlort	61	20.5	1.93	1.64
White Sands	FPS-16	41	21.7	.23	1.14
Texas	Verlort	61	91.6	2.37	2.19
Eglin	Verlort	74	39.4	1.17	.32
Cape Canaveral	FPS-16	20	10.0	.14	.43
San Salvador	FPS-16	14	30.8	.21	.36

TABLE XX. - LANDING POINT TRACKING DATA

Station	North latitude	West longitude	Approximate distance from actual landing point, nautical miles
Assumed time of retrofire (assuming correct attitudes)	21°04'	67°59'	235 NW
Differential correction based on Point Arguello, Calif., tracking: 30 calculations FPS-16 20 calculations Verlort	19°14'	63°34'	45 SE
Differential correction based on White Sands, N. Mex., tracking: 32 calculations	19°21'	63°47'	30 SE
Differential correction based on Corpus Christi, Tex., tracking: 41 calculations	19°24'	63°53'	20 SE
Differential correction based on Eglin Air Force Base, Fla., tracking: 02 calculations, FPS-16 06 points, Verlort	(late report)		
Differential correction based on Cape Canaveral, Fla.[a], tracking: 11 calculations FPS-16	19°24'	63°53'	20 SE
Cape IP-7090 integrated solution data, based on Cape Canaveral, Fla.: FPS-16 tracking	19°27'	63°59'	
Actual location reported by recovery ship	19°30'	64°15'	

[a]Start of transmission from Cape Canaveral, Fla., was deliberately delayed to obtain San Salvador data, so more tracking was actually available from Cape Canaveral.

TABLE XXI. - TELEMETRY PERFORMANCE

Station	Telemetry		Decommutator		Slant range		Elevation	
	Acquisition, hr:min:sec	Loss of signal, hr:min:sec	Acquisition, hr:min:sec	Loss of signal, hr:min:sec	Acquisition, nautical miles	Loss of signal, nautical miles	Acquisition, deg	Loss of signal, deg
Cape Canaveral, Florida[a]	0	00:07:46	0	00:07:35	0	1100		
Bermuda	00:03:01	00:10:34	00:03:07	00:10:32	740	890	-1	-1
Canary Islands	00:14:20	00:21:42	00:14:44	00:21:38	800	950	0	-1
Kano, Nigeria	00:21:09	00:28:37	00:21:26	00:28:33	880	950	0	-1
Zanzibar, East Africa	00:29:57	00:38:21	00:30:09	00:38:00	915	1090	-1	-1
Indian Ocean Ship	00:34:04	00:39:04	00:34:38	00:38:54				
Muchea, Australia	00:49:24	00:58:19	00:49:44	00:58:12	1030	1050	0	0
Woomera, Australia	00:54:06	01:03	00:54:20	01:02:55	1100	1030	-1	-1
Canton Islands	01:09:31	01:16:46	(c)	01:16:46	930	925	0	0
Hawaii	(b)							
Point Arguello, California	01:27:16	01:31:36	01:27:44	01:31:36	785	1000	0	0
Guaymas, Mexico	01:26:39	01:33:35	01:26:43	01:33:31	835	835	-1	-1
Corpus Christi, Texas	01:29:18	01:36:53	01:29:34	01:36:31	885	950	-1	-1
Eglin Air Force Base, Florida	01:32:11	01:37:44	(c)	(c)	780	560	0	+5
Cape Canaveral, Florida[a]	01:33:28	01:41:12	01:33:32	01:41:12	820	1080	-1	-1
Bermuda	01:36:44	01:44:14	01:36:59	01:44:12	840	940	-1	-1
Canary Islands	01:47:35	01:54:16	01:48:08	01:53:57	970	960	-1	-1
Kano, Nigeria	01:54:50	02:01:54	01:55:54	02:01:54	910	1020	0	-1
Zanzibar, East Africa	02:04:07	02:11:30	02:04:21	02:11:05	940	1150	0	-1
Indian Ocean Ship	02:04:48	02:13:39	02:05:01	02:13:29				
Muchea, Australia	02:23:00	02:31:47	02:23:24	02:31:44	1030	1020	-1	-1
Woomera, Australia	02:27:50	02:36:07	02:28:06	02:35:54	1030	1000	0	0
Canton Islands	02:43:10	02:49:44	02:43:25	02:49:44	905	865	0	0
Hawaii	02:49:14	02:55:12	02:49:48	02:55:12	920	780	-1	0

[a]Includes data from Grand Bahama Island and Grand Turk Island transmitted via submarine cable.

[b]Out of range.

[c]Not applicable.

TABLE XXI. - TELEMETRY PERFORMANCE - Concluded

Station	Telemetry		Decommutator		Slant range		Elevation	
	Acquisition, hr:min:sec	Loss of signal, hr:min:sec	Acquisition, hr:min:sec	Loss of signal, hr:min:sec	Acquisition, nautical miles	Loss of signal, nautical miles	Acquisition, deg	Loss of signal, deg
Point Arguello, California	02:58:44	03:05:04	02:58:52	03:05:04	800	825	0	0
Guaymas, Mexico	03:00:13	03:06:57	03:00:36	03:06:52	855	830	-1	-1
Corpus Christi, Texas	03:03:16	03:10:04	03:03:24	03:10:02	850	880	-1	-1
Eglin Air Force Base, Florida	03:05:41	03:12:46	(c)	(c)	790	910	0	-1
Cape Canaveral, Florida[a]	03:07:04	03:16:13	03:07:08	03:16:07	820		-1	
Bermuda	03:10:10	03:17:26	03:10:11	03:17:23	850	940	-1	-1
Canary Islands	03:22:31	03:25:14	03:24:54	03:25:01				
Kano, Nigeria	(b)							
Zanzibar, East Africa	(b)							
Indian Ocean Ship	03:39:04	03:46:44	03:39:13	03:46:49				
Muchea, Australia	03:56:48	04:04:32	03:57:08	04:04:25	1010	980	0	0
Woomera, Australia	04:03:13	04:06:40	04:03:37	04:06:27	985	930	0	0
Canton Islands	(b)							
Hawaii	04:21:58	04:29:11	04:22:17	04:29:05	935	810	-1	0
Point Arguello, California	04:31:10	04:38:20	04:31:41	04:38:20	940	790	-1	0
Guaymas, Mexico	04:34:02	04:40:03	04:34:24	04:39:58	820	720	-1	+1
Corpus Christi, Texas	04:37:03	04:42:53	04:37:07	04:42:50	790	645	0	+2
Eglin Air Force Base, Florida	04:39:37	04:43:59	(c)	(c)	680	415	+2	+10
Cape Canaveral, Florida[a]	04:40:58	04:43:56	04:41:02	04:43:56	(c)	(c)		
Grand Turk Island	04:48:43	04:49:12	04:48:45	04:48:51	(c)	(c)		

[a]Includes data from Grand Bahama Island and Grand Turk Island transmitted via submarine cable.

[b]Out of range.

[c]Not applicable.

TABLE XXII. - COMMAND HANDOVER SUMMARY

[Orbital coverage: Cape Canaveral, 10 kW into unipole antenna; Grand Bahama Island, 10 kW into sterling antenna; Bermuda, 9.5 kW into quadhelix antenna; Hawaii and California, 10 kW into quadhelix antenna; and Muchea and Guaymas, 600 W into quadhelix antenna.]

Station	Command carrier[a]		+10 μv carrier coverage above line of sight, percent
	ON	OFF	
Cape Canaveral, Florida	Launch	00:04:05 (00:04:07)	100
Cape Canaveral, Florida, (San Salvador)	00:04:05 (00:04:07)	00:06:02 (00:06:02)	74
Bermuda	00:05:58 (00:05:58)	00:12:00 (00:12:00)	67
Muchea, Australia	00:45:00 (00:45:00)	00:59:00 (00:59:00)	40
Guaymas, Mexico	01:20:00 (01:20:00)	01:33:00 (01:33:00)	47
Cape Canaveral, Florida	01:33:00 (01:33:05)	01:36:30 (01:36:36)	30
Cape Canaveral, Florida, (Grand Bahama Island)	01:36:30 (01:36:36)	01:38:00 (01:38:06)	100
Bermuda	01:37:58 (01:37:58)	01:45:00 (01:45:00)	87
Muchea, Australia	02:15:00 (02:15:00)	02:32:00 (02:32:00)	49
Hawaii	02:45:00 (02:45:00)	02:56:00 (02:56:00)	97
Point Arguello, California	02:56:00 (02:56:00)	03:04:00 (03:04:00)	91
Guaymas, Mexico	03:04:00 (03:04:01)	03:06:00 (03:05:59)	33

[a]The times in parentheses are actual; times not in parentheses are planned.

TABLE XXII. - COMMAND HANDOVER SUMMARY - Concluded

[Orbital coverage: Cape Canaveral, 10 kW into unipole antenna; Grand Bahama Island, 10 kW into sterling antenna; Bermuda, 9.5 kW into quadhelix antenna; Hawaii and California, 10 kW into quadhelix antenna; and Muchea and Guaymas, 600 W into quadhelix antenna.]

Station	Command carrier[a]		+10 μv carrier coverage above line of sight, percent
	ON	OFF	
Cape Canaveral, Florida	03:06:00 (03:06:00)	03:10:30 (03:10:29)	14
Bermuda	03:10:30 (03:10:30)	03:18:00 (03:19:00)	81
Muchea, Australia	03:54:00 (03:54:00)	04:05:00 (04:05:00)	31
Hawaii	04:15:00 (04:15:00)	04:30:00 (04:30:00)	82
Point Arguello, California	04:30:00 (04:30:00)	04:38:00 (04:38:00)	97
Guaymas, Mexico	04:38:00 (04:38:09)	04:40:00 (04:40:01)	55
Cape Canaveral, Florida	04:40:00 (04:40:00)	04:43:11 (04:43:10)	35
	[b](04:47:11)	(04:52:35)	0

[a]The times in parentheses are actual; times not in parentheses are planned.

[b]Turned on in an attempt to communicate with the spacecraft during reentry.

TABLE XXIII. - COMMAND FUNCTION SUMMARY

Station	Function	Signal transmission: Time of initiation, hr:min:sec	Signal transmission: Duration of signal transmission, sec	Slant range, nautical miles	Signal strength at spacecraft, microvolts
Cape Canaveral, Florida, (San Salvador)	ASCO[a]	00:05:09.9	2	415	+50
Muchea, Australia	Z Cal[b]	00:53:49.5	15	155	30
	R Cal[c]	00:54:08	46.5	170	20
Guaymas, Mexico	Z Cal	01:29:31.8	18	140	20
	R Cal	01:30:07	32	135	15
Cape Canaveral, Florida, (Grand Bahama Island)	Z Cal	01:37:00.5	4	375	30
	R Cal	01:37:10.5	6	370	30
Muchea, Australia	Z Cal	02:27:04	12	165	30
	R Cal	02:27:21	16	145	30
	R Cal	02:27:38	1	150	30
	R Cal	02:27:40	1	155	25
	R Cal	02:27:42	1	160	12
	R Cal	02:27:45	1	165	5
	R Cal[d]	02:27:47	1	170	3
Point Arguello, California	Z Cal	03:01:12.2	14	310	10
	R Cal	03:01:34	21	290	+50

[a]ASCO - Auxiliary sustainer cutoff.

[b]Z Cal - Instrumentation zero calibration.

[c]R Cal - Instrumentation full-scale calibration.

[d]Not received by spacecraft.

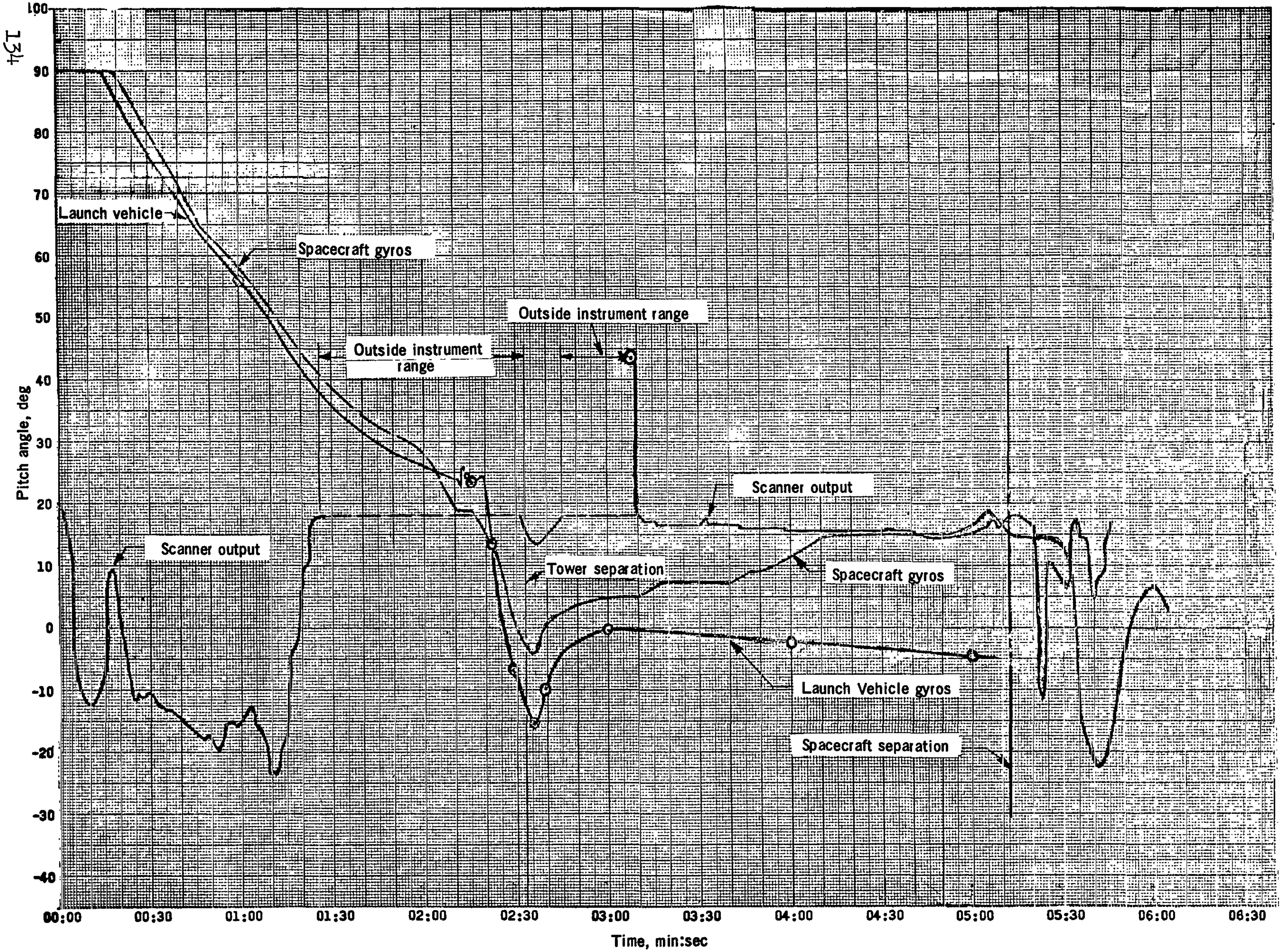


Figure 17.- Spacecraft and launch-vehicle indicated attitudes during powered flight.

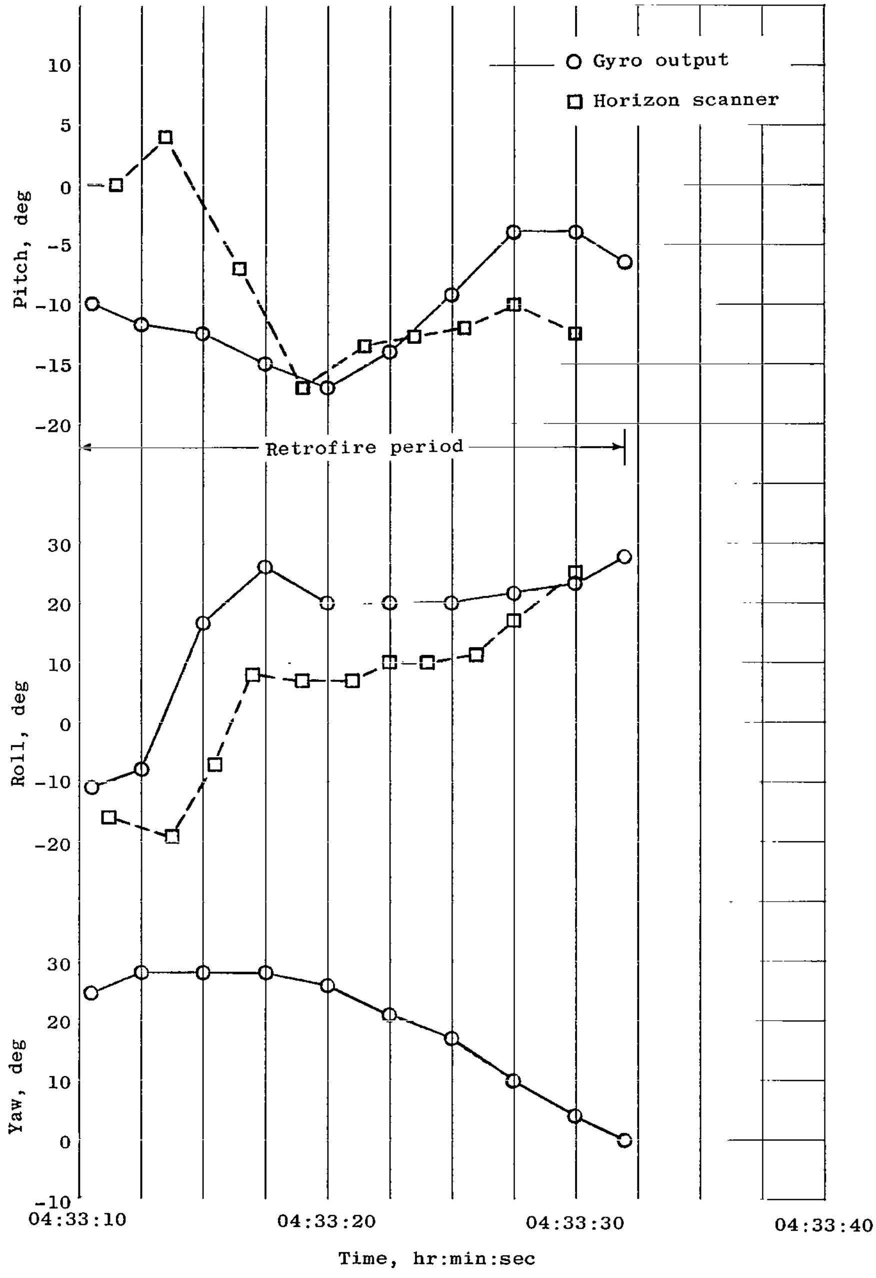


Figure 18.- Horizon scanner and gyro output during retrofire period for MA-7.

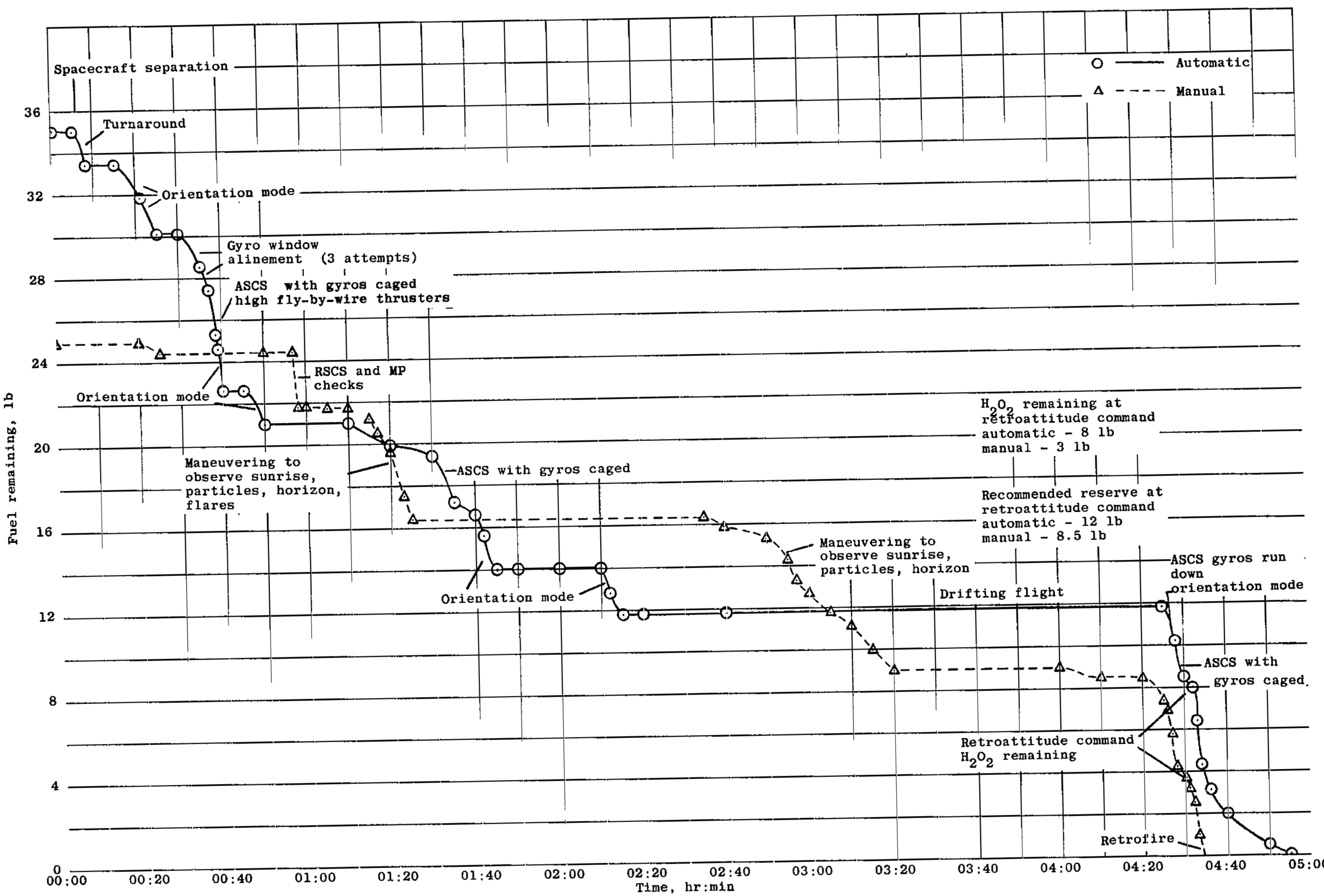


Figure 19.- H_2O_2 fuel usage.

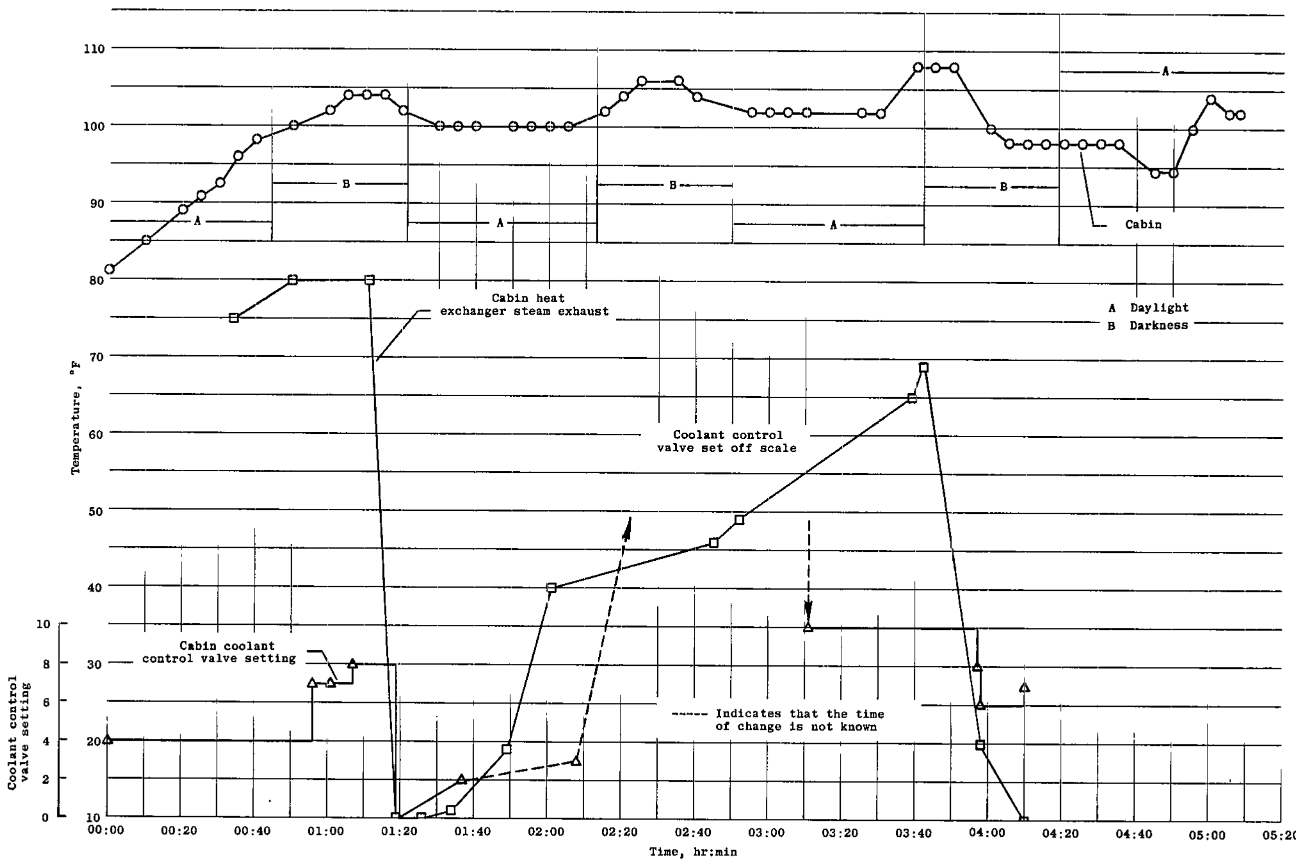


Figure 20.- Variation of cabin-air temperature and cabin-heat-exchanger steam-exhaust temperature and associated coolant control valve settings with time.

