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FIRST U.S. MANNED SIX-PASS ORBITAL MISSION (MERCURY-ATLAS 8, SPACECRAFT 16)

DESCRIPTION AND PERFORMANCE ANALYSIS

Edited by John H. Boynton

Manned Spacecraft Center
Houston, Texas

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • SEPTEMBER 1968

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ABSTRACT

The results and analyses of the third U.S. manned orbital mission are presented. The mission was accomplished October 3, 1962, as a phase of Project Mercury. Spacecraft and launch-vehicle descriptions, mission operations, and postflight analyses are included. Particular treatment is given to the investigations of spacecraft systems performance and aeromedical analyses of the pilot.

FOREWORD

The first U.S. manned six-pass orbital mission was an extension of the two previous manned three-pass orbital missions and added significantly to the knowledge gained in those two limited-duration missions. An overall analysis of the mission performance is presented, and only the minimum necessary supporting data are included.

General acknowledgment is made of the extensive effort on the part of the entire Mercury team. The team consisted of many organizations external to the NASA Manned Spacecraft Center and included the Department of Defense, the spacecraft prime contractor and subcontractors, the NASA Goddard Space Flight Center for the Mercury Worldwide Network, the launch-vehicle prime contractor and subcontractors, and the many organizations and Government agencies which directly or indirectly made the success of the mission possible.

This report represents the contributions of an assigned flight evaluation team which was comprised of systems specialists and operations personnel from throughout the NASA Manned Spacecraft Center, without whose analytical and documentary efforts a report of this technical completeness would not be possible.

The Mercury-Atlas 8 (MA-8) report is being published at this time to complete the Mercury technical documentation series and provide a source of historical data in much greater technical detail than that previously available. Further, to preserve a public record of the state of knowledge at the time of the mission, discussions and engineering conclusions remain essentially as they were written at the end of the MA-8 postflight data evaluation, despite any results from subsequent flight programs.

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FIRST U. S. MANNED SIX-PASS ORBITAL MISSION

(MERCURY-ATLAS 8, SPACECRAFT 16)

DESCRIPTION AND PERFORMANCE ANALYSIS

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SUMMARY

The Mercury-Atlas 8 mission was the third U. S. manned orbital mission; all mission objectives were accomplished. A description of the mission, the test objectives, and a comprehensive postflight evaluation are presented.

During the Mercury-Atlas 8 countdown, a single unscheduled hold of approximately 15 minutes was made for required repairs to a Canary Islands radar facility. Weather conditions at the launch site were satisfactory in the primary landing areas. Lift-off occurred at approximately 7:15 a.m. eastern standard time, October 3, 1962, 2 hours 35 minutes after the pilot, Walter M. Schirra, Jr., entered the spacecraft.

Launch-vehicle performance was satisfactory, and trajectory data indicated a mission-continue (go) condition at orbital insertion. An acceptable orbit was attained, with deviations from nominal values of space-fixed flight-path angle and velocity of -0.0079° and 15 ft/sec, respectively. The perigee and apogee of the orbit differed from the planned values of 86.97 and 144.2 nautical miles by 0.03 nautical mile and 8.6 nautical miles, respectively.

Spacecraft separation and manual turnaround were accomplished satisfactorily. The performances of the spacecraft systems and the pilot were excellent throughout the mission, as were the support activities from all ground elements, including flight control, Mercury Worldwide Network, and recovery. Minor problems encountered during the mission included an elevated suit-circuit temperature condition during the first 1.5 orbital passes and a reduction in the quality of air-to-ground voice transmissions.

The pilot performed the manual turnaround, checked out the spacecraft control system periodically, performed extended periods of drifting flight, took photographs of terrestrial features, and performed visual spacecraft yaw-alinement experiments. Pilot adherence to the flight plan was excellent, and his performance added confidence to the feasibility of future long-duration manned missions.

Retrofire was accomplished on time by the spacecraft clock and with the control system in the automatic mode. Spacecraft attitudes were excellent prior to and during retrofire. Computed data based on retrofire conditions indicated a normal spacecraft landing, and the prediction was transmitted to the recovery forces. All spacecraft events occurred on time during reentry, and the pilot actuated the drogue parachute near the 40 000-foot-altitude level as planned.

Recovery forces tracked the spacecraft by radar and visually sighted it during descent. The spacecraft landed approximately 4 nautical miles from the recovery aircraft carrier U. S. S. Kearsarge at 4:28 p. m., eastern standard time.

Helicopters from the aircraft carrier deployed swimmers who immediately installed the spacecraft auxiliary flotation collar as a precautionary measure. The carrier picked up the spacecraft with the pilot still inside 40 minutes after landing. Five minutes later, the pilot released the spacecraft hatch aboard the carrier and egressed in excellent condition.

INTRODUCTION

The third manned orbital mission of Project Mercury was successfully accomplished October 3, 1962, from the Missile Test Annex at Cape Canaveral,[1] Florida. This was the fifth orbital mission of a Mercury specification spacecraft and the eighth of a series of Mercury missions utilizing the Atlas launch vehicle. The mission was, therefore, designated as the Mercury-Atlas 8 (MA-8) mission. Walter M. Schirra, Jr. (figs. 1 and 2), was pilot of the spacecraft for the MA-8 mission. The data and information presented add to the data previously published (refs. 1, 2, and 3) on the first and second U. S. manned orbital missions.

The MA-8 mission was planned for six orbital passes, the ground tracks of which are shown in figure 3. The mission was a continuation of a program to acquire operational experience and information for extended manned orbital space flight. The objectives of the mission were to evaluate the performance of the man-spacecraft system in a six-pass orbital mission; to evaluate the effects of an extended orbital space flight on the pilot and to compare this analysis with those of previous missions and pilot-simulator programs; to obtain additional pilot evaluation of the operational suitability of the spacecraft and supporting systems for a manned orbital mission; to evaluate the performance of spacecraft systems replaced or modified as a result of the previous three-pass orbital missions; and to evaluate the performance of