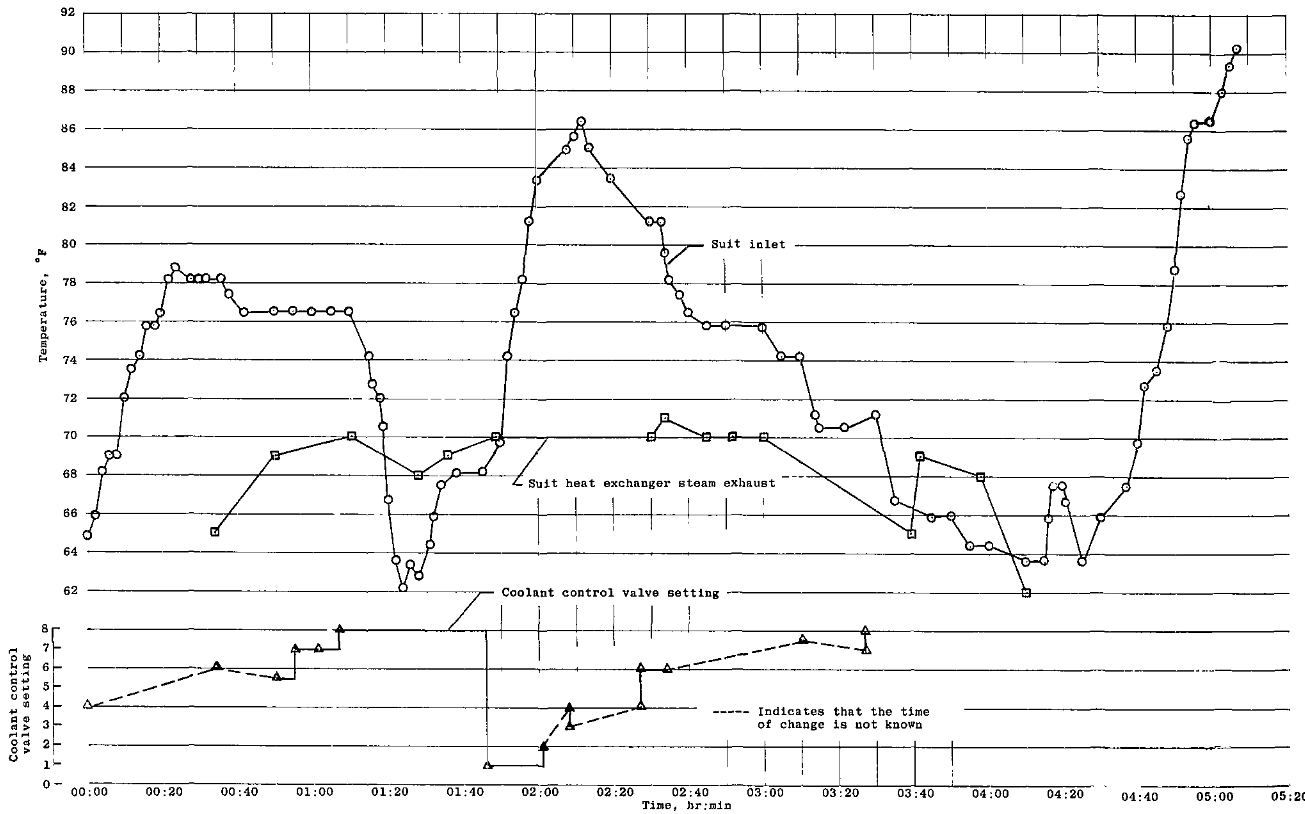


Figure 21.- Variation of suit inlet temperature and suit-heat-exchanger steam-exhaust temperature and associated coolant control valve settings with time.

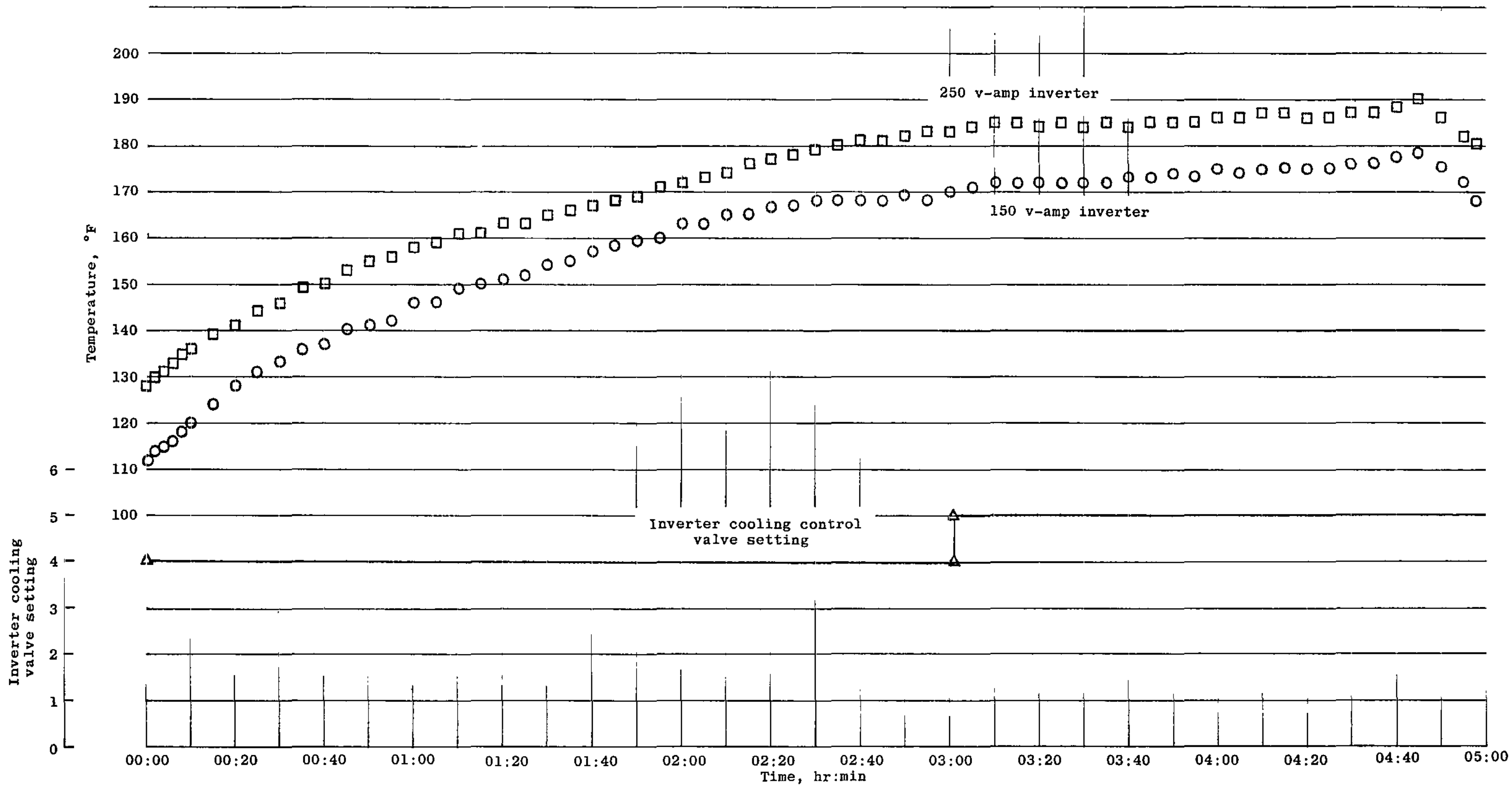


Figure 22.- Variation of 150 V-amp and 250 V-amp inverter temperatures and associated cooling control valve settings with time.

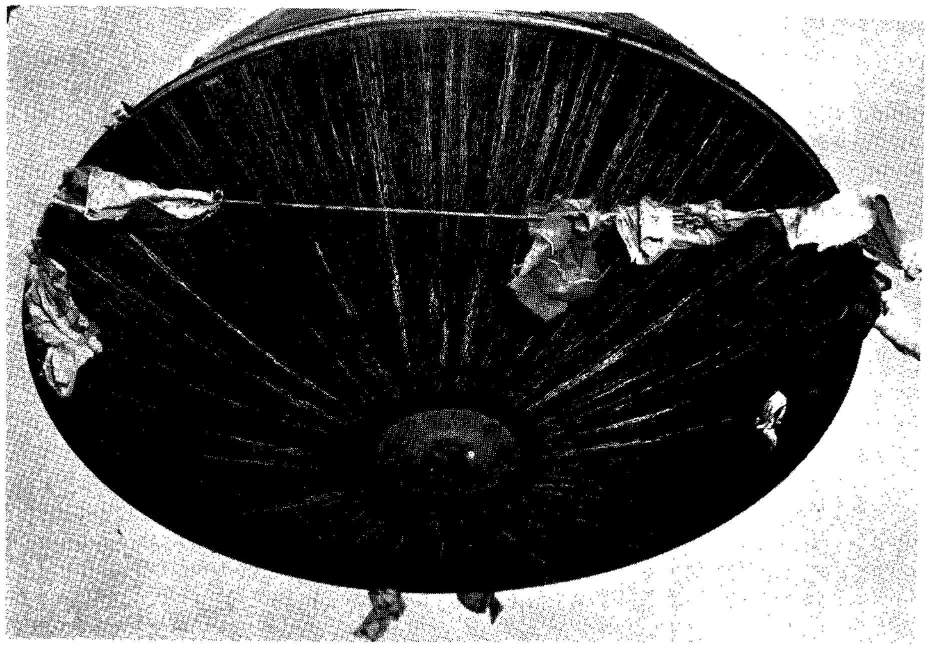


Figure 23.- Postflight photograph of Spacecraft 18 ablation shield.

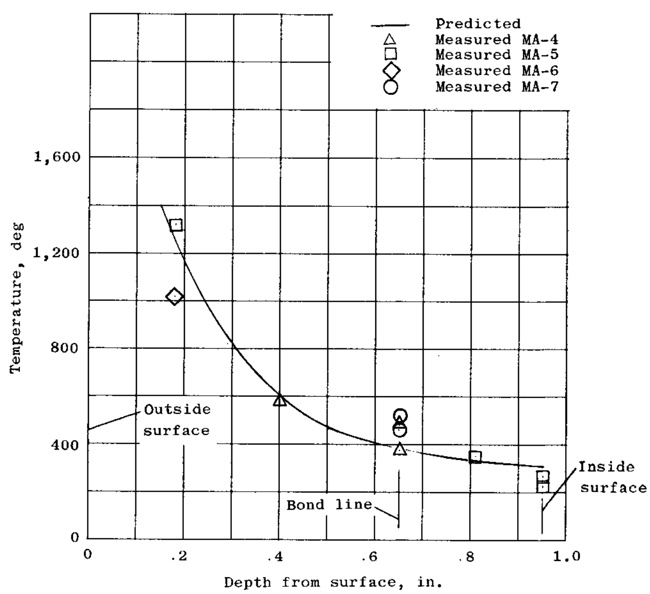
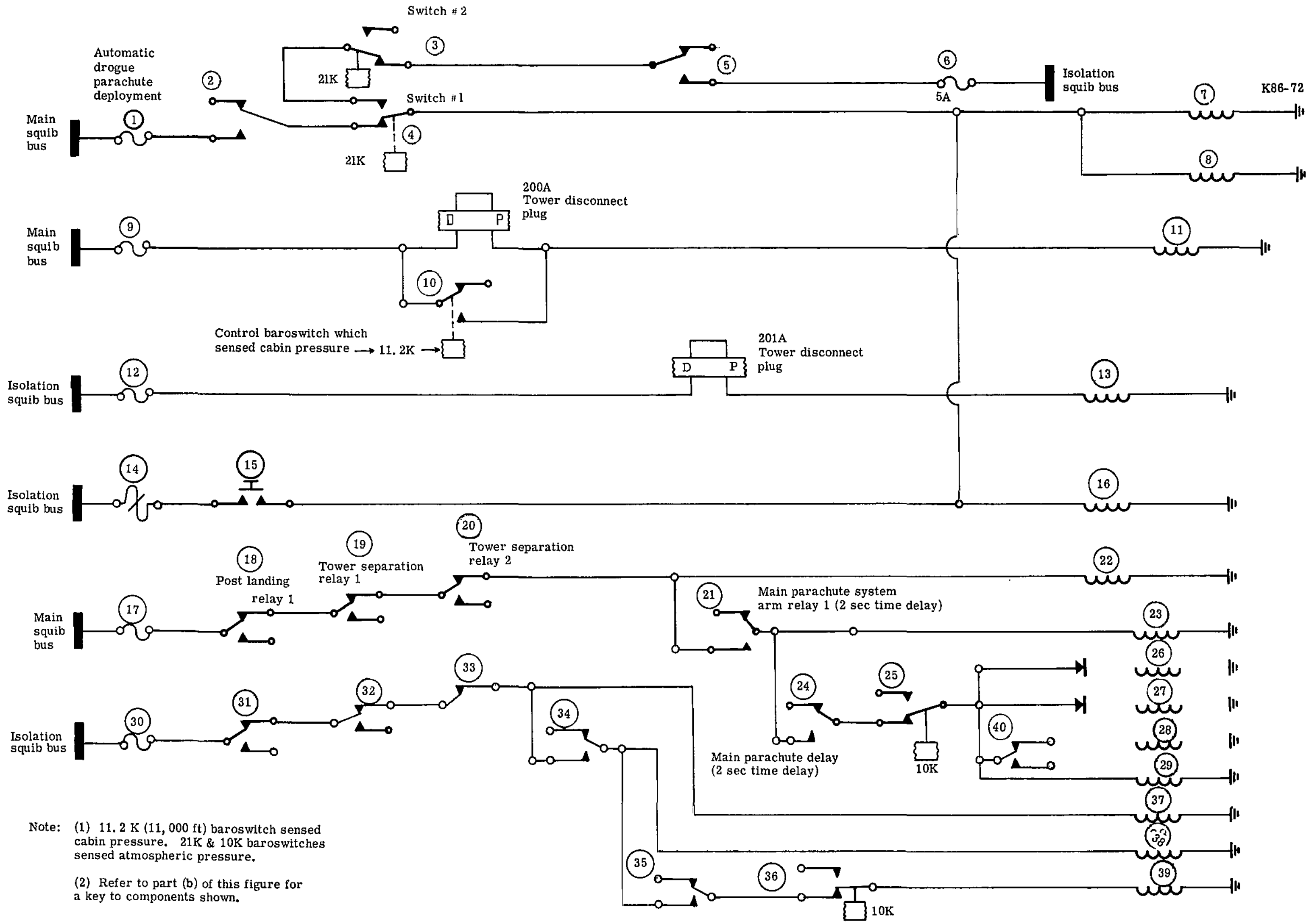


Figure 24.- Maximum ablation shield temperatures experienced on flights.

Figure 25.- Postflight photograph of Spacecraft 18 prior to disassembly in Hangar S.



(a) Schematic diagram.

Figure 26.- Logic diagram for parachute deployment system.

1. Automatic drogue parachute deployment fuse (5A)
2. Main parachute system arm no. 1 (2 sec time delay)
3. 21,000-foot barostat switch no. 2
4. 21,000-foot barostat switch no. 1
5. Main parachute system arm no. 2 (2 sec time delay)
6. Automatic drogue parachute deployment fuse (5A)
7. Drogue parachute deployment relay
8. Inlet-air door release
9. Automatic main system lockout fuse (5A)
10. 11,250-foot barostat switch
11. Tower separation relay no. 1
12. Automatic main system lockout fuse (5A)
13. Tower separation relay no. 2
14. Emergency drogue parachute deployment fuse (5A x)
15. Drogue parachute deployment
16. Emergency drogue parachute deployment relay
17. Automatic main deployment fuse (5A)
18. Postlanding system relay no. 1
19. Tower-separation relay no. 1
20. Tower-separation relay no. 2
21. Main-parachute system arm relay no. 1 (2 sec time delay)
22. Main-parachute system arm relay no. 1 (2 sec time delay)
23. Main-parachute delay relay no. 1 (2 sec time delay)
24. Main-parachute time delay no. 1 (2 sec time delay)
25. 10,000-foot barostat switch no. 1
26. 10,000 descent
27. 10,000 descent relay no. 1
28. Main-deployment warning light relay (2 sec time delay)
29. Main-deployment no. 1
30. Automatic main-deployment fuse (5A)
31. Postlanding system relay no. 2
32. Tower-separation relay no. 1
33. Tower-separation relay no. 2
34. Main-parachute system arm relay no. 2 (2 sec time delay)
35. Main-parachute delay no. 2 (2 sec time delay)
36. 10,000-barostat switch no. 2
37. Main-parachute system arm relay F no. 2 (2 sec time delay)
38. Main-parachute delay relay no. 2 (2 sec time delay)
39. Main deployment no. 2
40. Antenna-fairing separation signal

(b) Key to components shown in part (a) of this figure.

Figure 26. - Concluded.

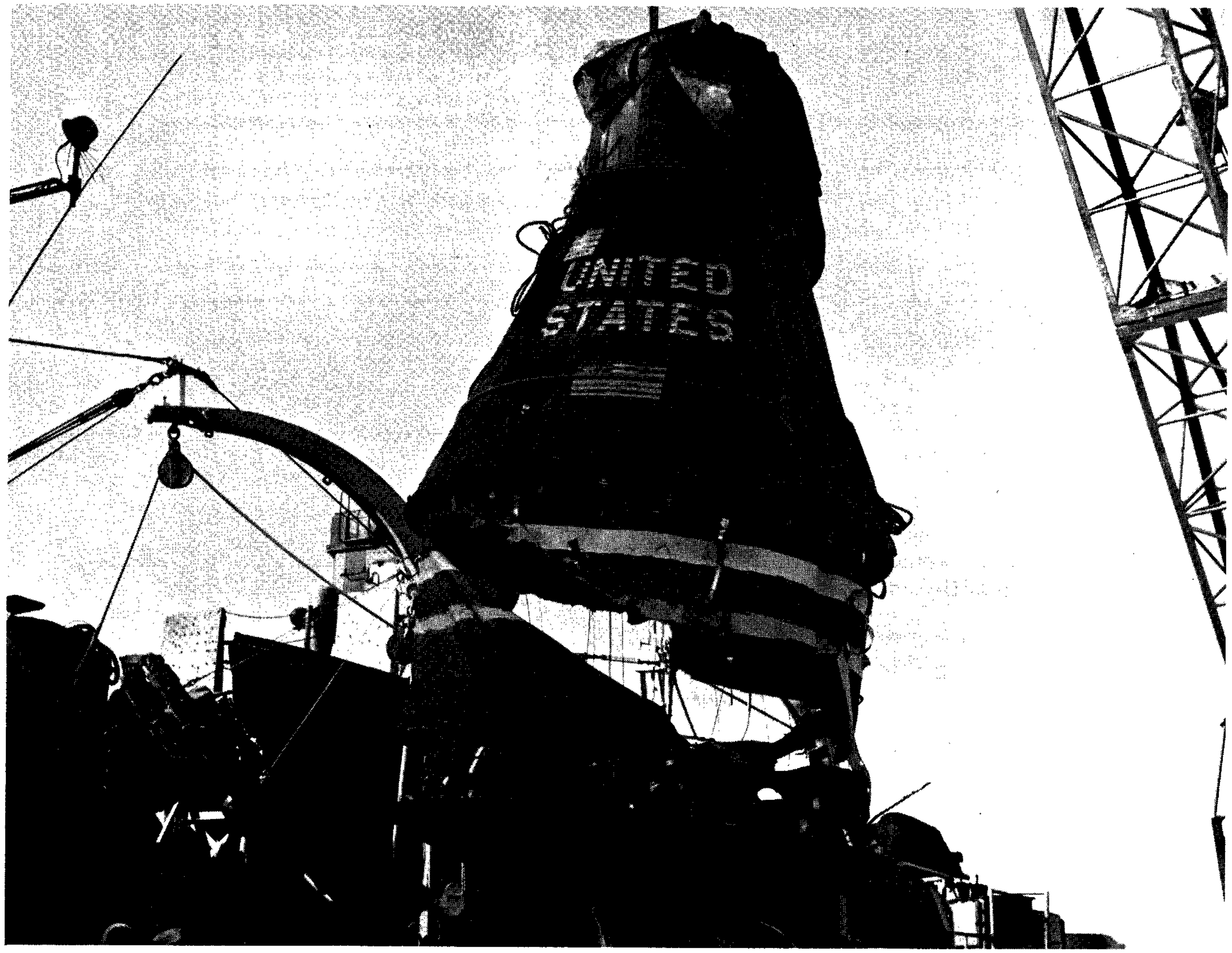


Figure 27.- Spacecraft 18 depicting postflight damage to landing bag and suspension straps.

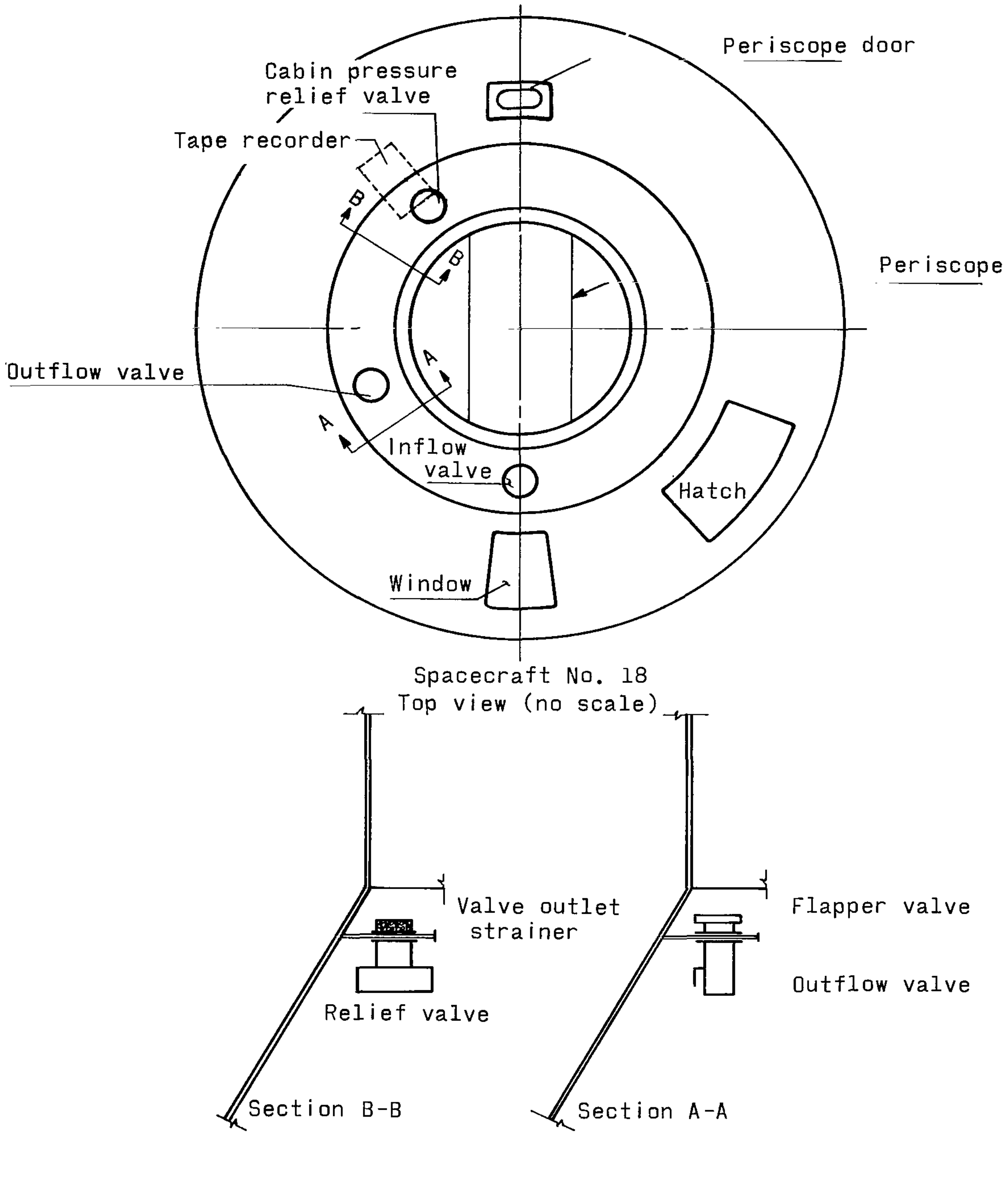


Figure 28.- Sketch showing location of valves in spacecraft small pressure bulkhead.

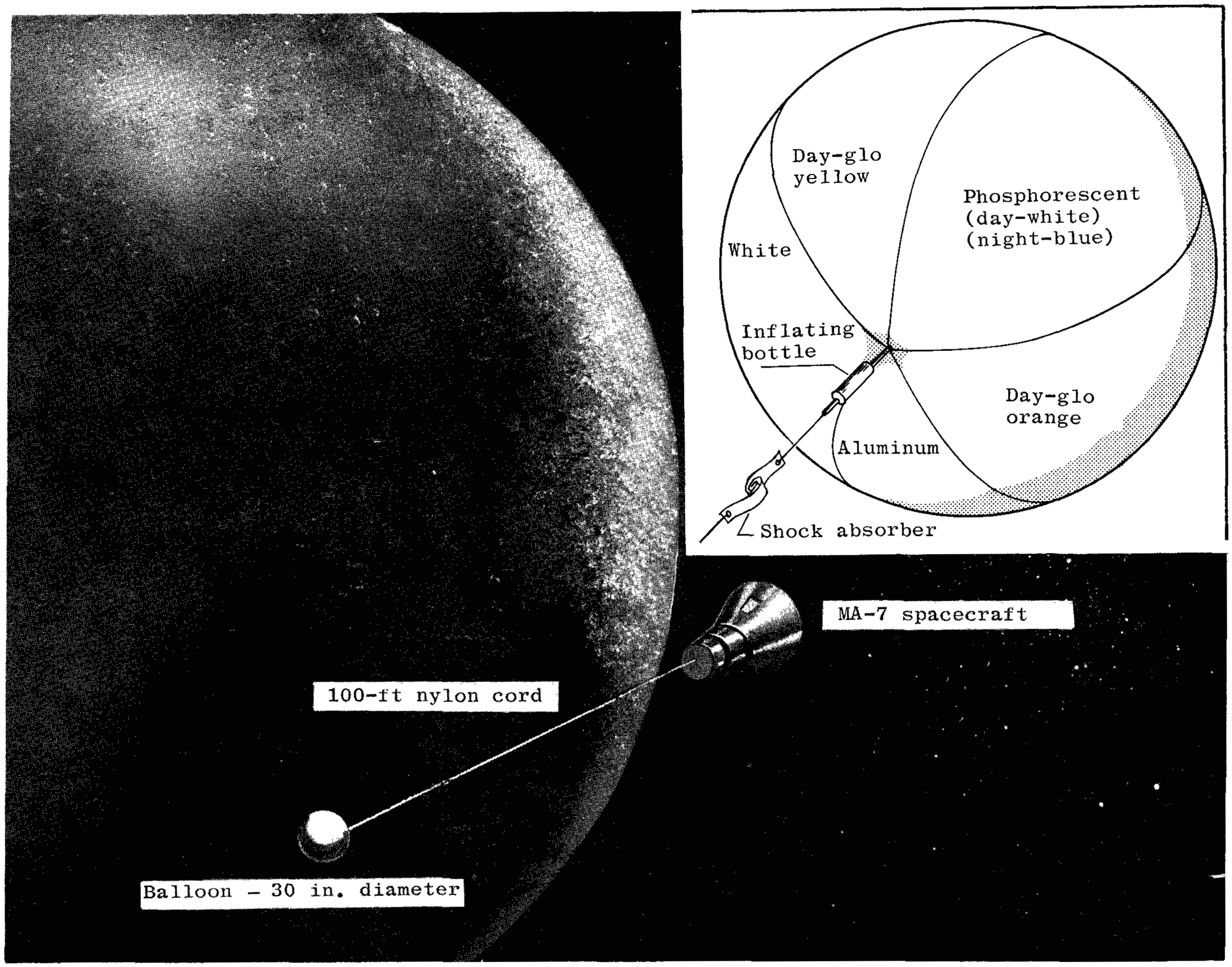
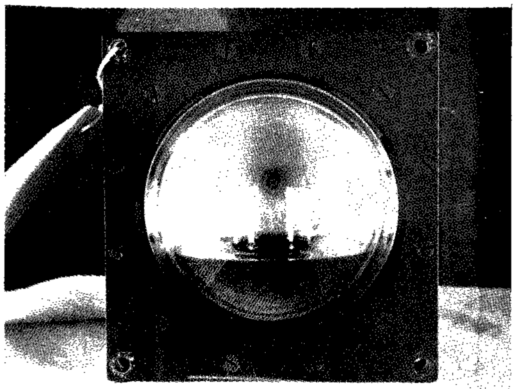
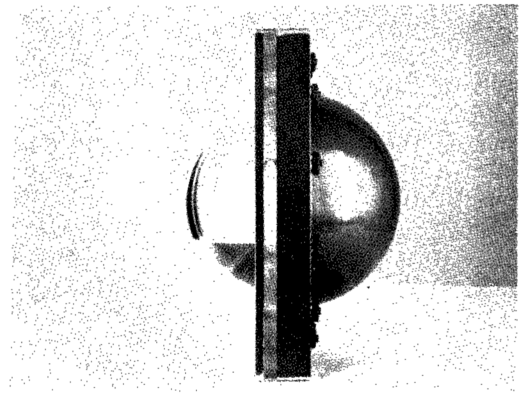


Figure 29.- Balloon experiment planned deployment configuration.



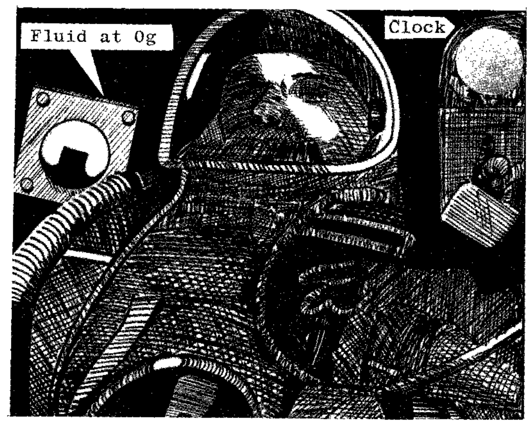
Front view



Side view

(a) Flight apparatus

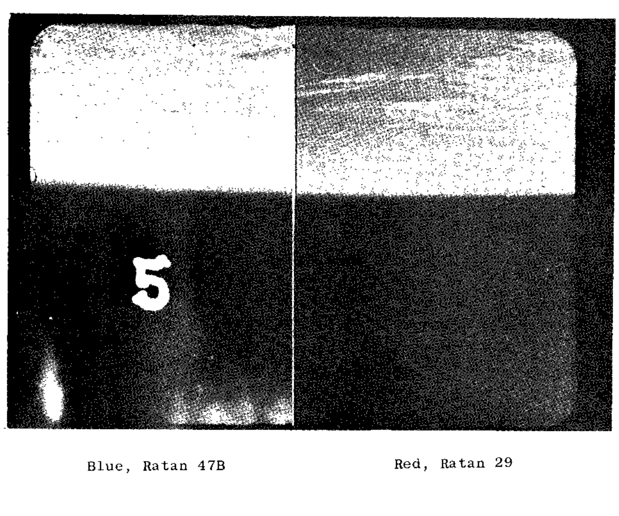
Actual film data



Location sketch

(b) Inflight configuration

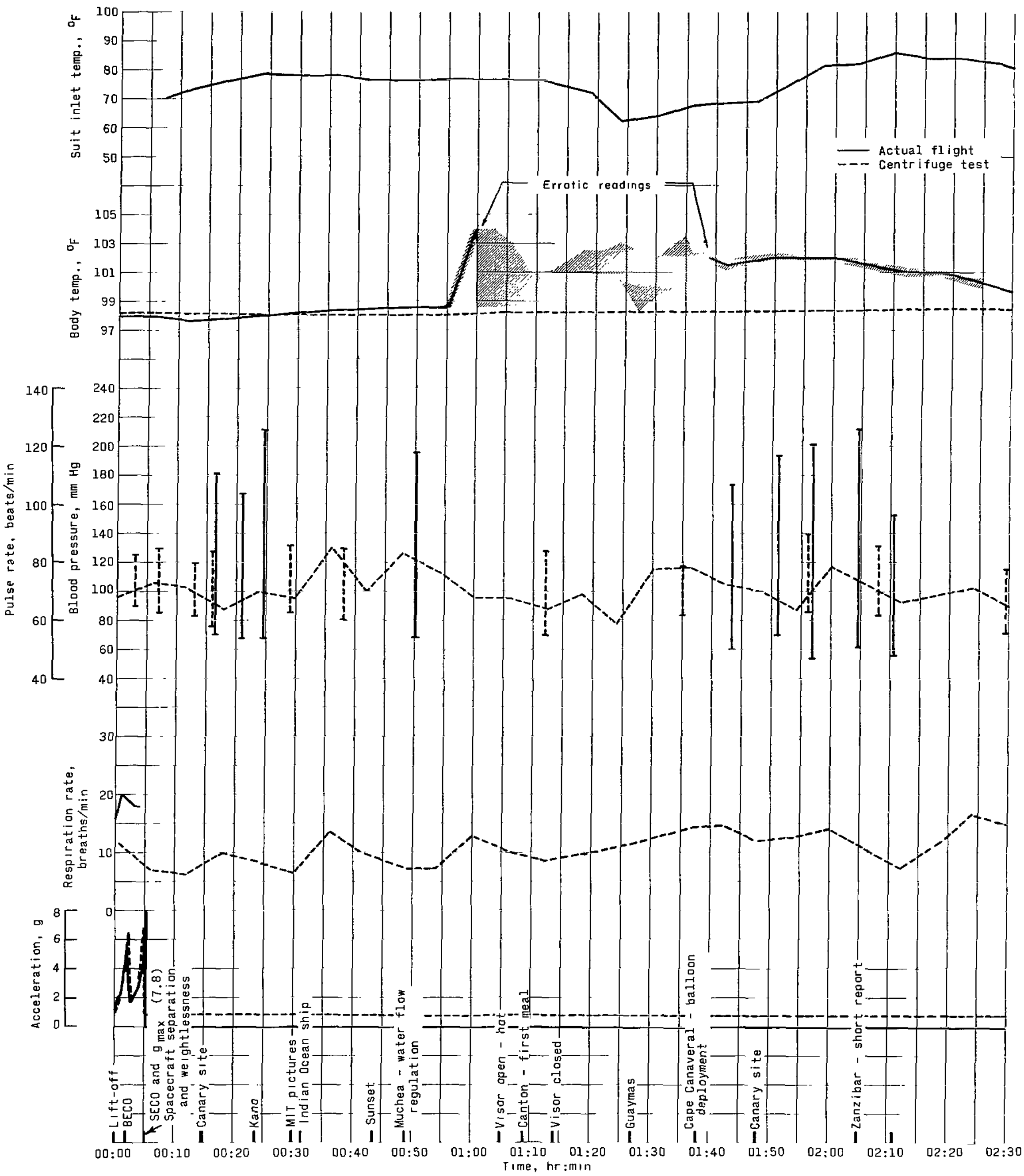
Figure 30.- Zero-gravity experiment.



Blue, Ratan 47B

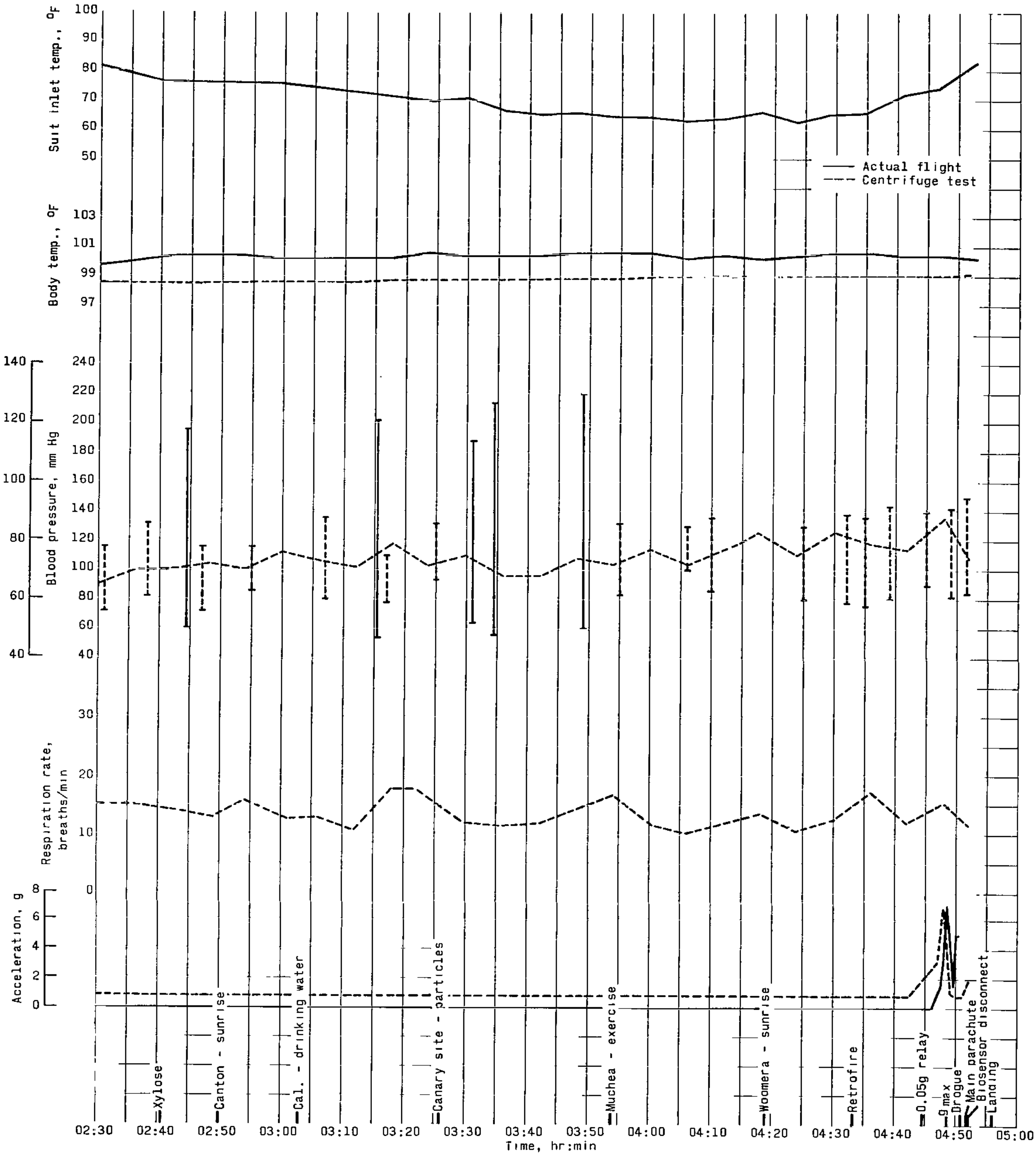
Red, Ratan 29

Figure 31.- MIT horizon-definition photograph.



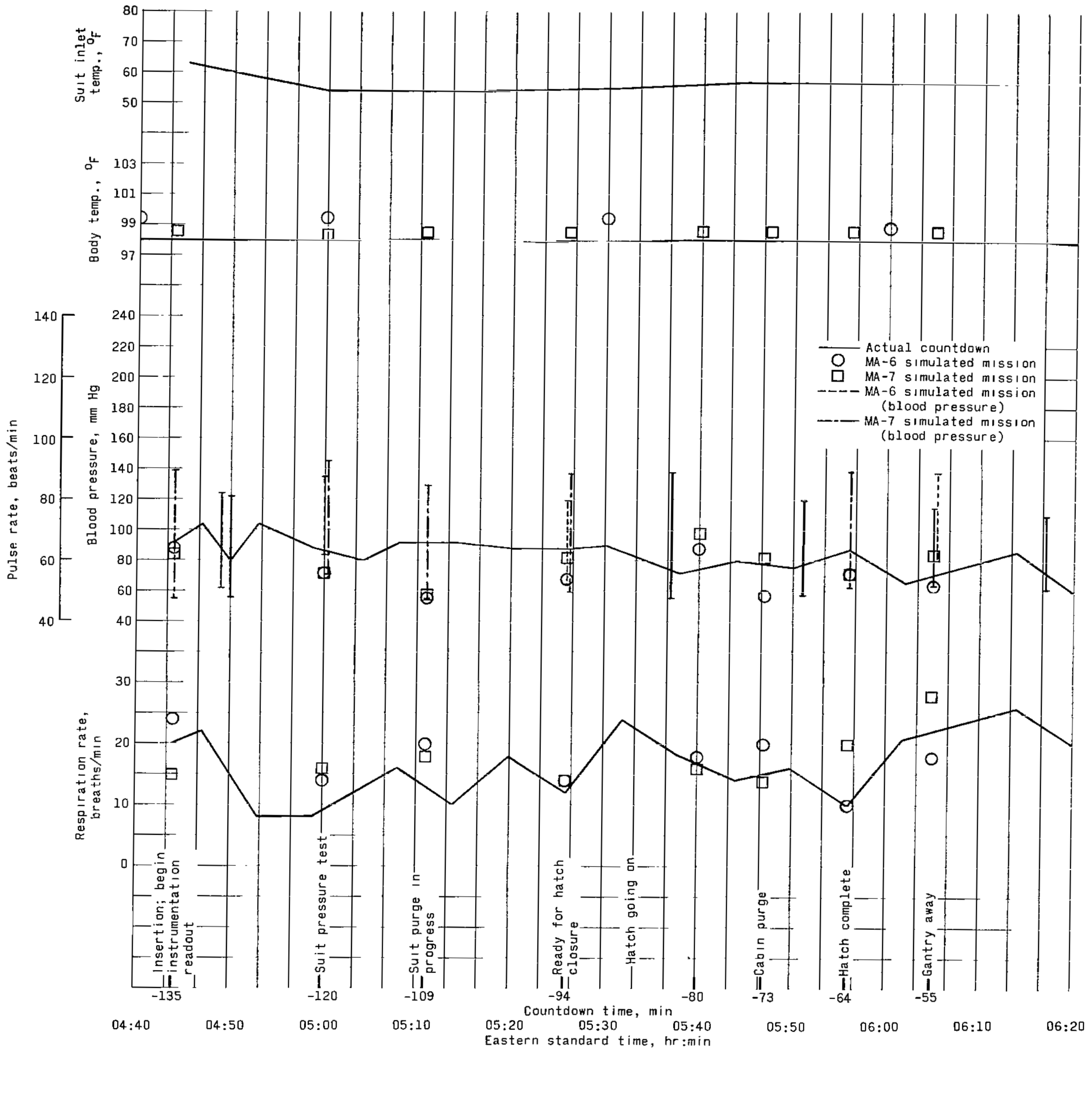
(a) Flight elapsed time, 00:00 to 02:30.

Figure 32.- Flight: respiration rate, pulse rate, body temperature and suit inlet temperature during the MA-7 flight, with values from the Mercury-Atlas three-orbit centrifuge dynamic simulation.



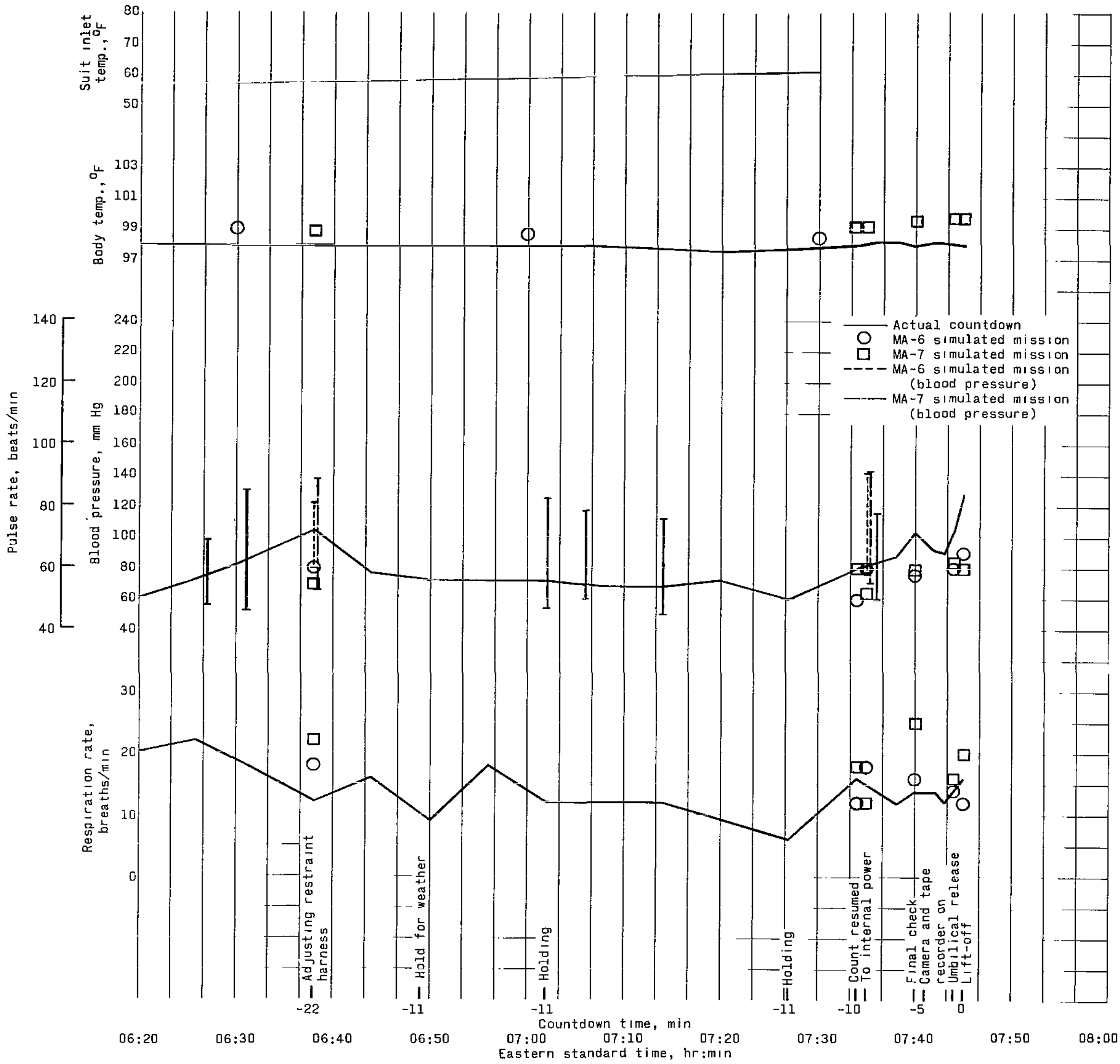
(b) Flight elapsed time, 02:30 to biosensor disconnect, 04:52.

Figure 32.- Concluded.



(a) Countdown, 04:40 to 06:20.

Figure 33.- Preflight: respiration rate, pulse rate, blood pressure, body temperature and suit inlet temperature for MA-7 countdown with values at selected events from the MA-6 simulated launch of January 17, 1962, and the MA-7 simulated launch of May 10, 1962.



(b) Countdown, 06:20 to 07:45 (lift-off).

Figure 33.- Concluded.

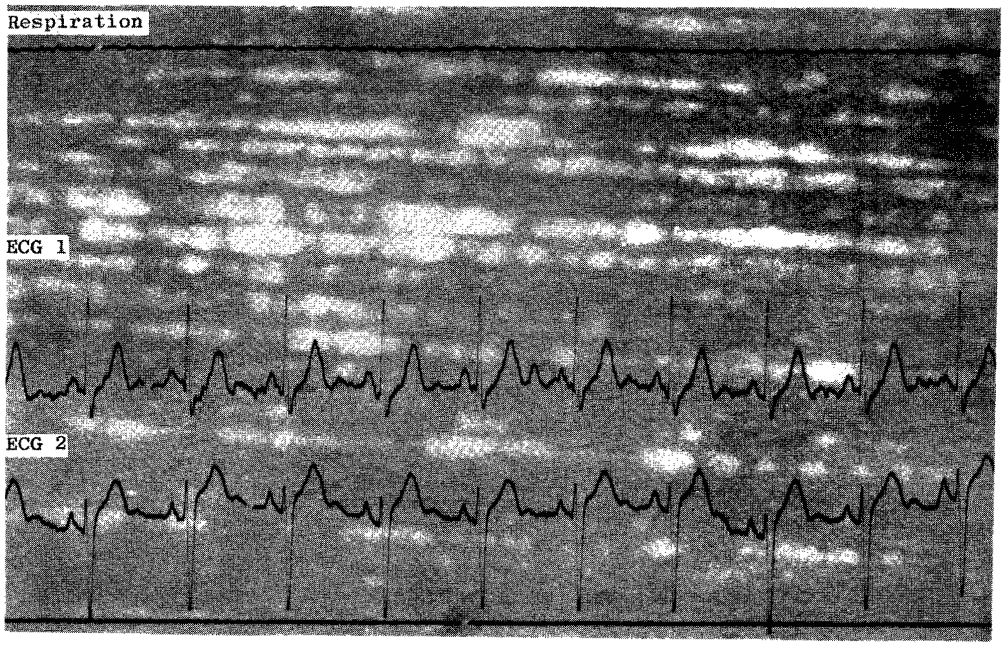


Figure 34.- Sample of playback record from the onboard tape showing physiologic data after 1 minute of weightlessness. (Recorder speed 25 mm/sec.)

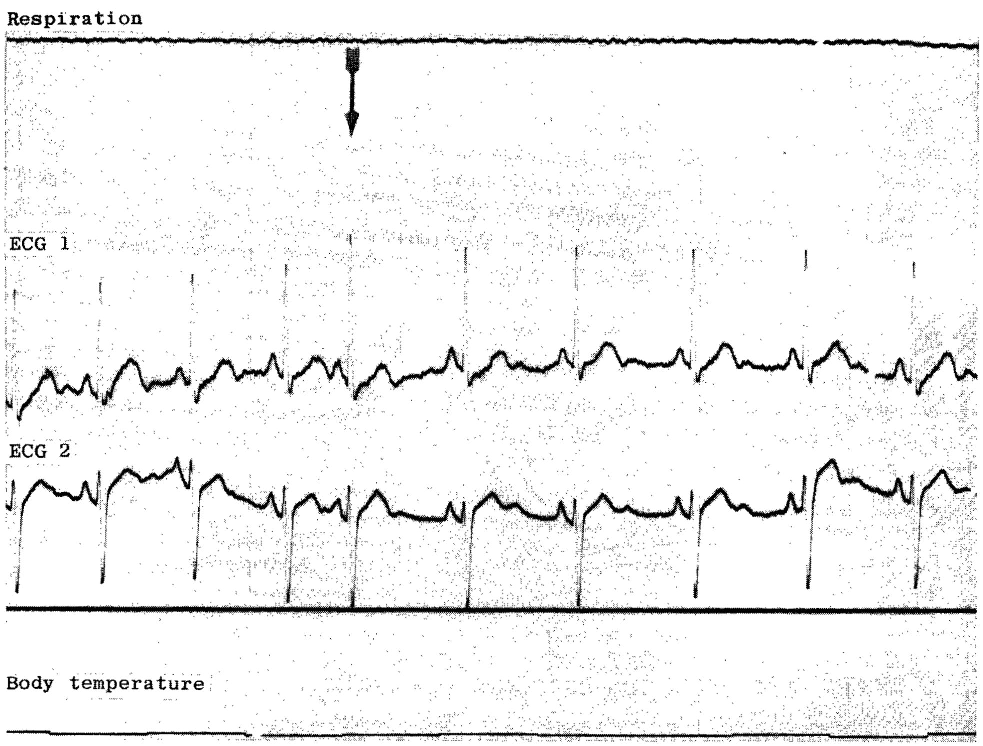


Figure 35.- Sample of physiological data from playback of the onboard tape at 04:32:06 mission elapsed time, 1 minute 15 seconds before retrofire, illustrating a premature atrial contraction. (Recorder speed 25 mm/sec.)

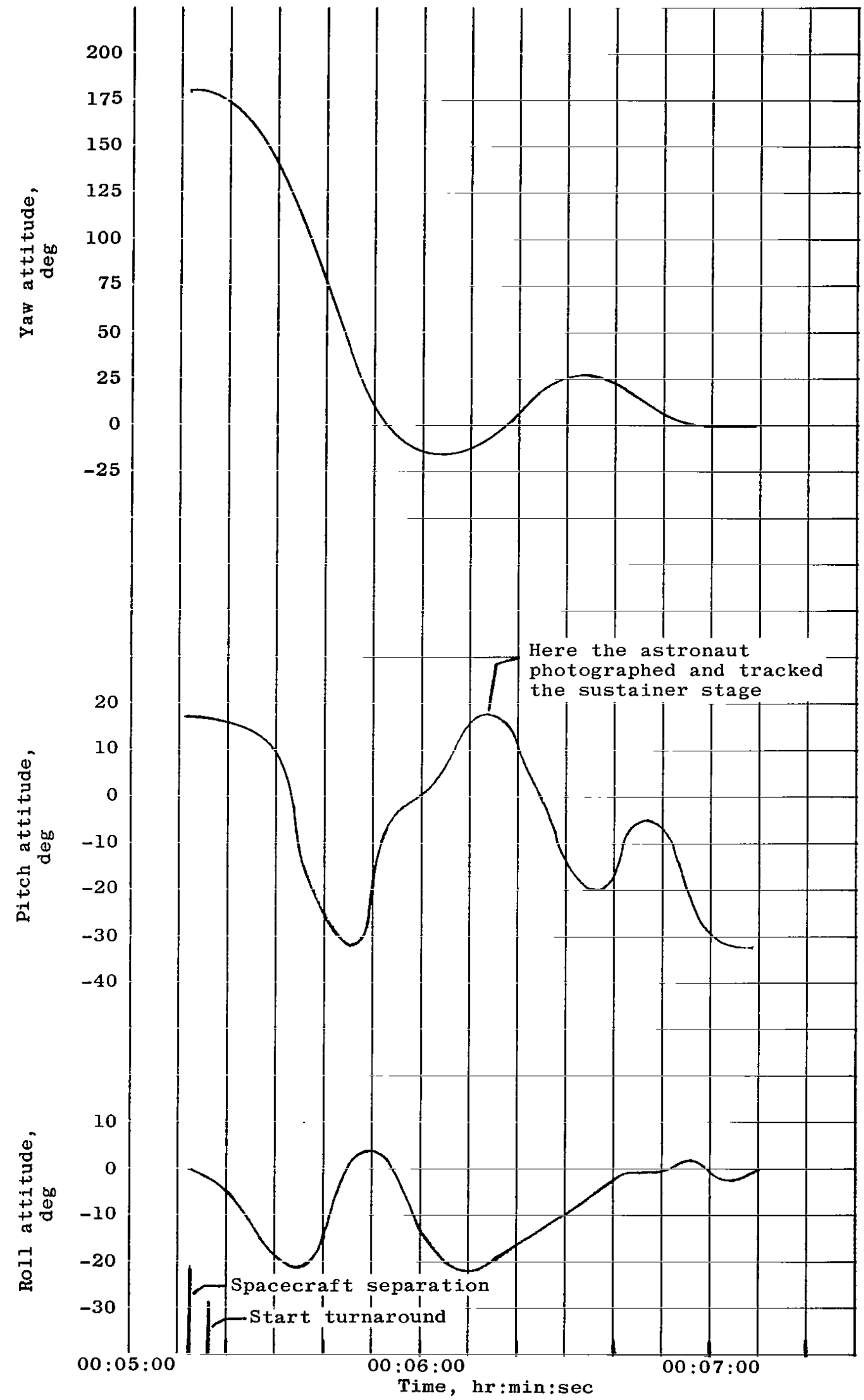


Figure 36.- Turnaround maneuver: fly-by-wire control mode, rate and attitude gyro indicator.

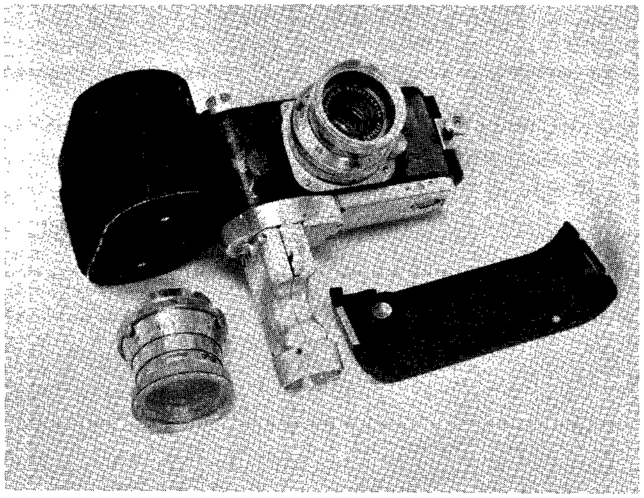


Figure 37.- 35mm hand-held camera.

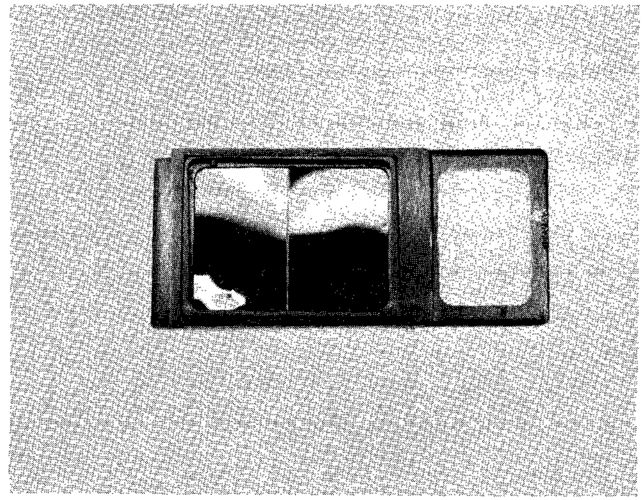


Figure 38.- MIT filter mosaic.

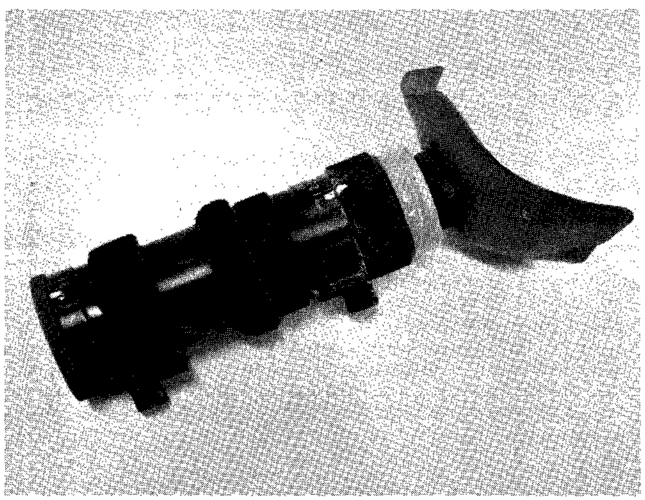


Figure 39.- Photometer.

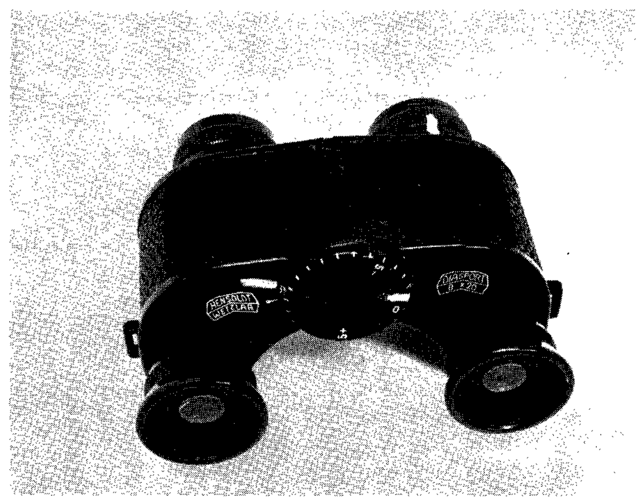


Figure 40.- Binoculars.

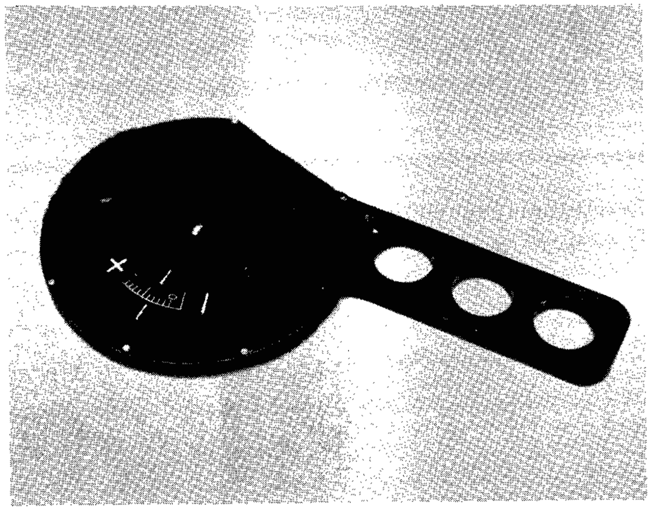


Figure 41.- Extinction photometer.

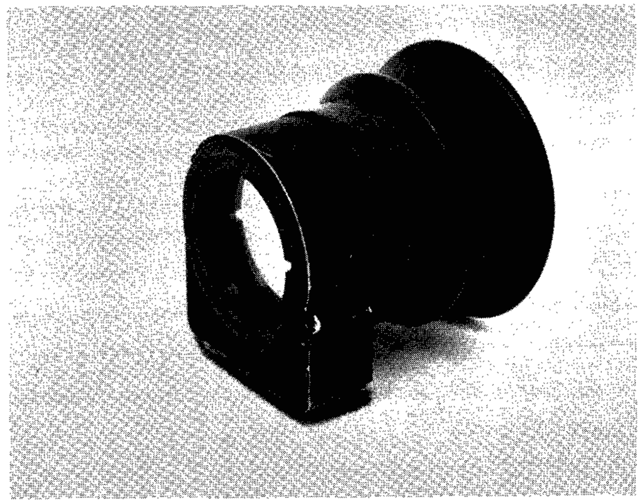


Figure 42.- Airglow filter.

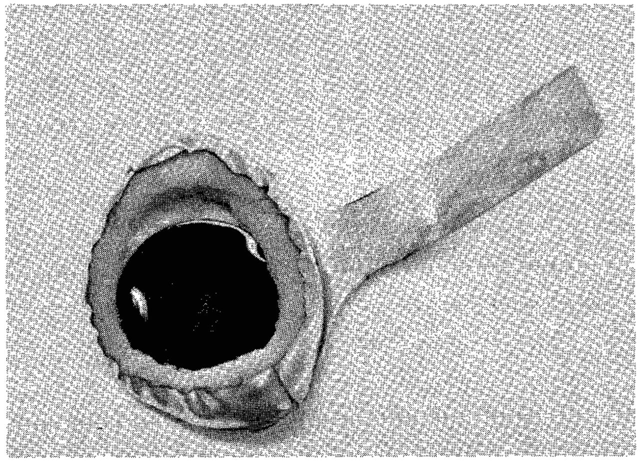


Figure 43.- Night adaption eye cover.

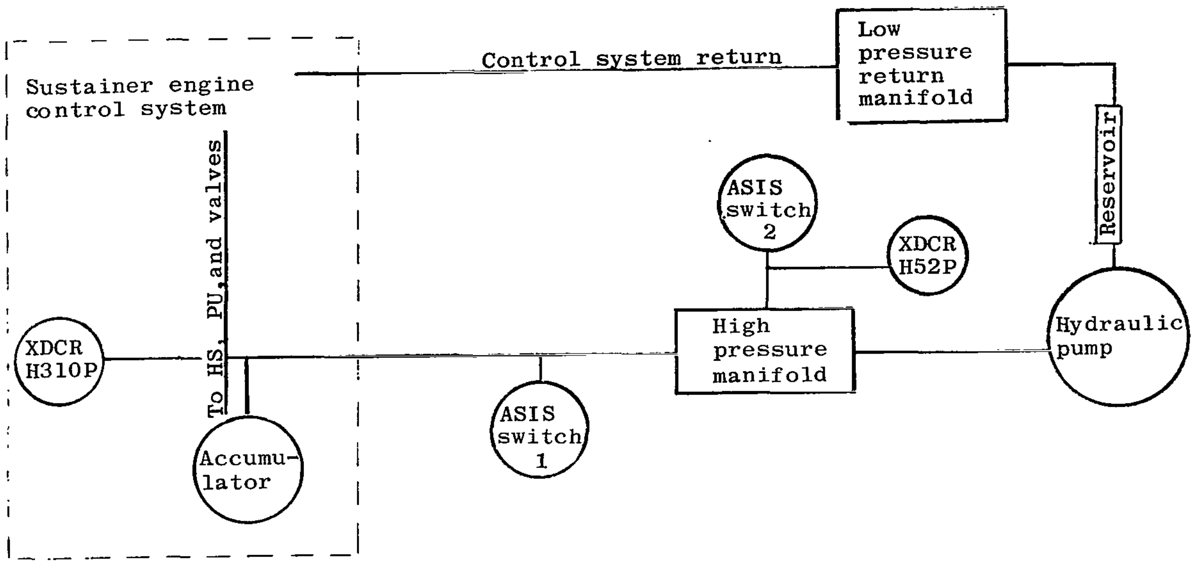


Figure 44.- Atlas launch-vehicle hydraulic diagram.

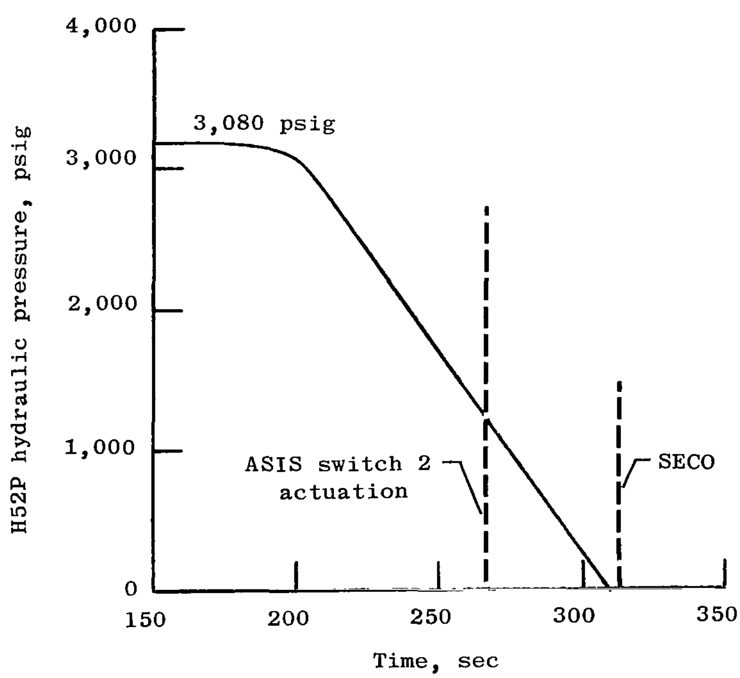
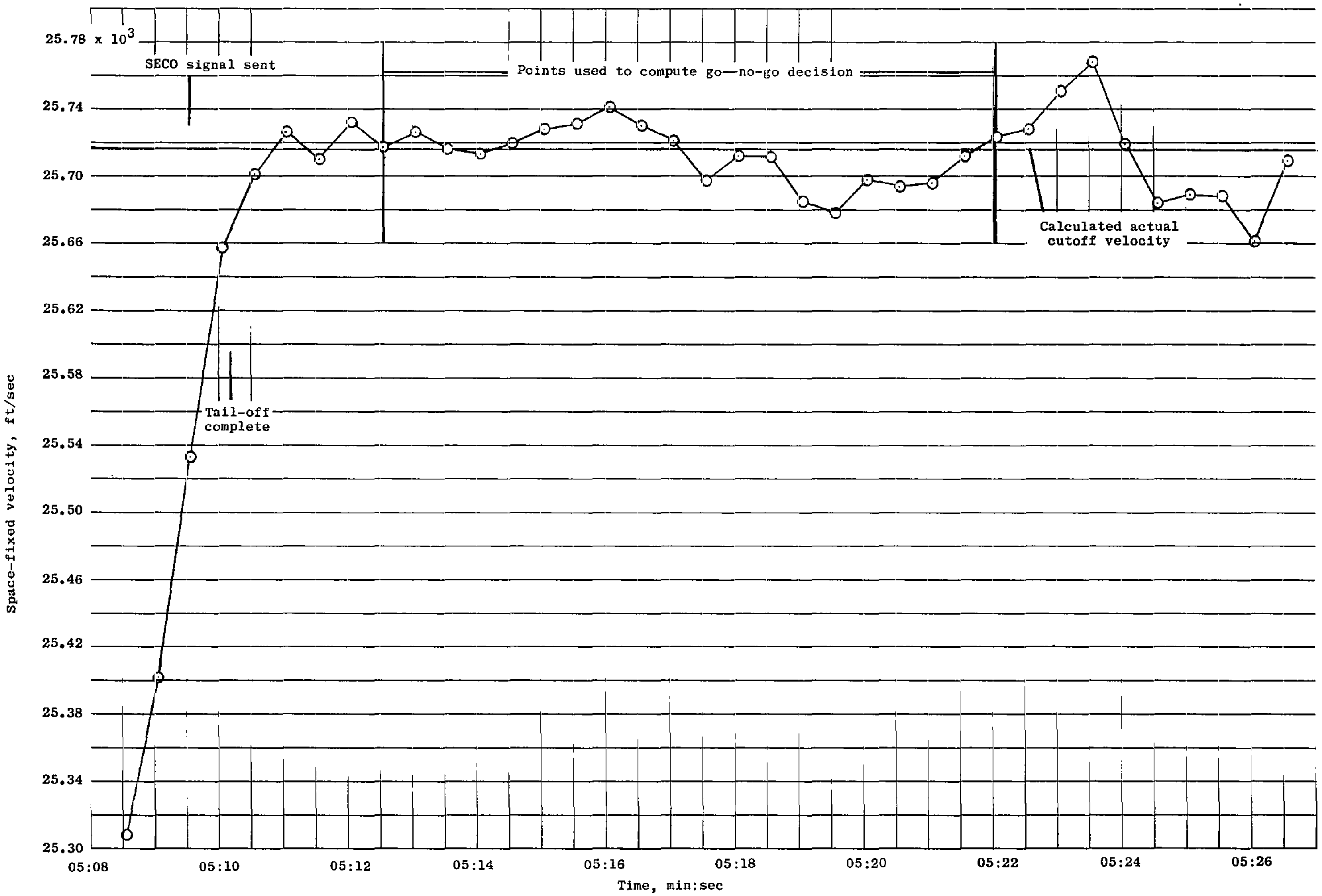
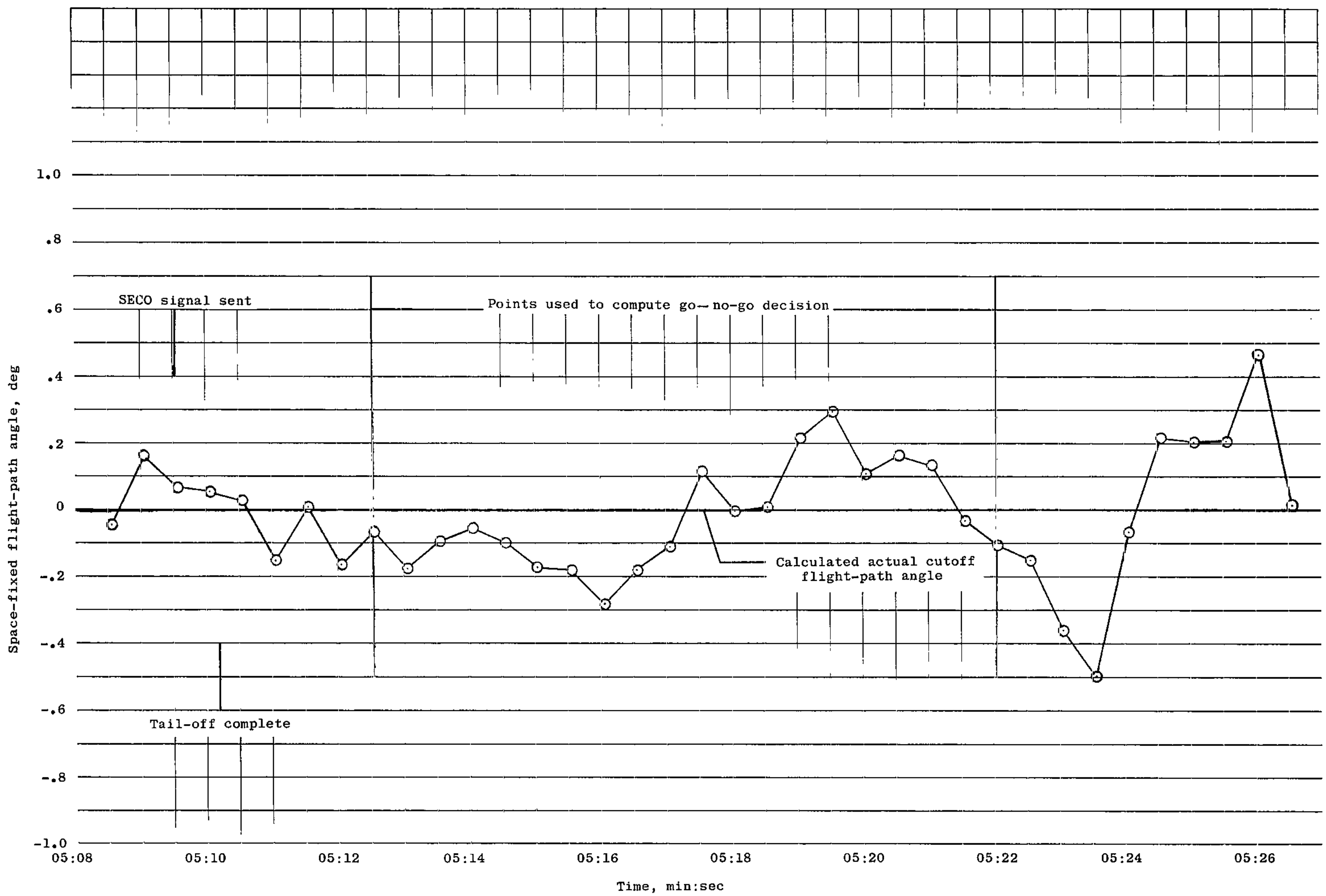


Figure 45.- Pressure at transducer H52P.



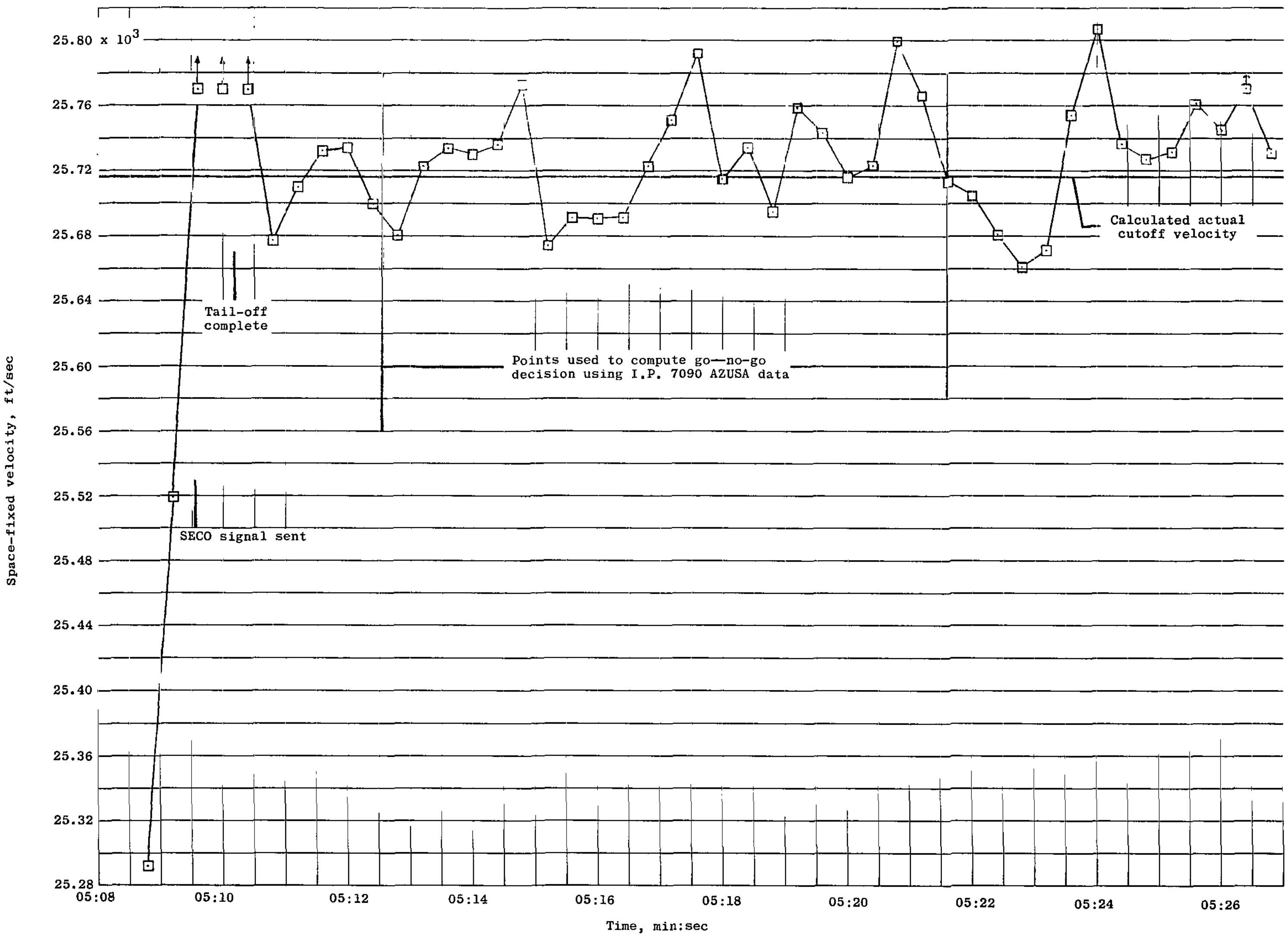
(a) Space-fixed velocity.

Figure 46.- Space-fixed velocity and flight-path angle in the region of cutoff using General Electric-Burroughs guidance computer data.



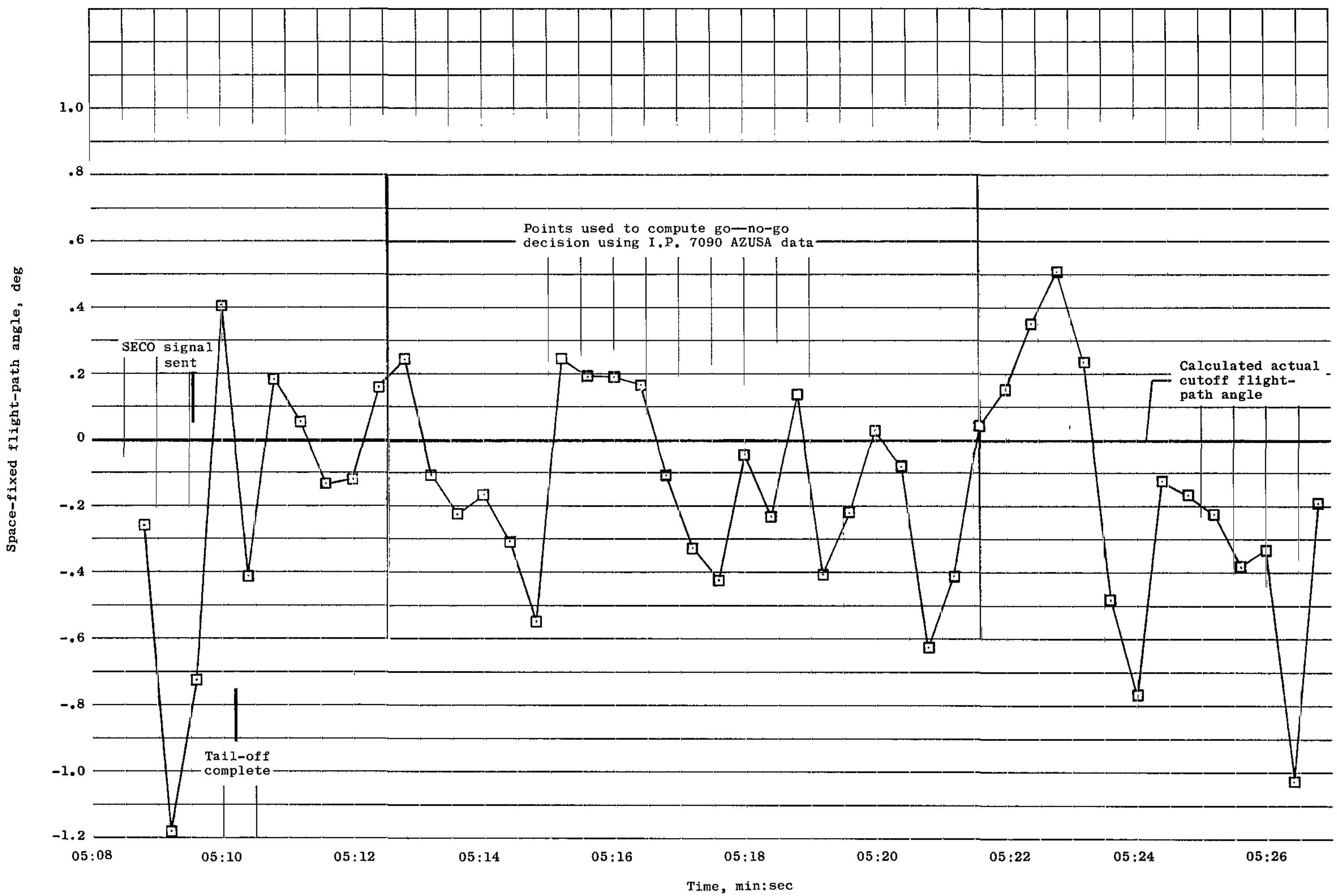
(b) Space-fixed flight-path angle.

Figure 46.- Concluded.



(a) Space-fixed velocity.

Figure 47.- Space-fixed velocity and flight-path angle in the region of cutoff using I.P. 7090 data.



(b) Space-fixed flight-path angle.

Figure 47.- Concluded.

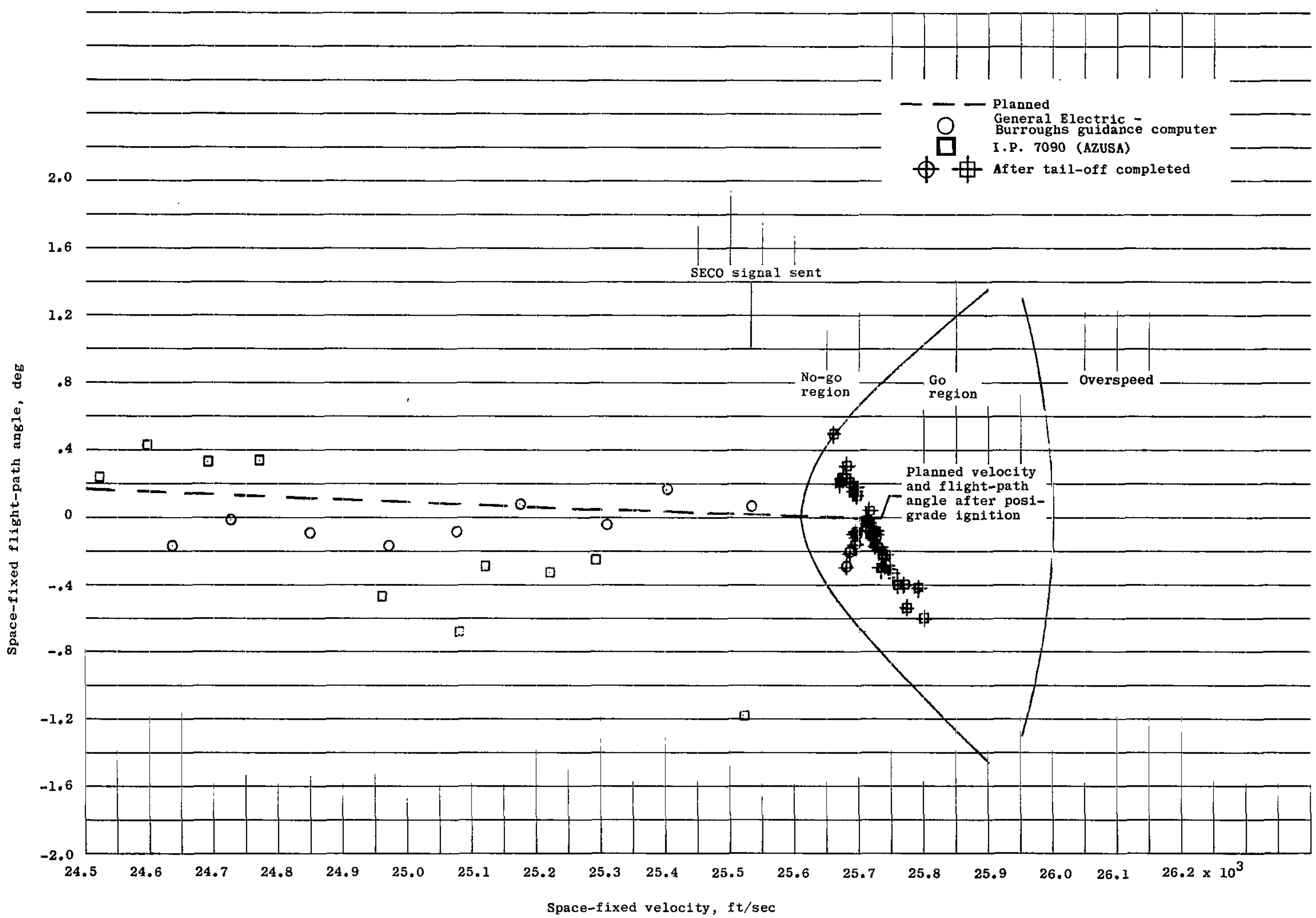


Figure 48.- Space-fixed flight-path angle plotted against space-fixed velocity in the region of cutoff.

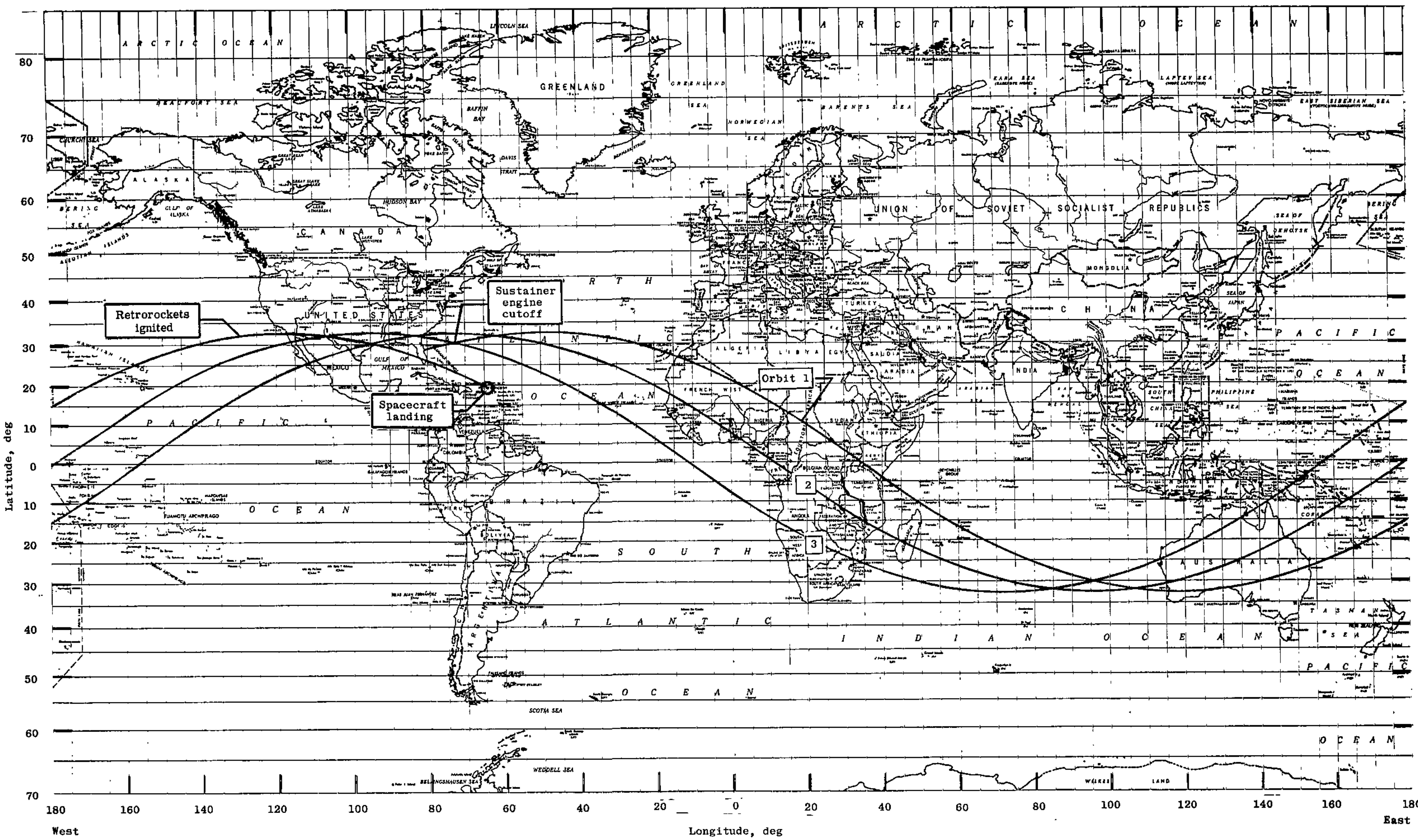


Figure 49.- Ground track for the MA-7 orbital mission.

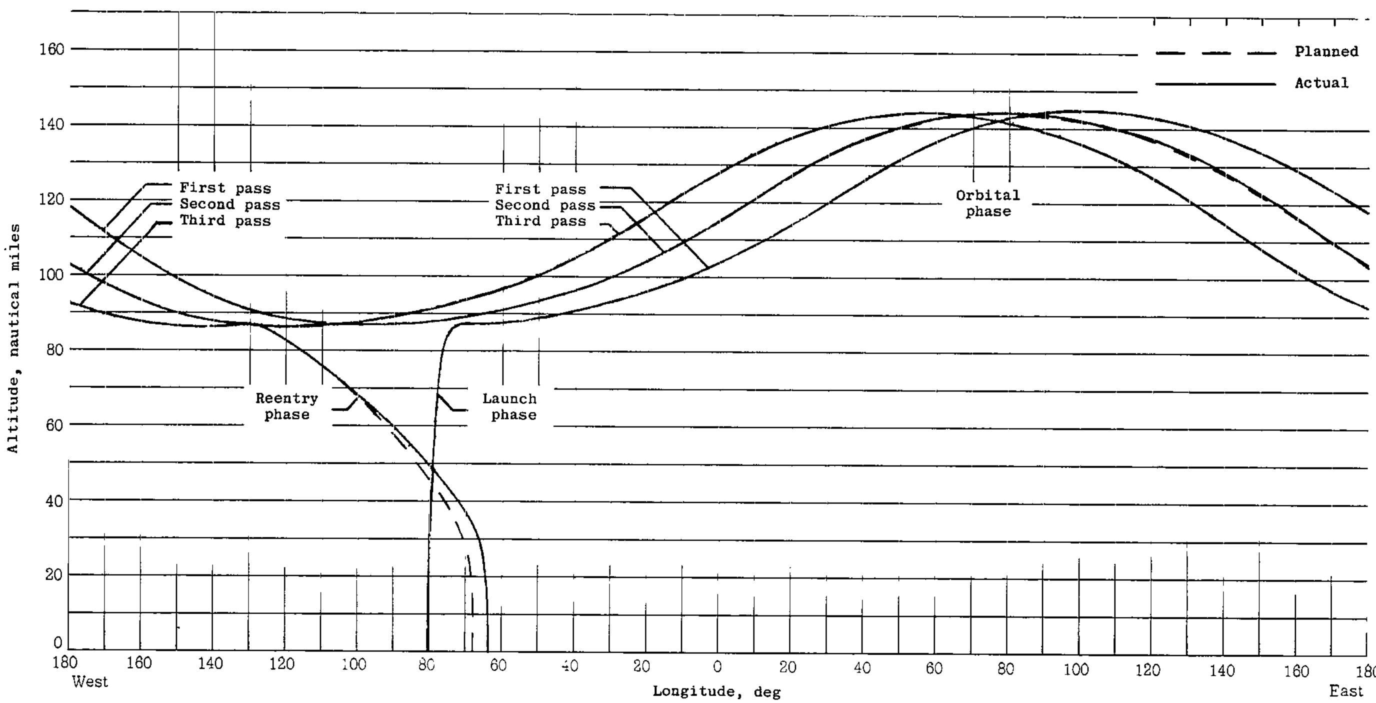
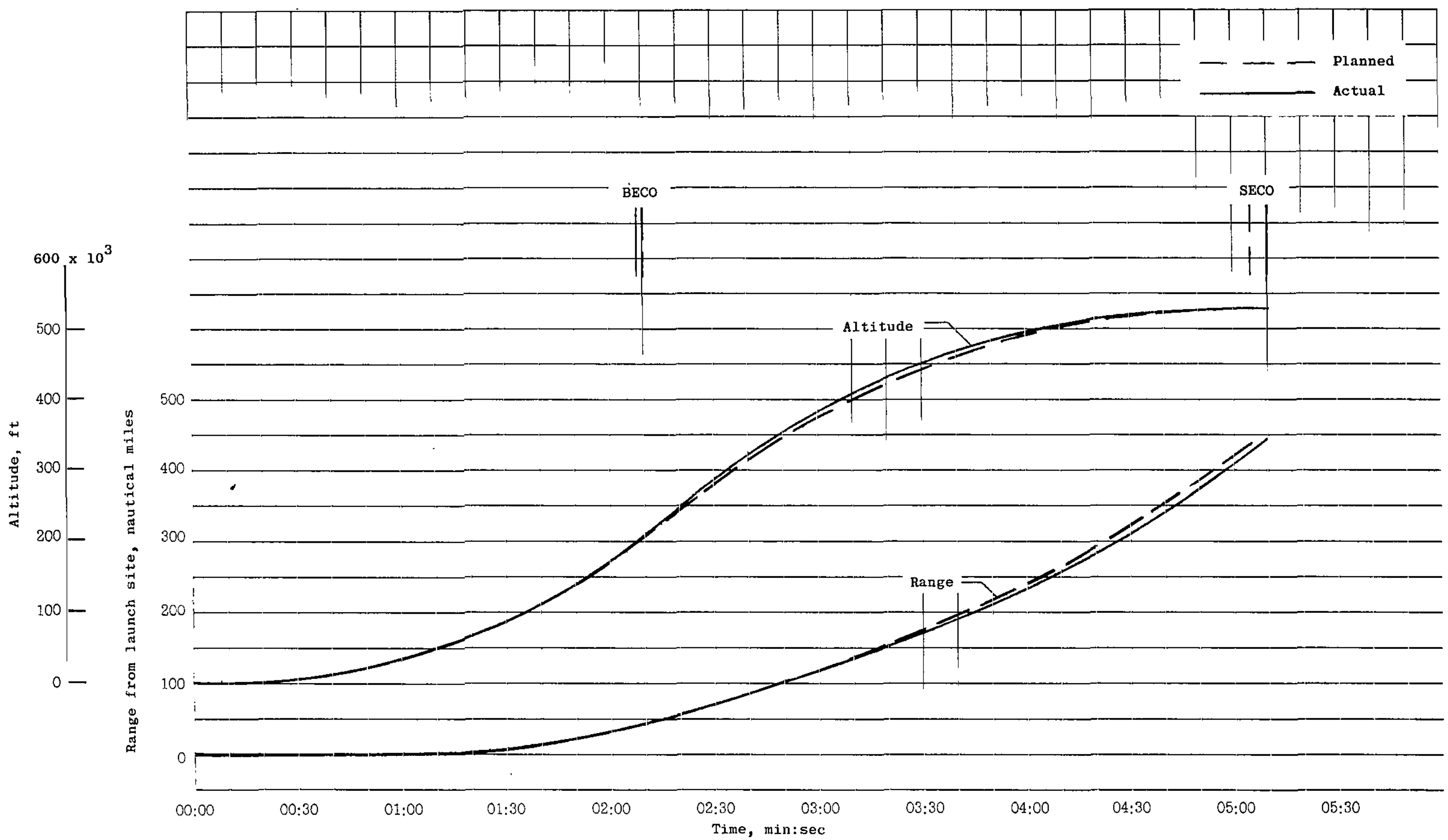


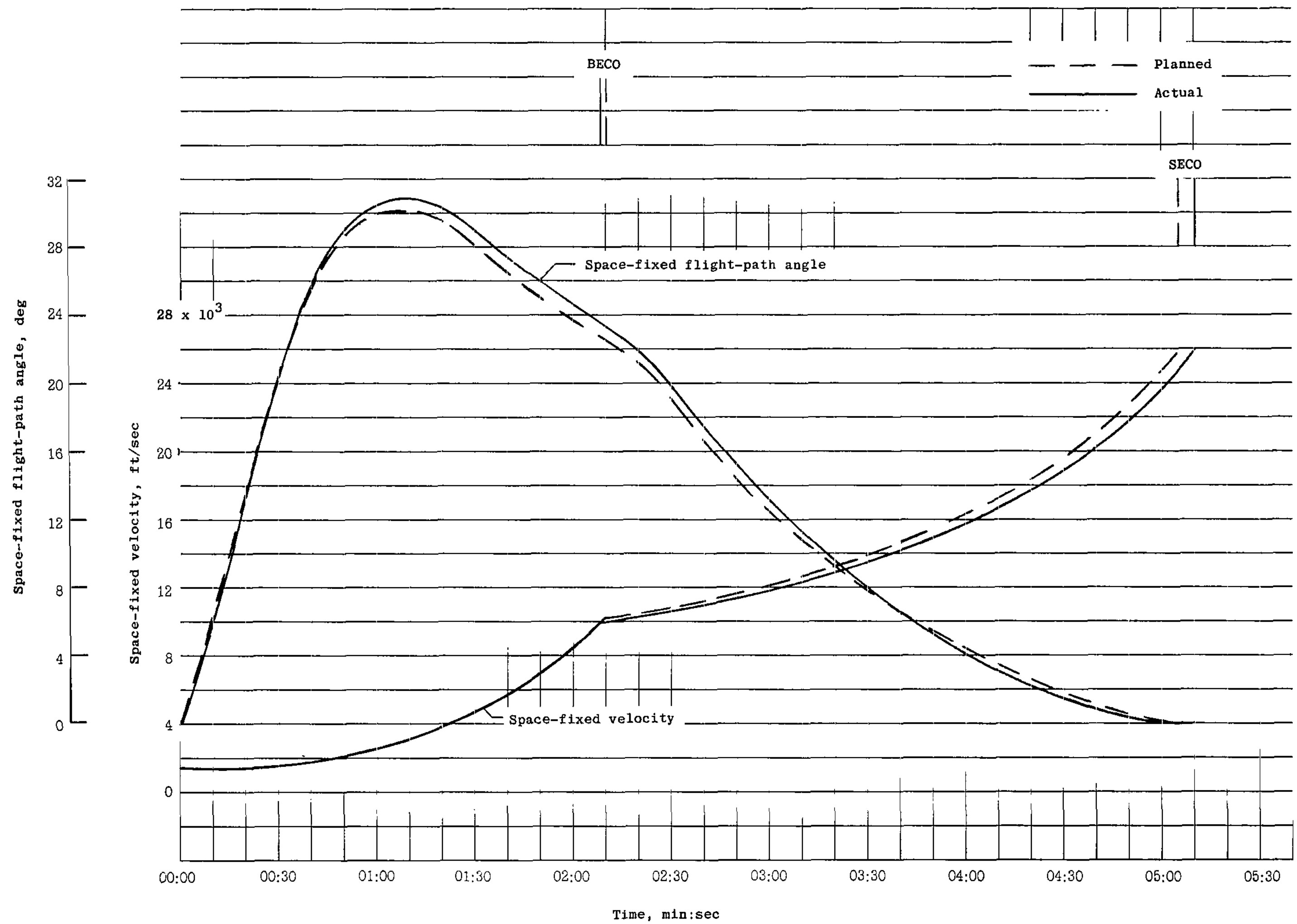
Figure 50.- Altitude plotted against longitude profile.



(a) Altitude and range.

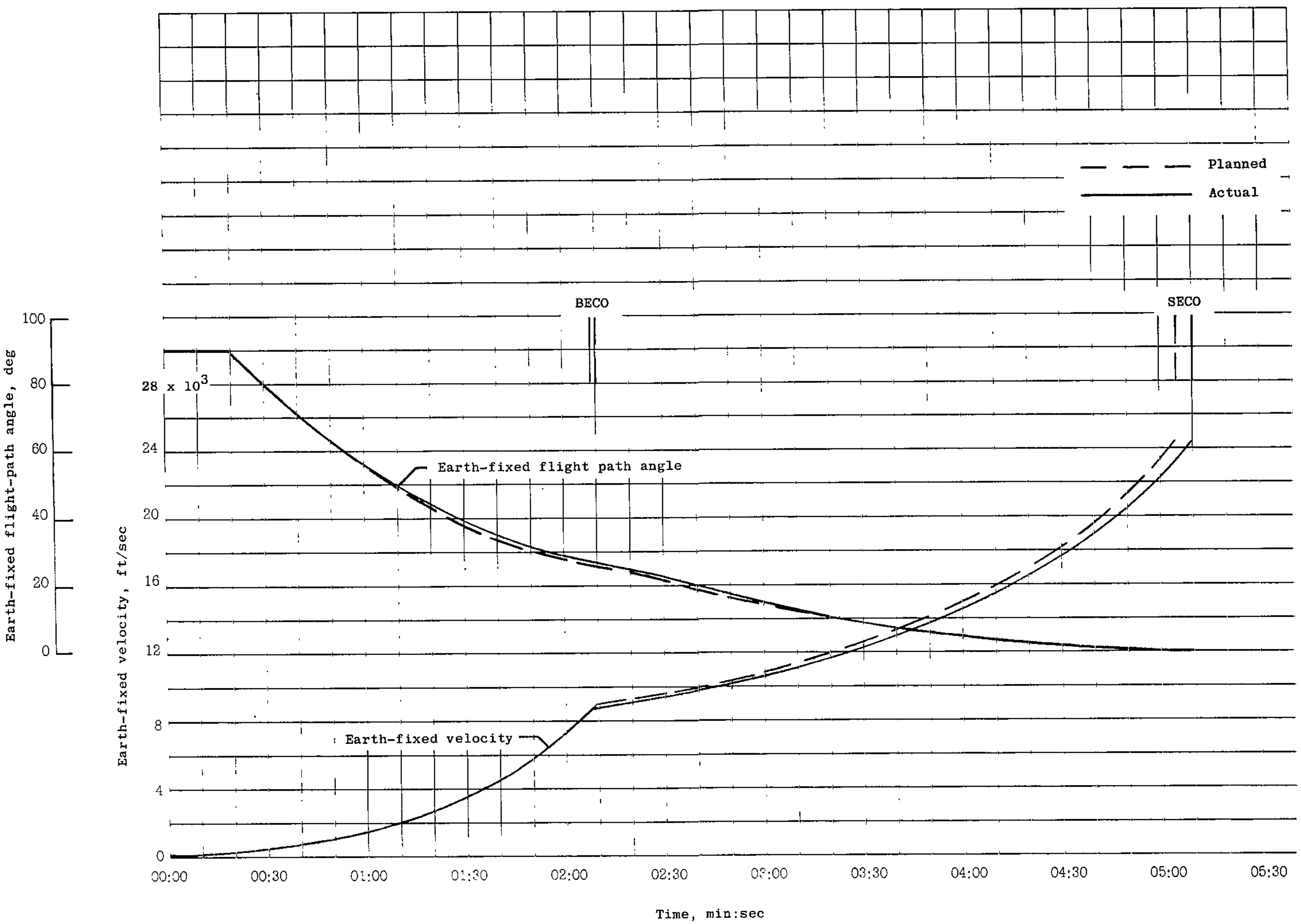
(a) Altitude and range.

Figure 51.- Time histories of trajectory parameters for MA-7 mission launch phase.



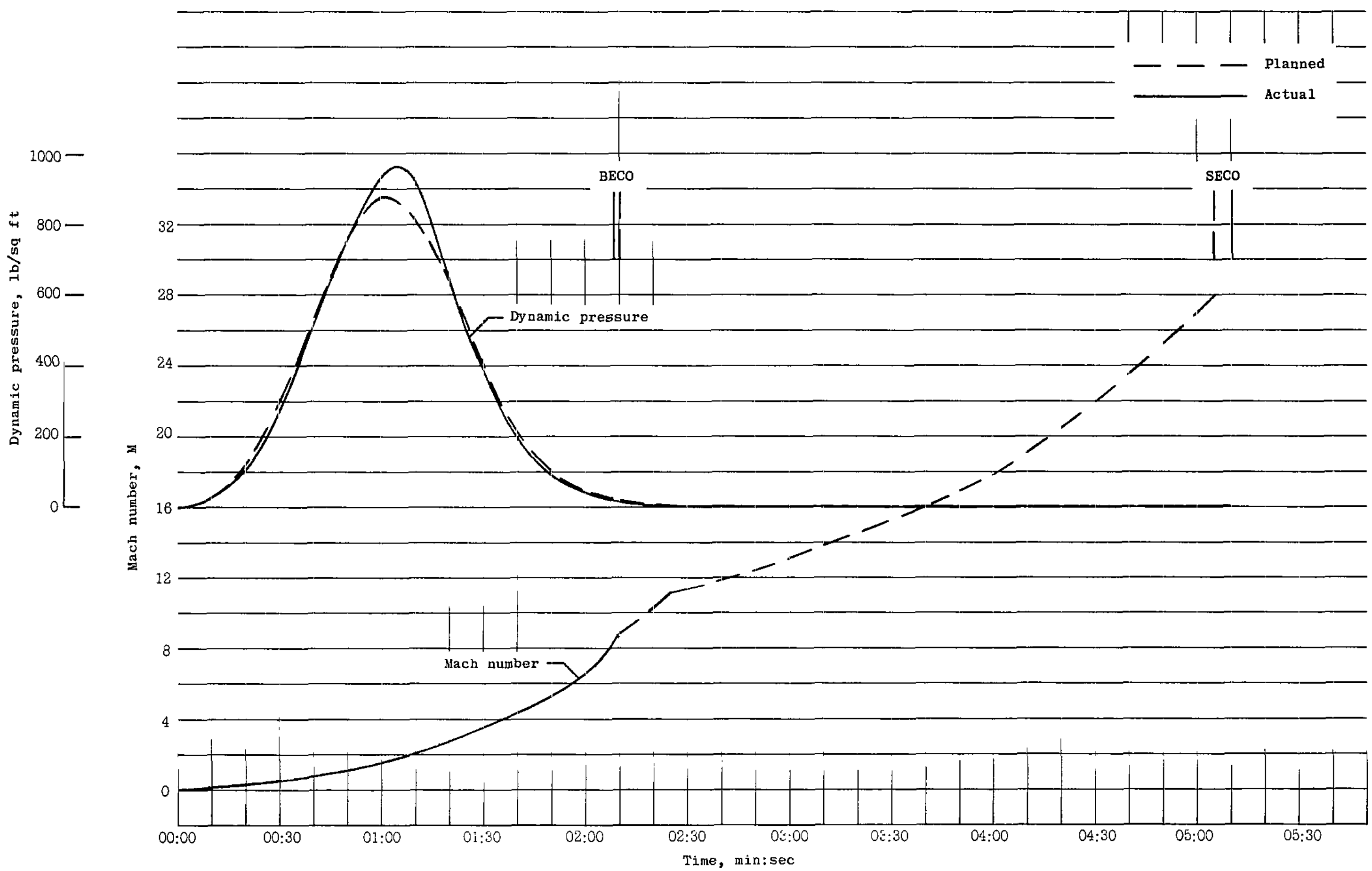
(b) Space-fixed velocity and flight-path angle.

Figure 51.- Continued.



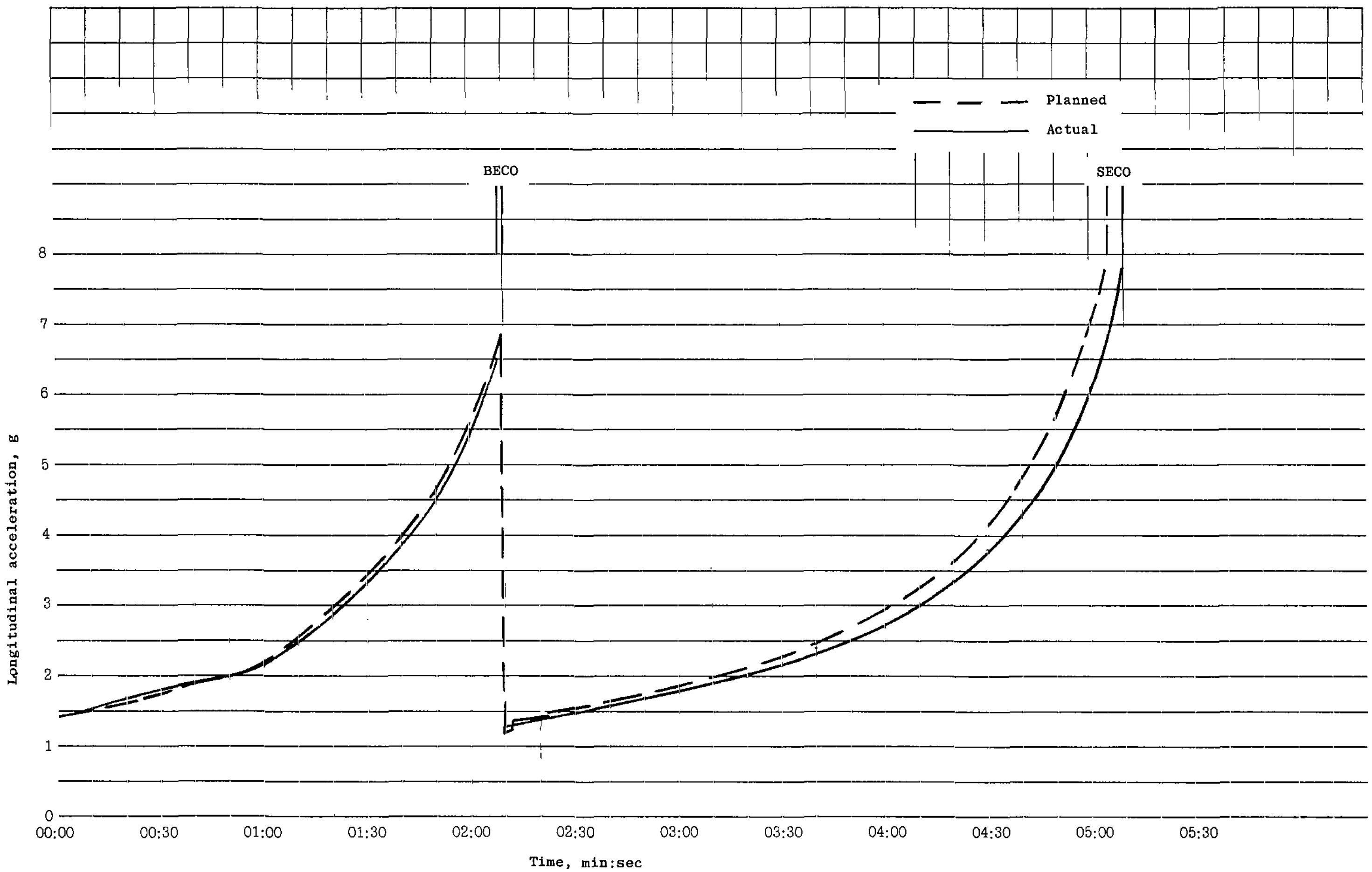
(c) Earth-fixed velocity and flight-path angle.

Figure 51.- Continued.



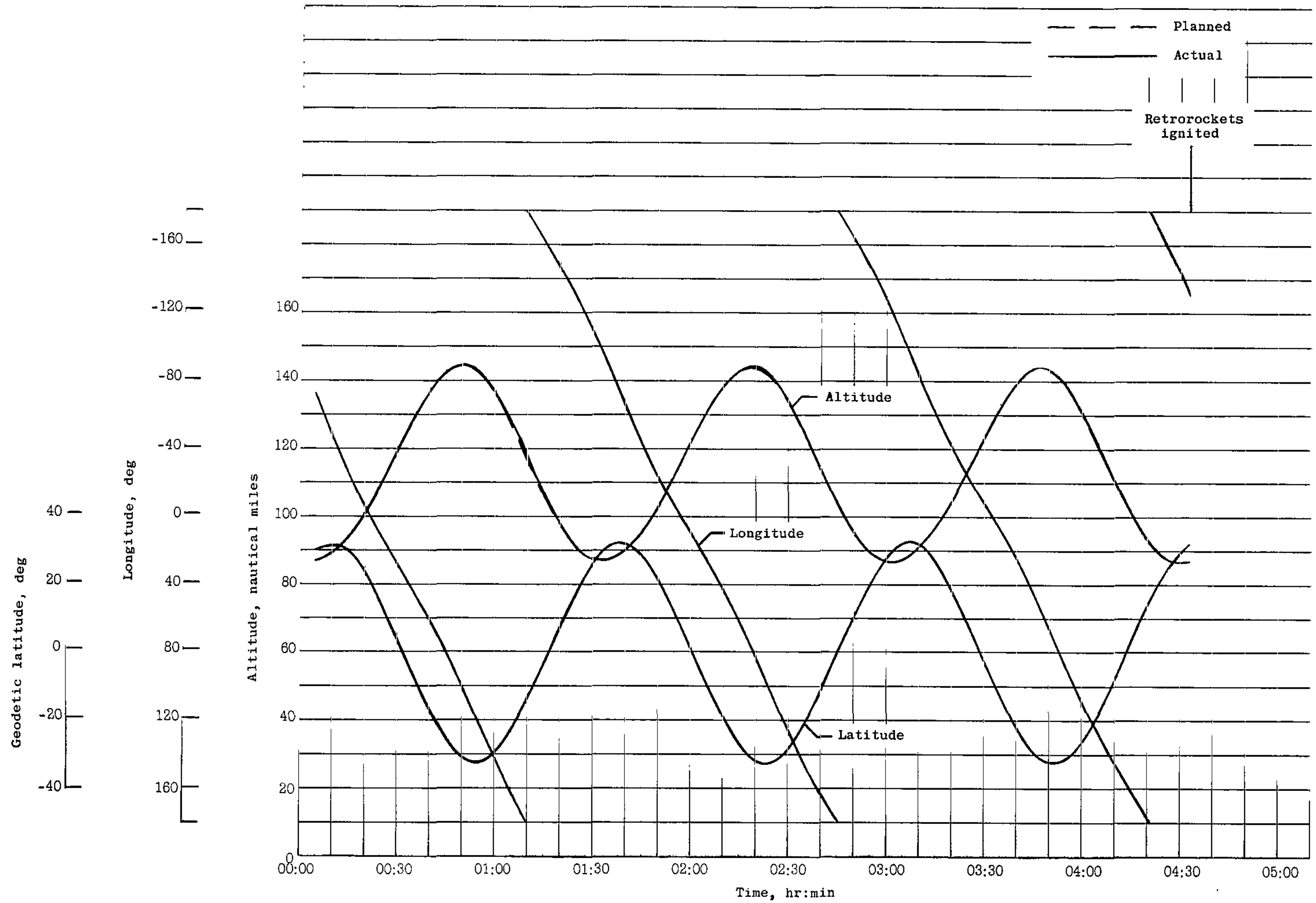
(d) Dynamic pressure and Mach number.

Figure 51.- Continued



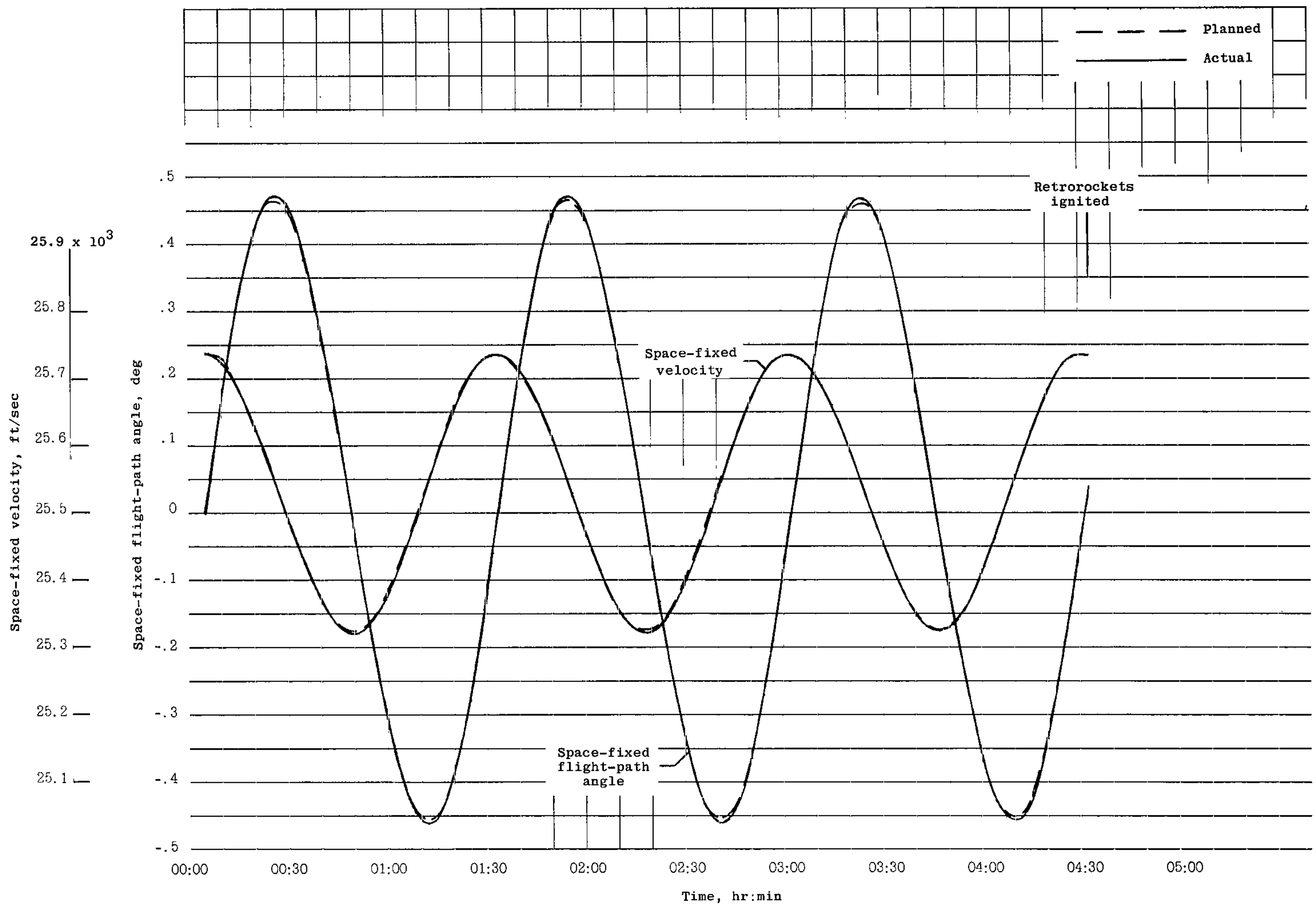
(e) Longitudinal deceleration along spacecraft Z-axis.

Figure 51.- Concluded.



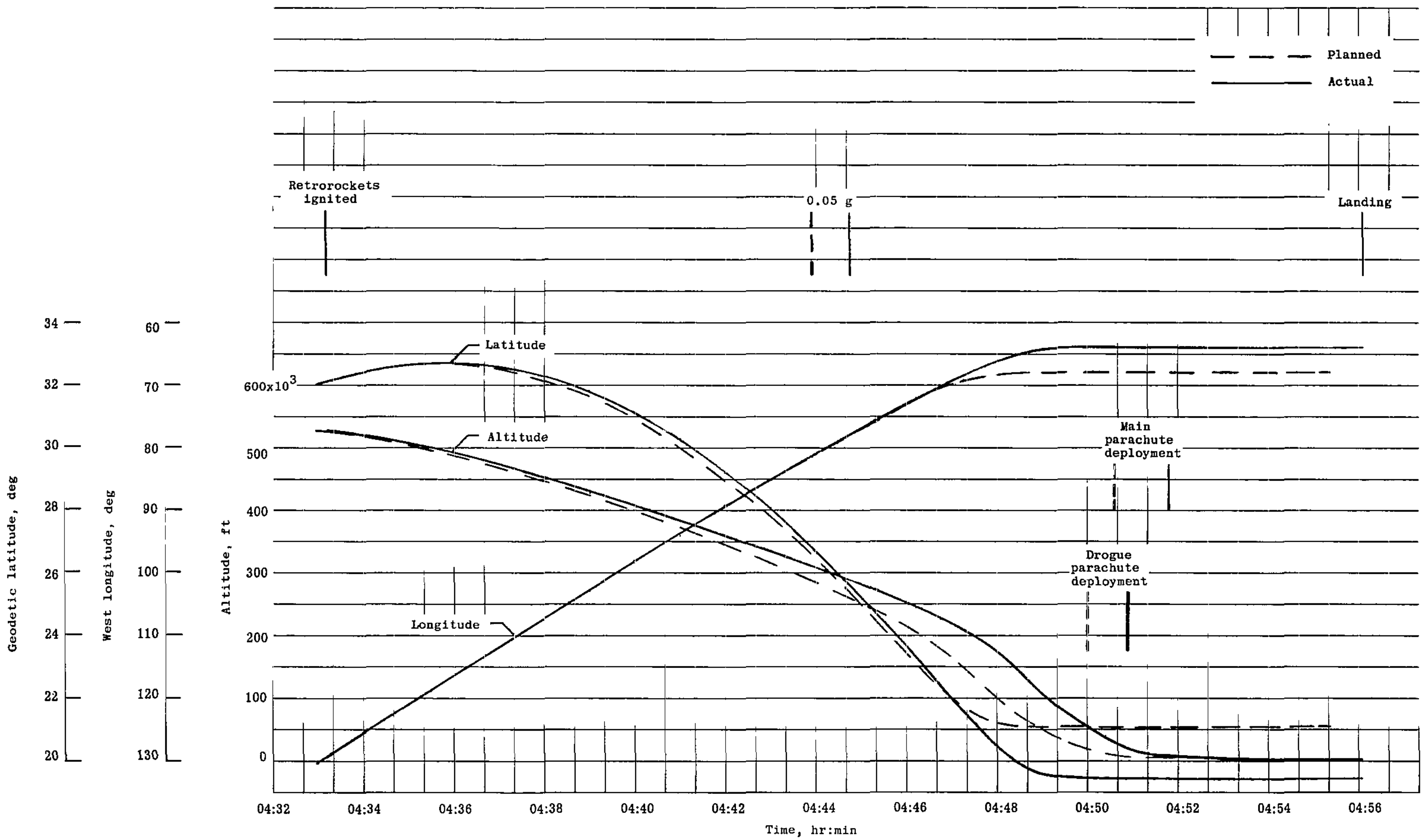
(a) Latitude, longitude, and altitude.

Figure 52.- Time histories of trajectory parameters for MA-7 mission orbital phase.



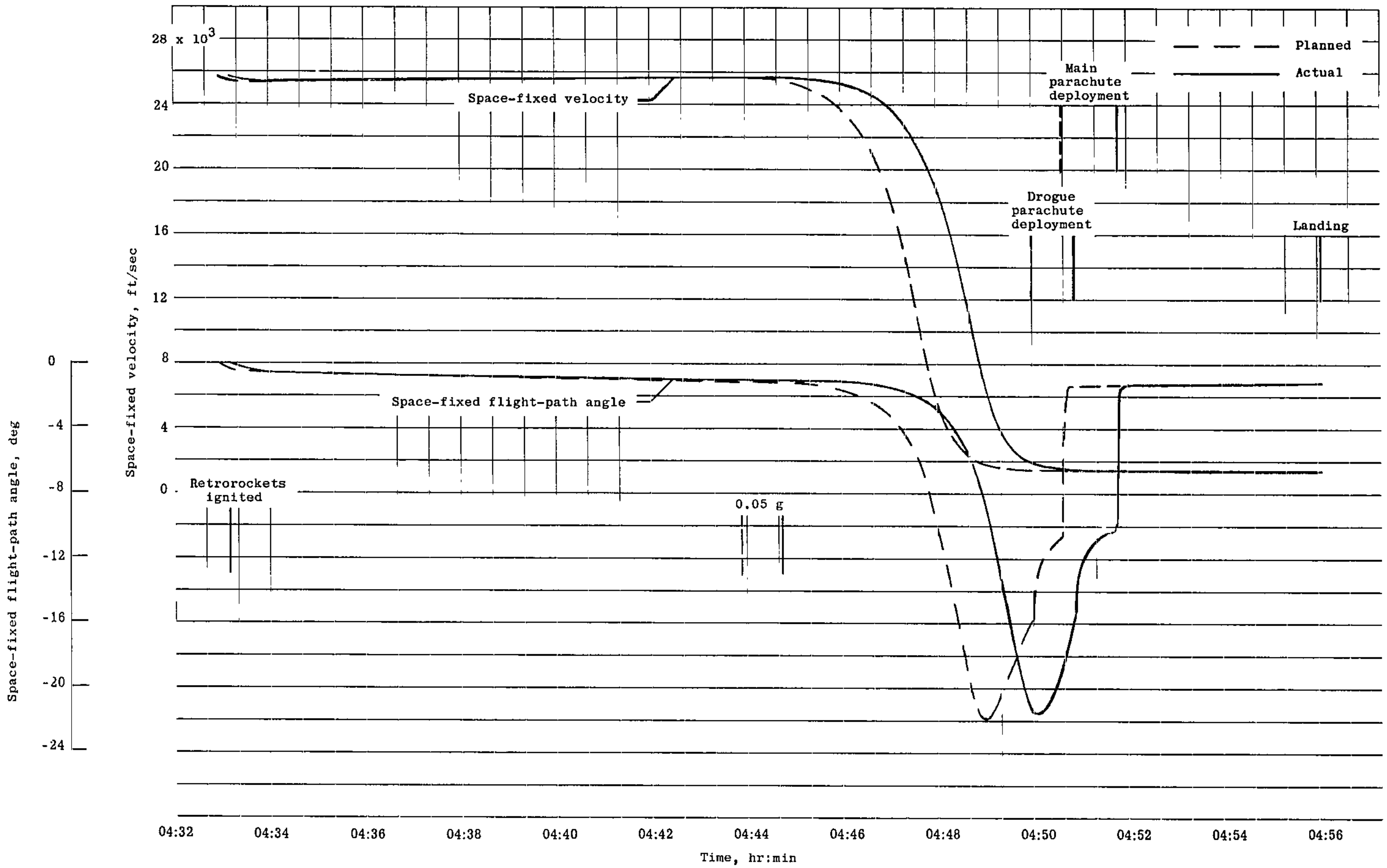
(b) Space-fixed velocity and flight-path angle.

Figure 52.- Concluded.



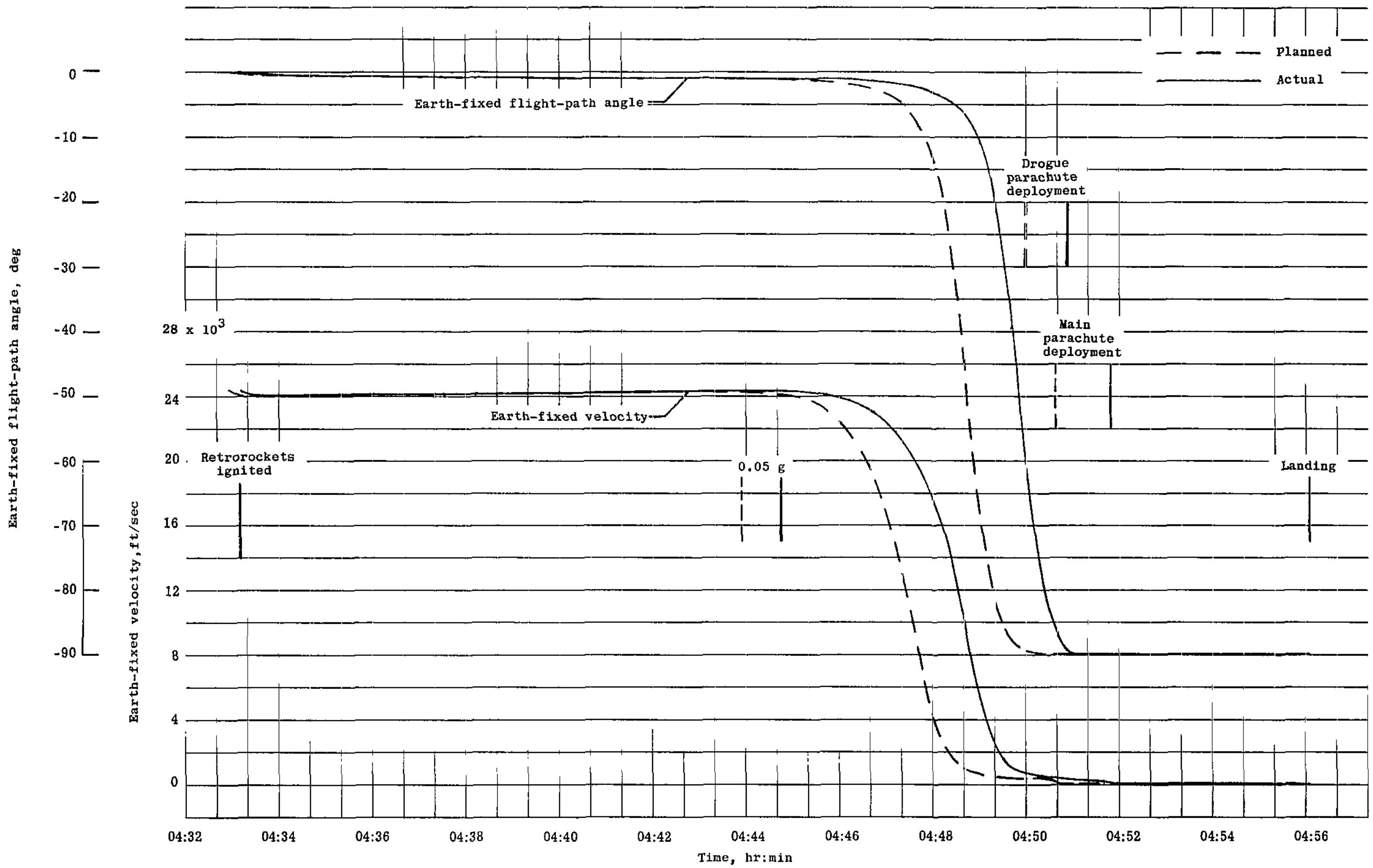
(a) Latitude, longitude, and altitude.

Figure 53.- Time histories of trajectory parameters for MA-7 mission reentry phase.



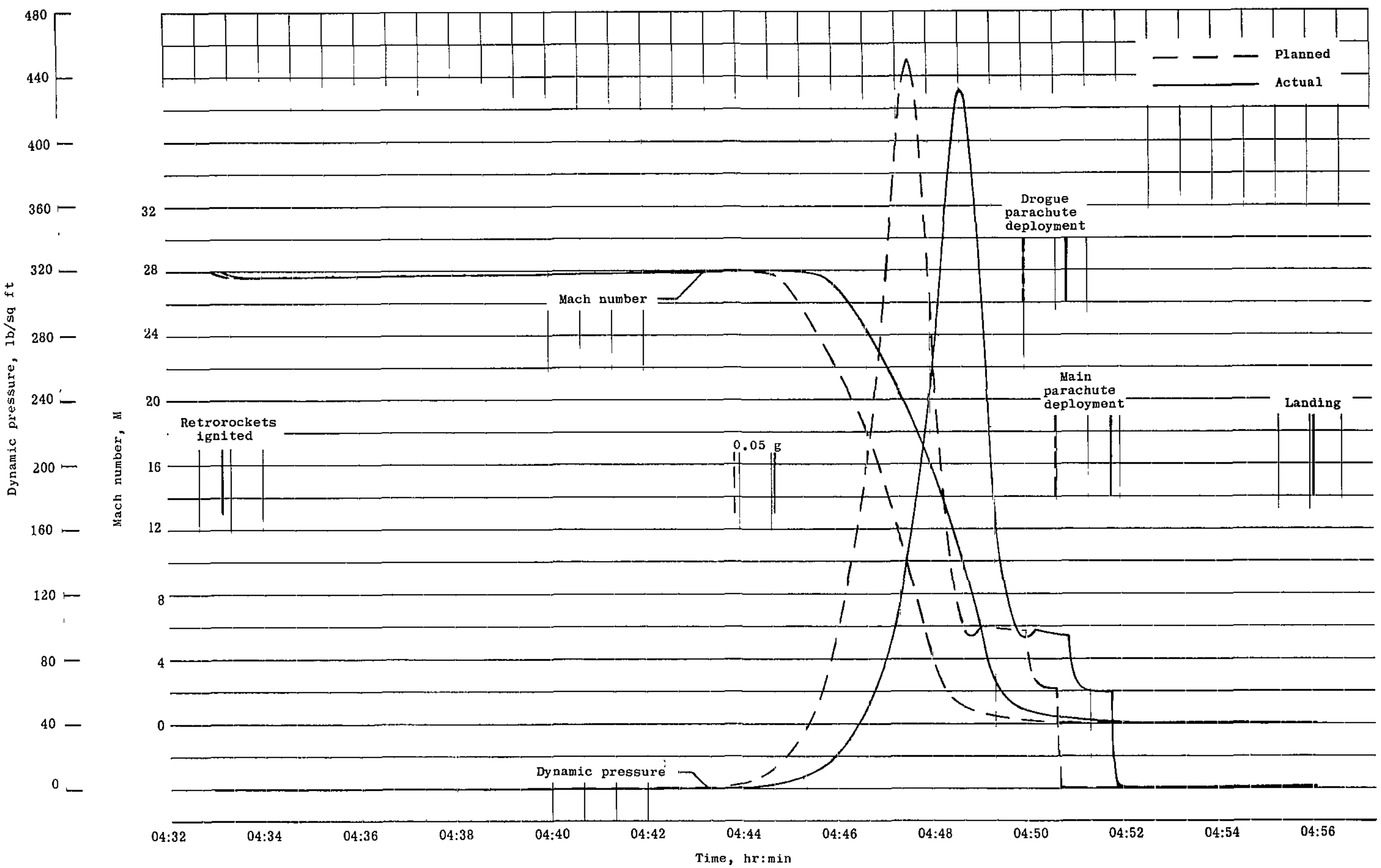
(b) Space-fixed velocity and flight-path angle.

Figure 53.- Continued.



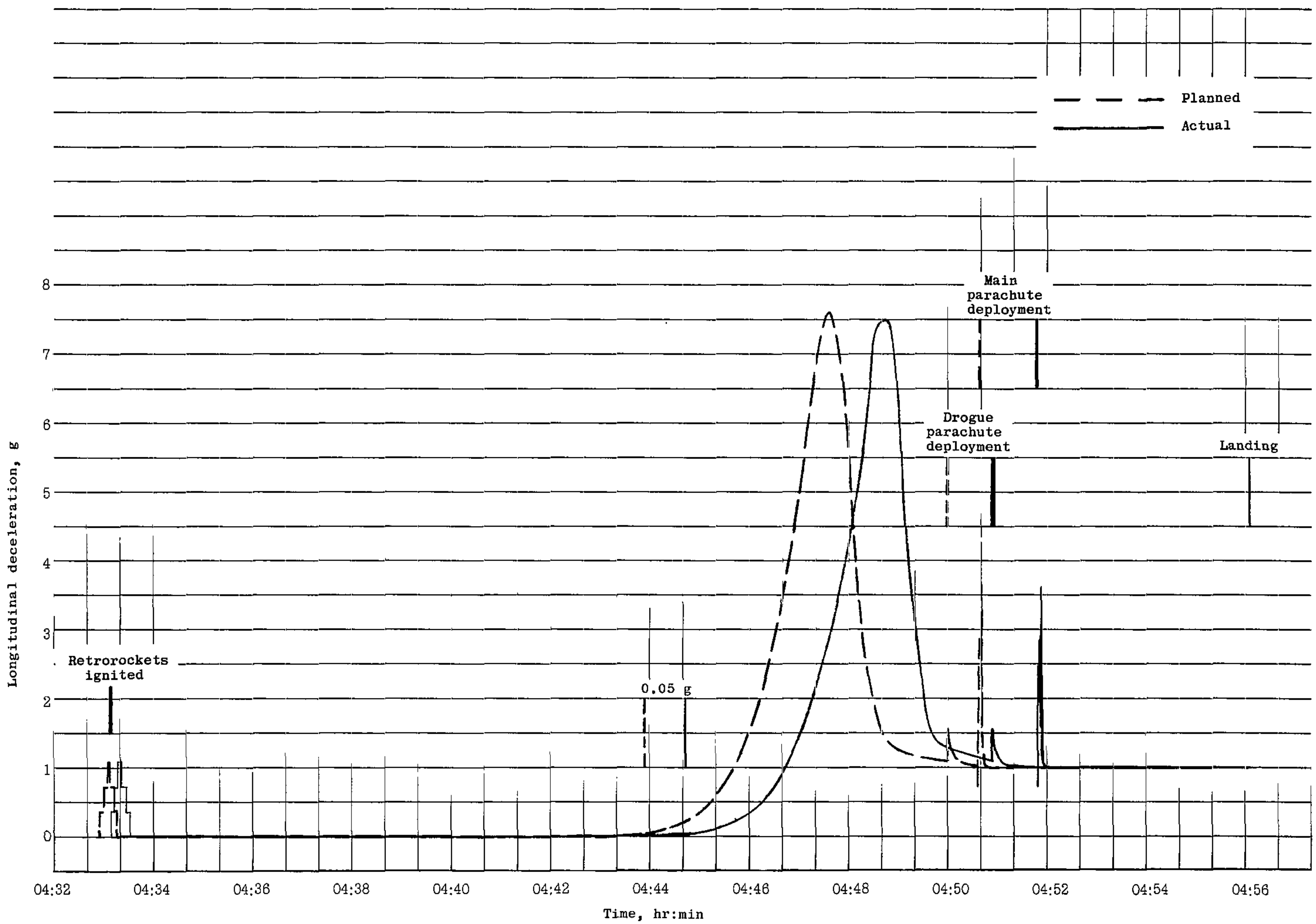
(c) Earth-fixed velocity and flight-path angle.

Figure 53.- Continued.



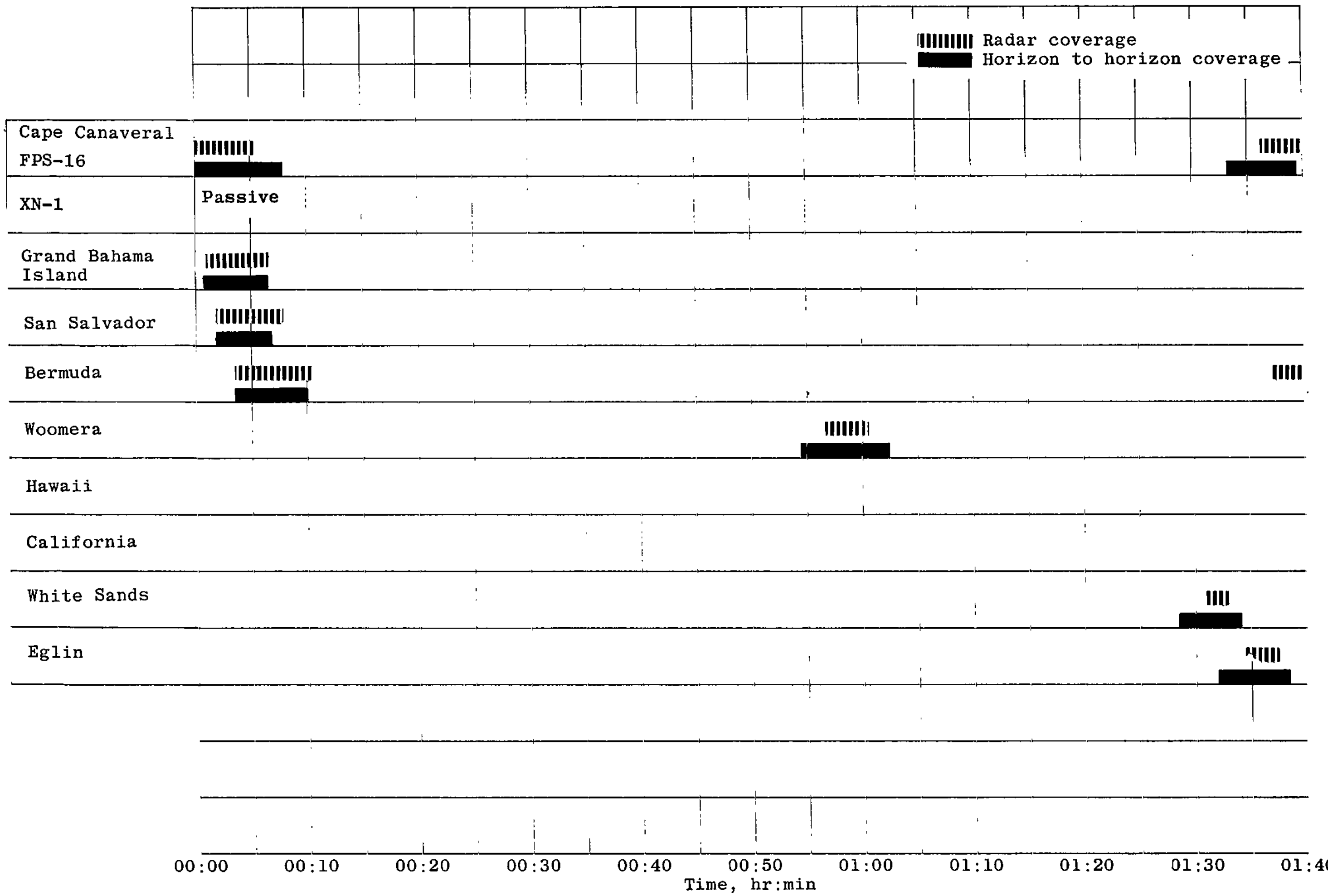
(d) Dynamic pressure and Mach number.

Figure 53.- Continued.



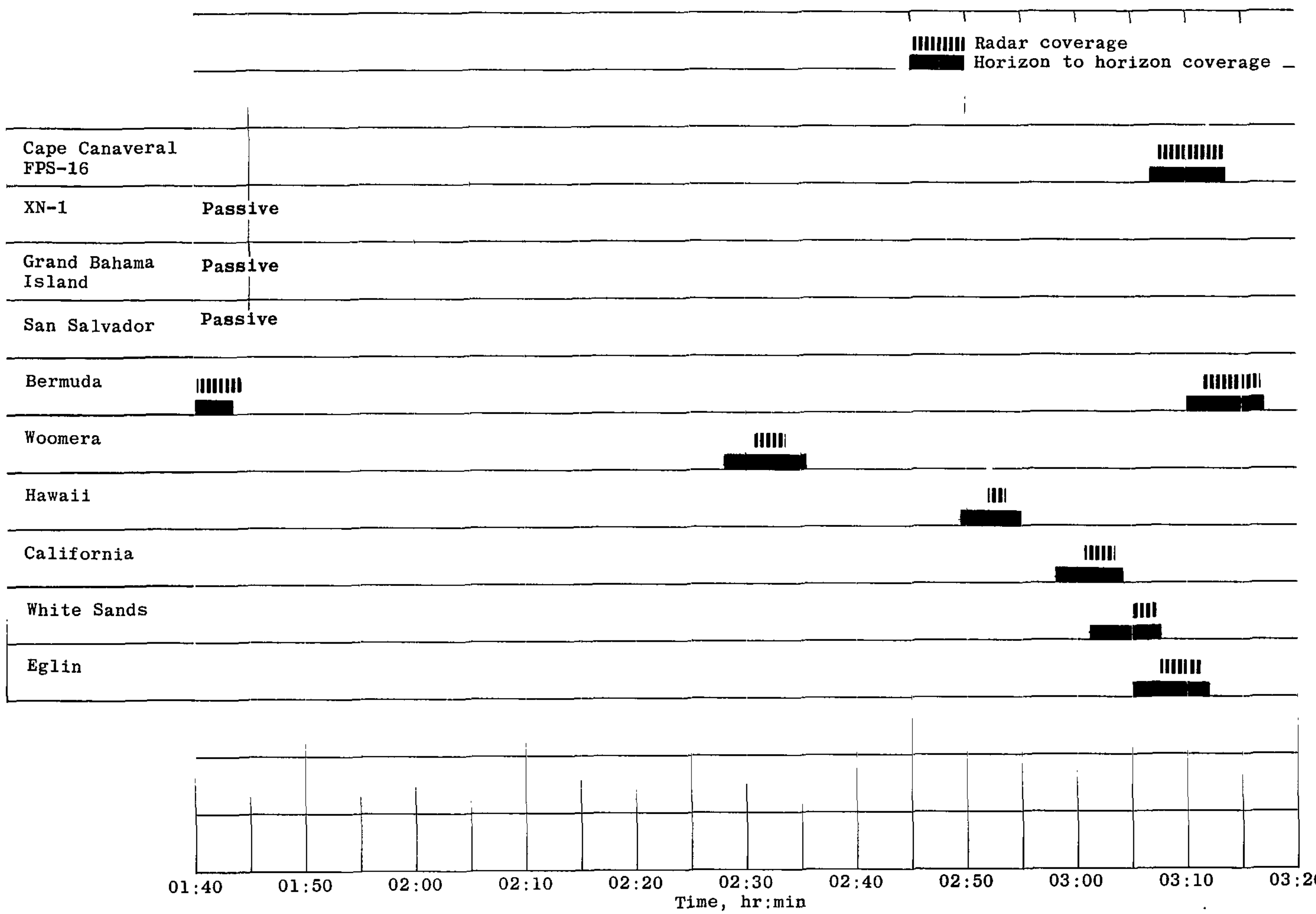
(e) Longitudinal deceleration along spacecraft Z-axis.

Figure 53.- Concluded.



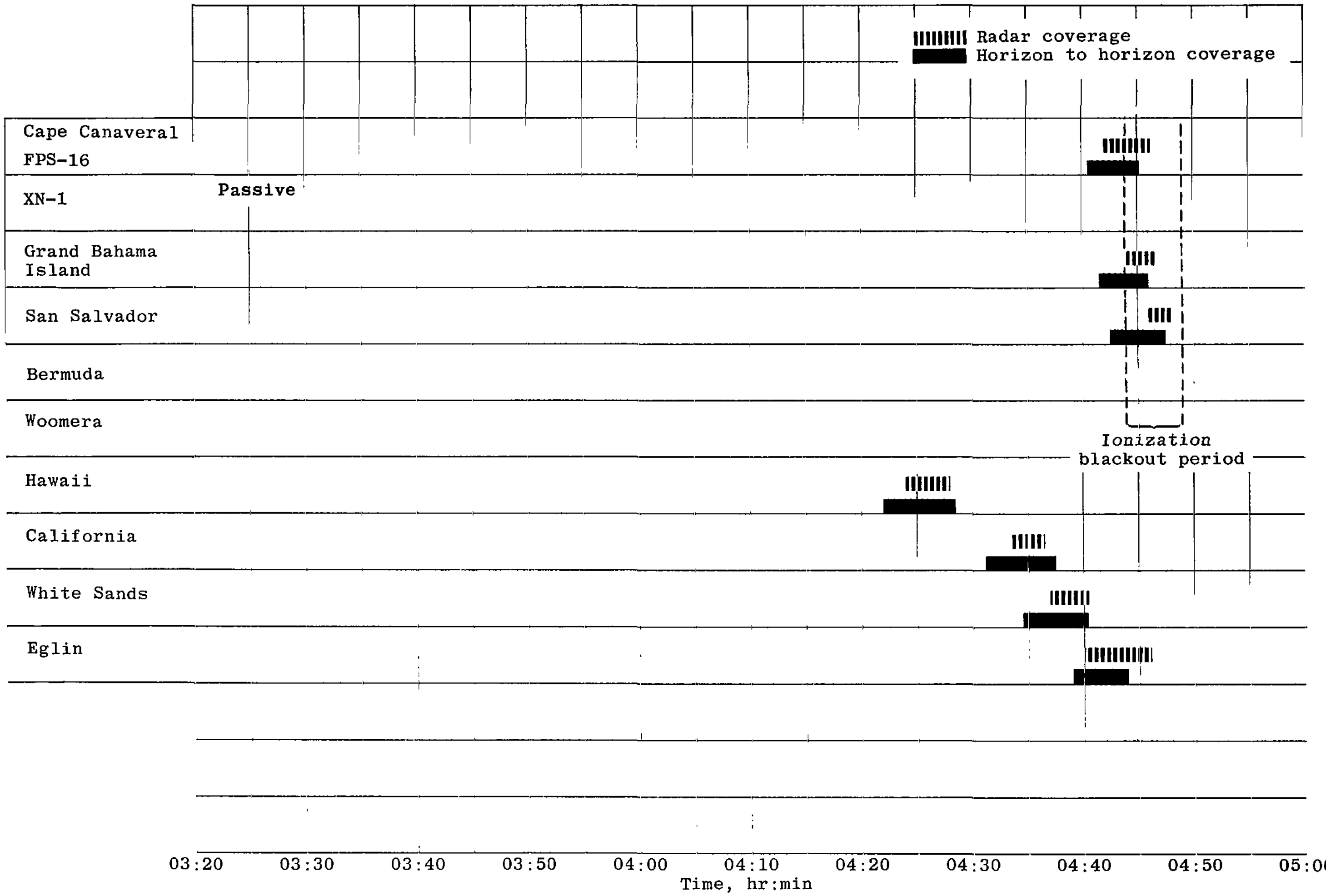
(a) First orbital pass.

Figure 54.- C-band radar coverage.



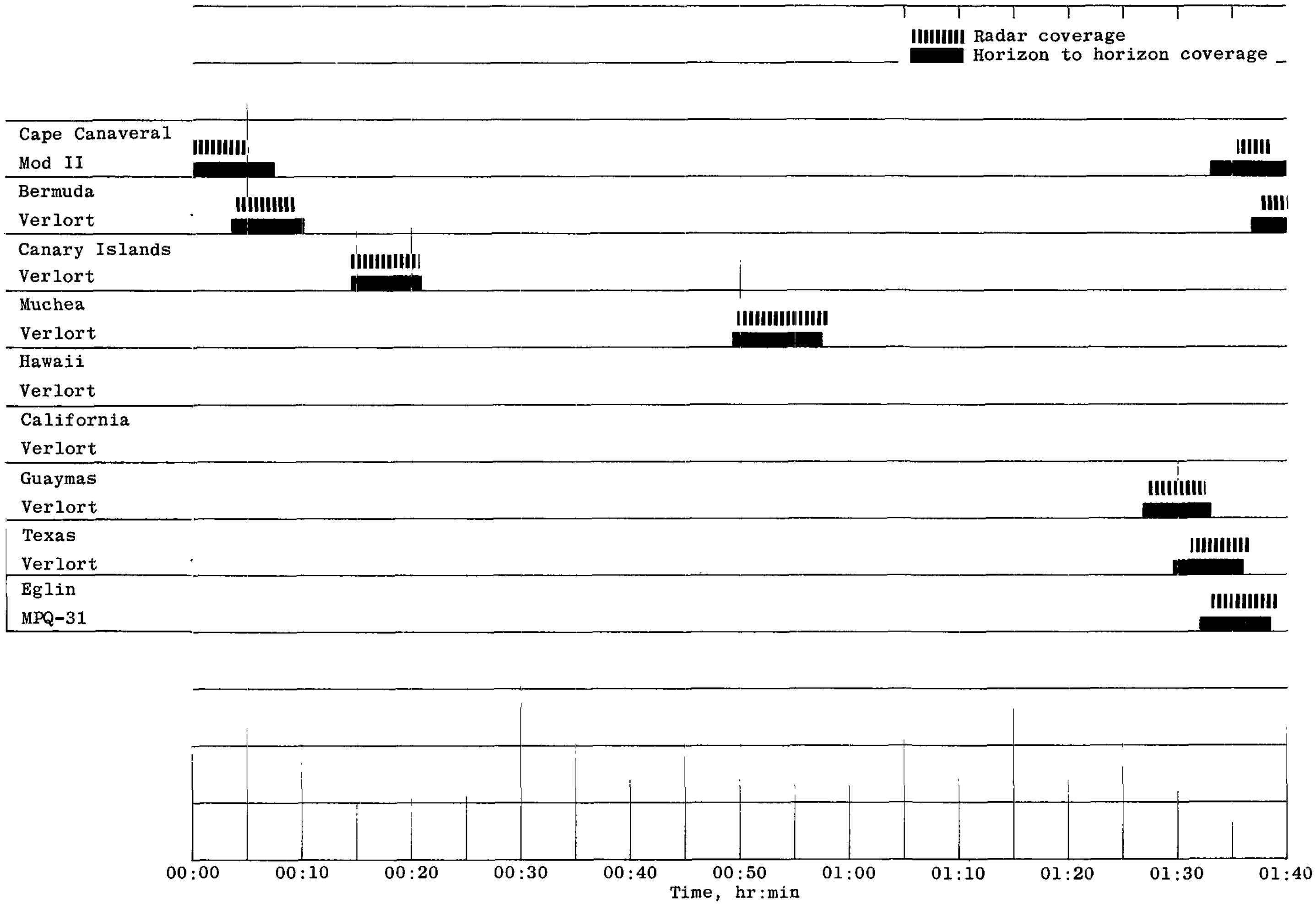
(b) Second orbital pass.

Figure 54.- Continued.



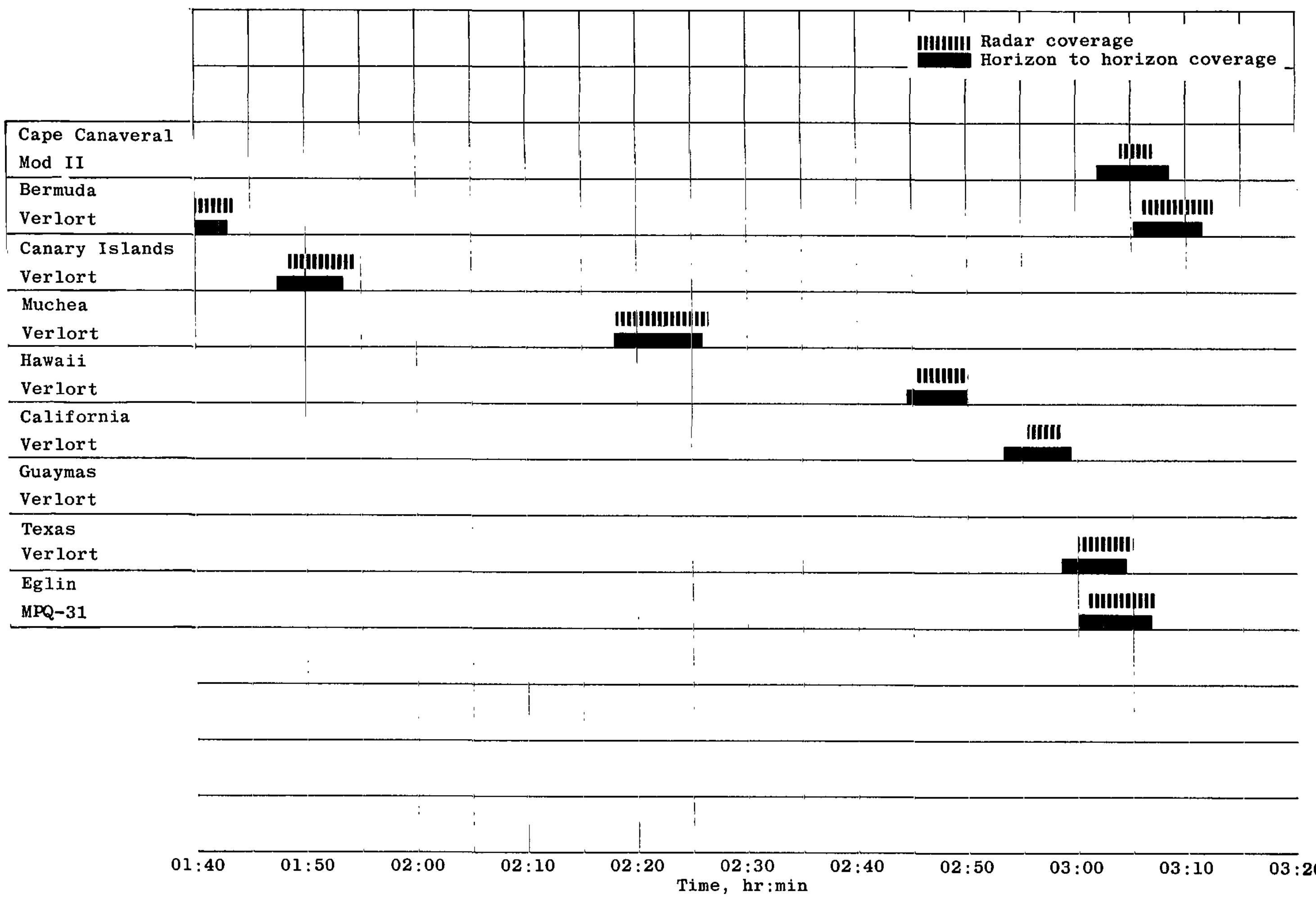
(c) Third orbital pass

Figure 54.- Concluded.



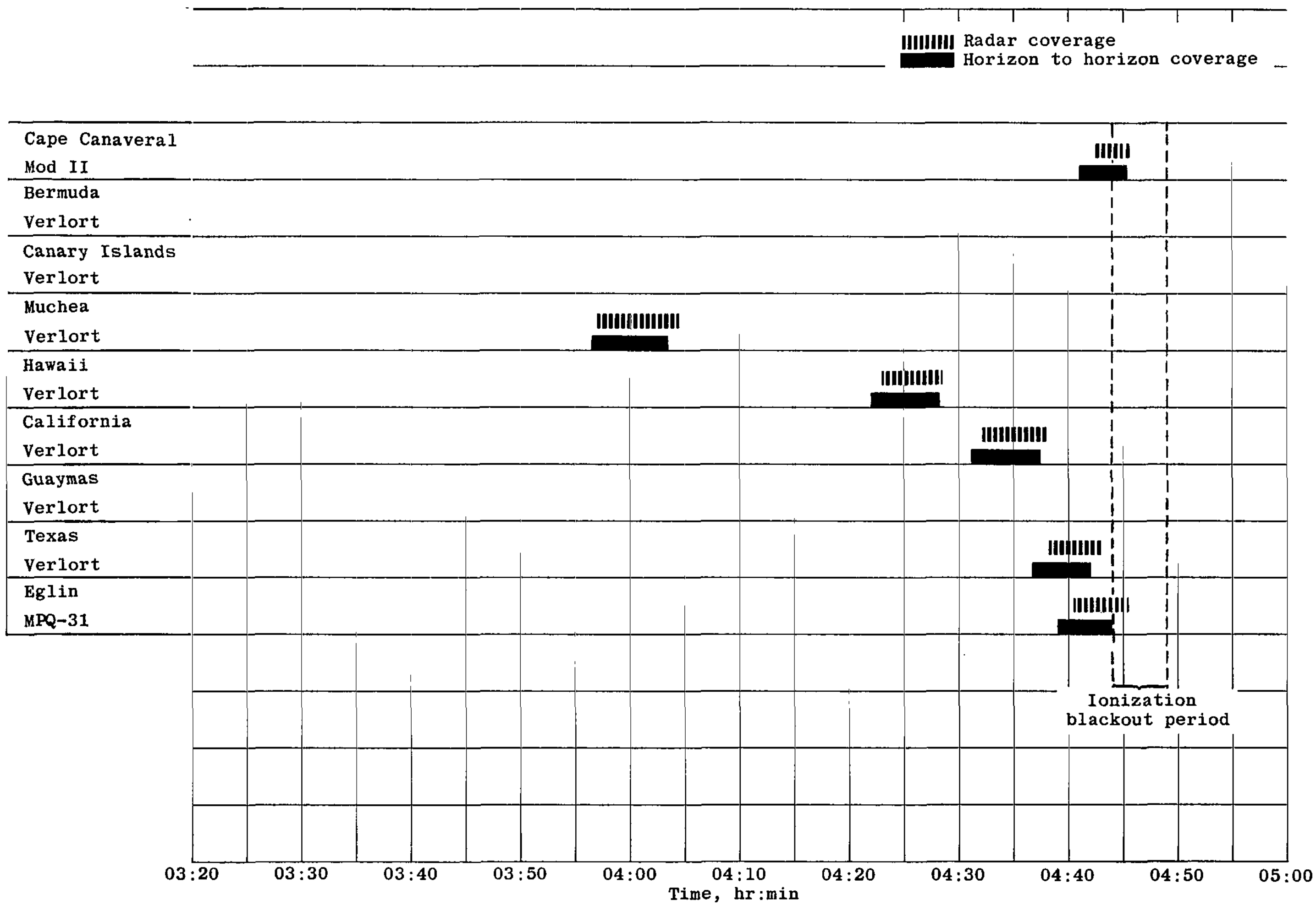
(a) First orbital pass.

Figure 55.- S-band radar coverage.



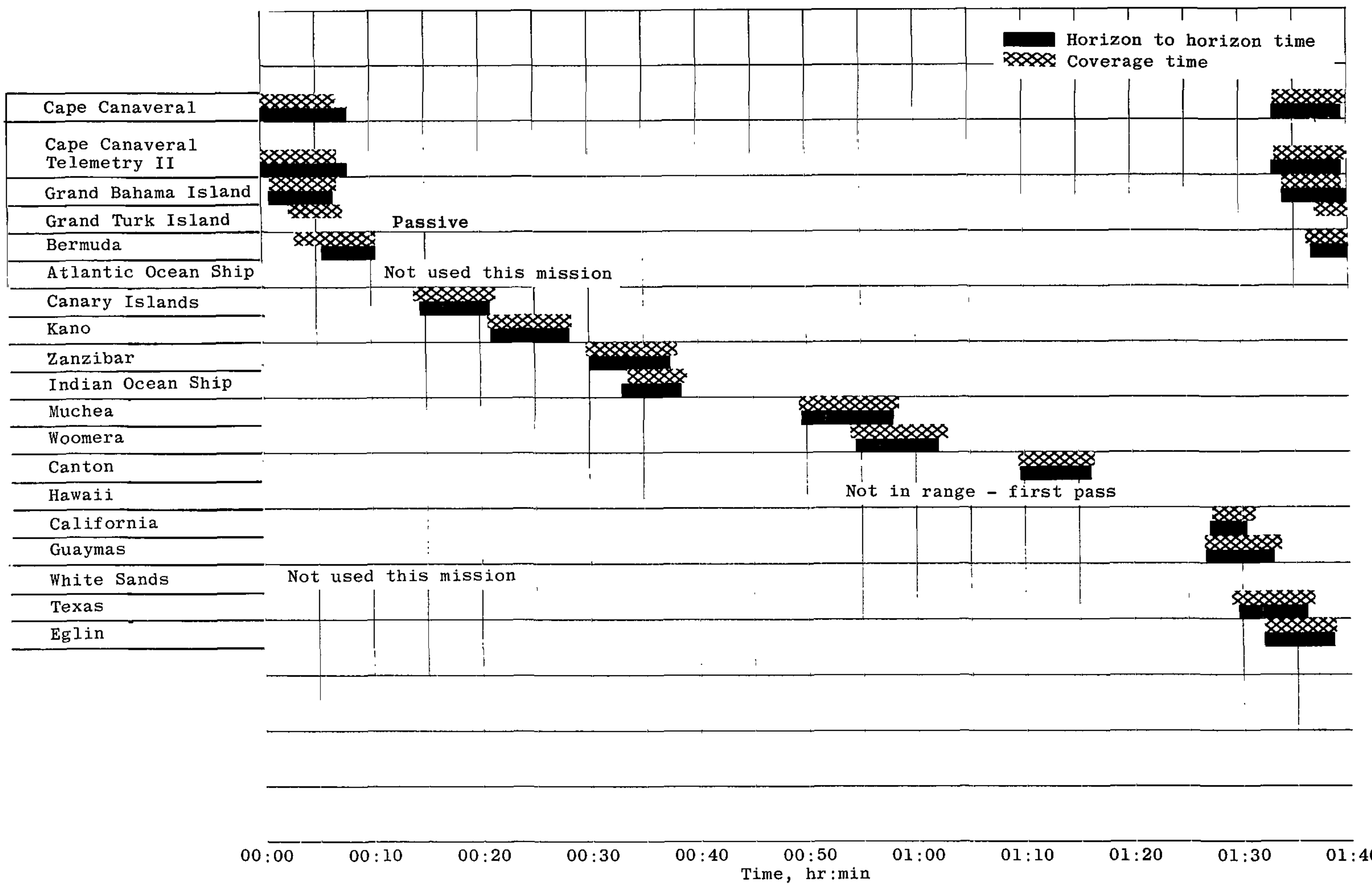
(b) Second orbital pass.

Figure 55.- Continued.



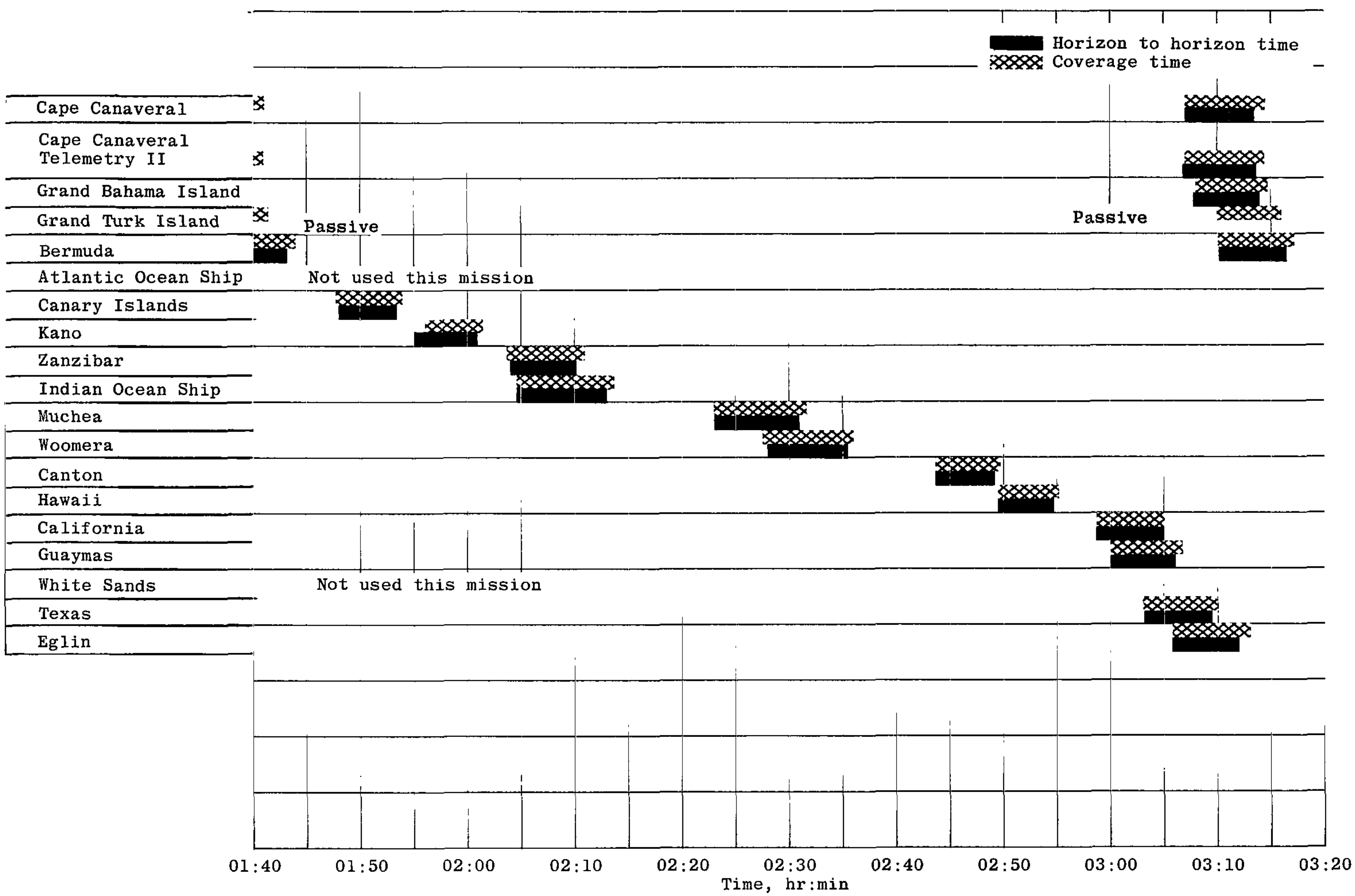
(c) Third orbital pass.

Figure 55.- Concluded.



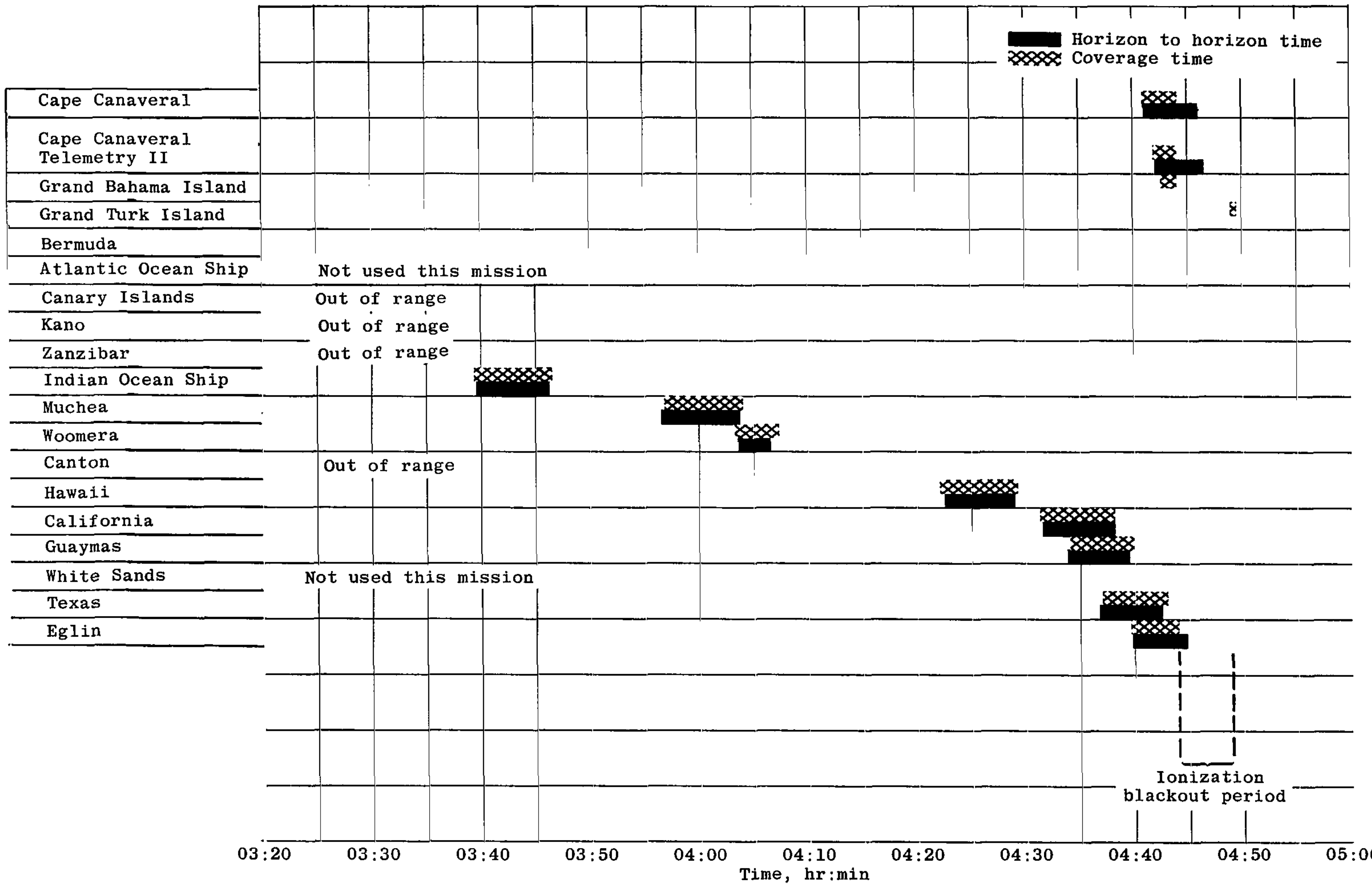
(a) First orbital pass.

Figure 56.- Telemetry reception coverage.



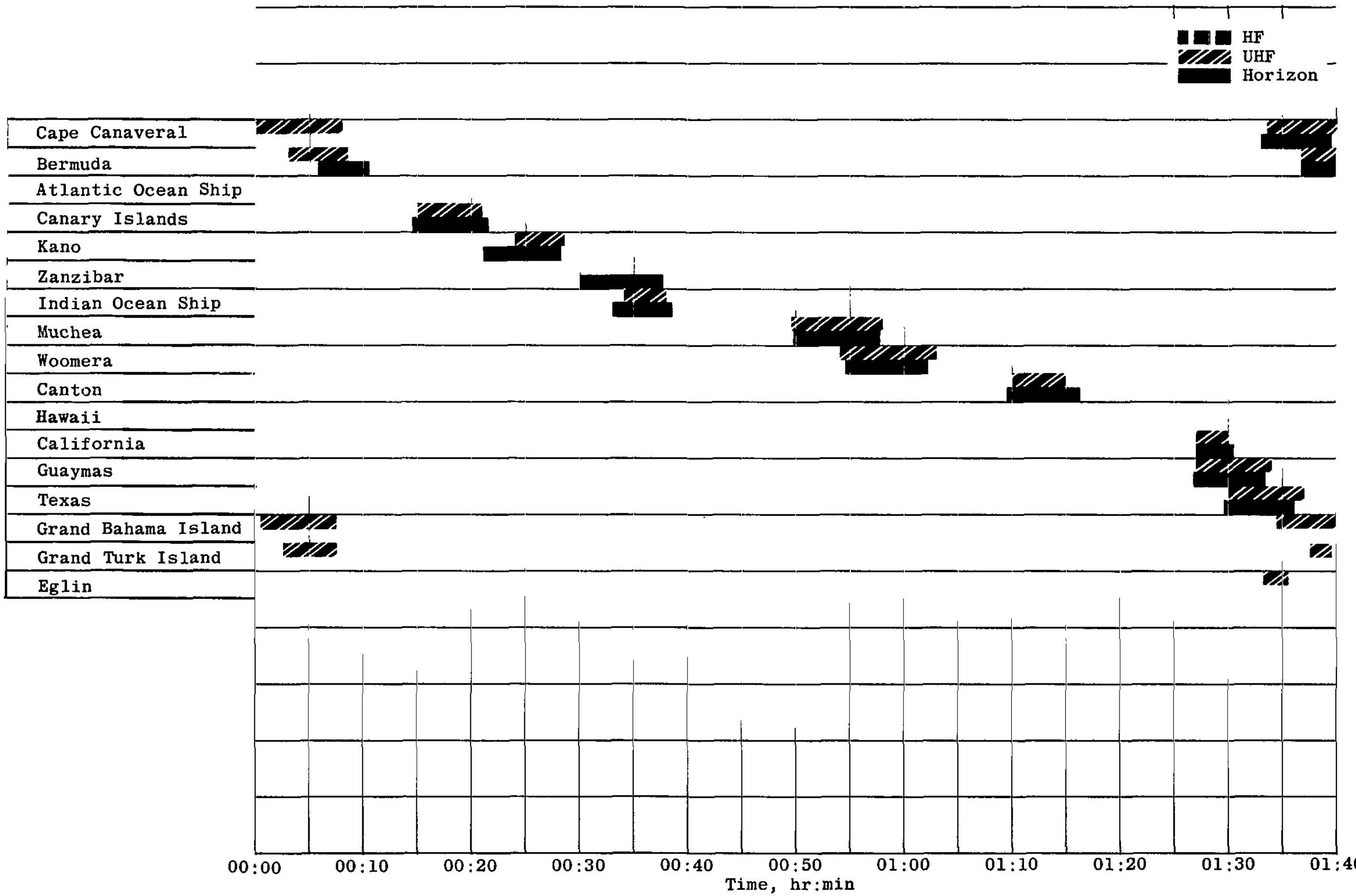
(b) Second orbital pass.

Figure 56.- Continued.



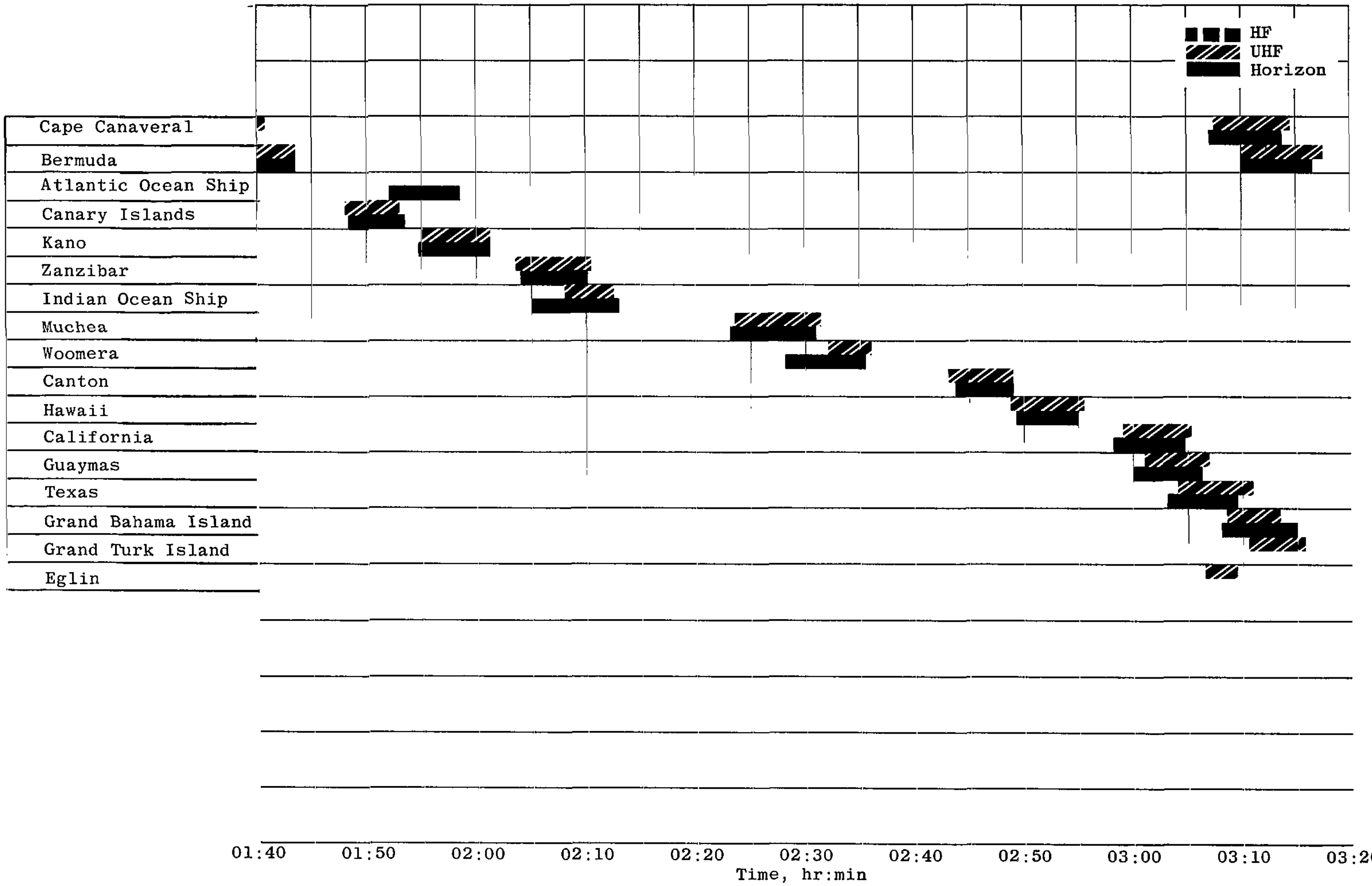
(c) Third orbital pass.

Figure 56.- Concluded.



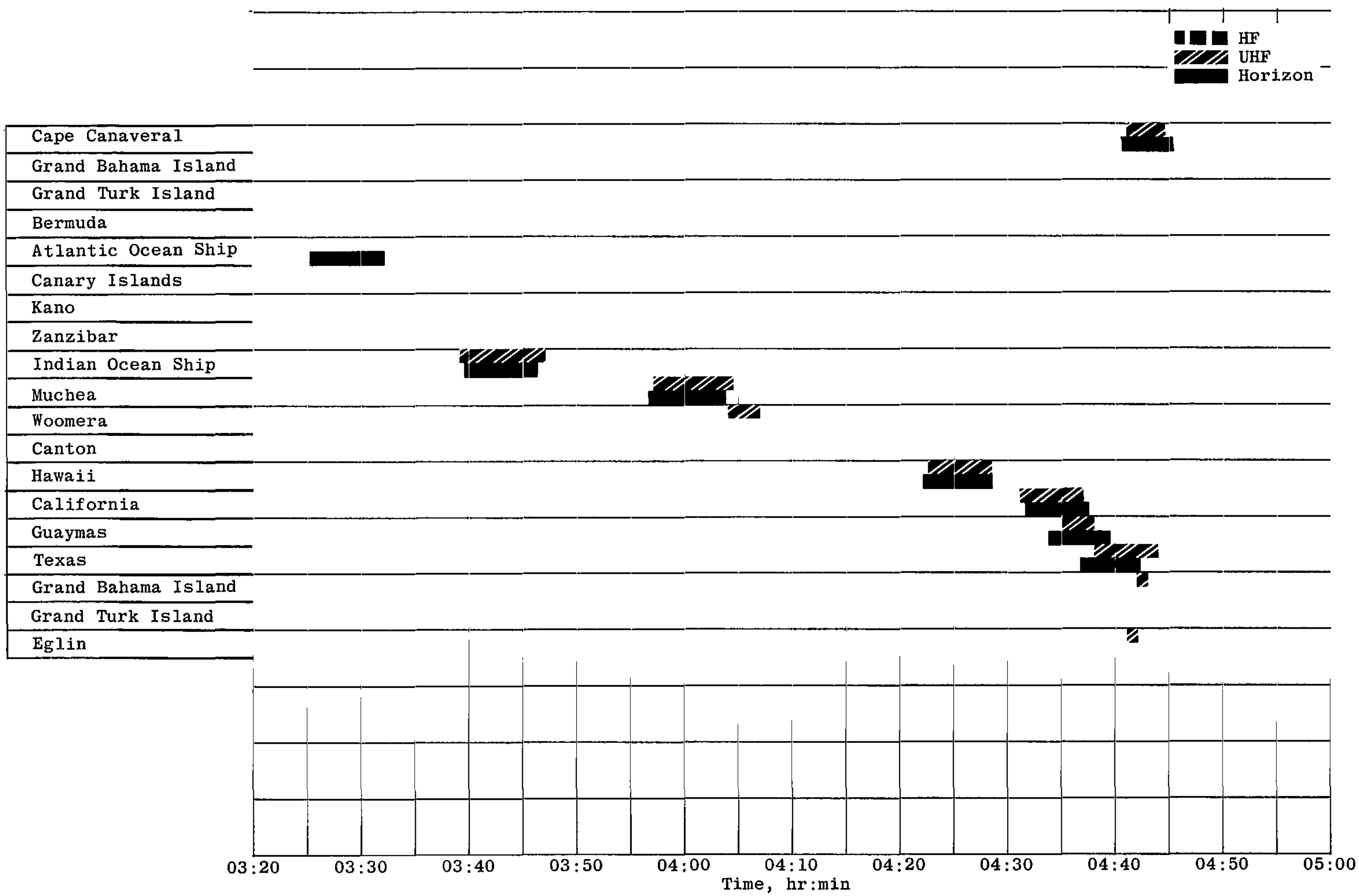
(a) First orbital pass.

Figure 57.- HF and UHF voice coverage.



(b) Second orbital pass.

Figure 57.- Continued.



(c) Third orbital pass.

Figure 57.- Concluded.

CONCLUDING REMARKS

The second United States manned orbital flight was an unqualified success with all primary mission objectives accomplished. The MA-7 spacecraft systems operation and the pilot performance further indicate that flights of longer duration are feasible in the Mercury spacecraft. Missions of longer duration will, however, require that control activity be reduced and that extended periods of drifting flight be included in the flight plan.

The problems, malfunctions, and anomalies which did occur were not sufficient to compromise the mission. The single mission-critical malfunction that occurred involved a failure in the spacecraft pitch horizon scanner which is a component of the automatic stabilization and control system. Other areas of concern included cabin and suit temperatures, high rates of fuel usage, and uncertainties in the telemetered inflight blood-pressure data.

Postflight inspection of the pitch horizon scanner was not possible since it was lost when the antenna canister was jettisoned during the normal landing sequence; however, the failure was apparently of a random nature in view of the fact that the scanner had been fully qualified on previous flights. Because of the malfunctioning scanner, which resulted in pitch errors in the spacecraft attitude-gyro system, the pilot was required to assume manual control of the spacecraft during the retrofire period. Although manual control was adequate, spacecraft attitude was not within the range prescribed to permit automatic initiation of the retrofire signal. Subsequent manual initiation of the signal occurred several seconds later than scheduled, and this delayed signal, along with the non-optimum spacecraft attitude, contributed to the fact that the spacecraft landed approximately 250 nautical miles downrange and 15 nautical miles north of the nominal landing point.

The cabin and suit temperatures were higher than desired, although not intolerable. A major contributor to the problem is the time lag that exists between manual selection of a comfort control valve setting and the subsequent temperature change at the monitoring point. This lag resulted in difficulty in determining the correct valve setting. Extensive postflight testing has shown that relocation of the monitoring point will reduce the time lag and minimize the effect it has on system control.

The high rate of fuel usage resulted in early depletion of both automatic and manual fuel. Double authority control was inadvertently employed at times during the flight, and the fly-by-wire high-thrust units were accidently activated during certain maneuvers, both of which contributed to the high usage rate of spacecraft fuel. In order to prevent inadvertent use of the high-thrust jets when the fly-by-wire mode of control is used, future Mercury spacecraft will contain a switch which will allow the pilot to disable and reactivate the high-thrust units at his discretion. An automatic override will reactivate these thrusters just prior to retrofire. Additionally, a revision in fuel management and control training procedures has been instituted for the next mission.

The data transmitted from the blood-pressure measuring system were questionable during the flight, primarily because of the magnitude of the data and the intermittency with which they were received. The mission was continued since associated information indicated the continued well-being of the astronaut. The intermittent signals were found to be a result of a broken cable in the microphone pickup; however, this did not affect the magnitude of the data received since an intermittent short circuit allows either transmission of valid signals or none at all. The blood-pressure measuring system was thoroughly checked during postflight tests, and the problem was determined to be incorrect preflight calibration. Because of this problem, it was concluded that the inflight blood-pressure data were not reducible to the actual blood pressure of the astronaut.

The success of the MA-7 mission provided another significant milestone in the Mercury flight program. The knowledge gained will enhance and lend confidence to future Mercury missions possessing objectives of even greater ambition and more demanding operational implications.

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1. Staff of NASA Manned Spacecraft Center: Technical Memorandum X-563, First United States Manned Three-Pass Orbital Mission (Mercury-Atlas 6, Spacecraft 13). Part I, Description and Performance Analysis. CONFIDENTIAL

2. Staff of the NASA Manned Spacecraft Center: Results of the Second United States Manned Orbital Space Flight, May 24, 1962. UNCLASSIFIED

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—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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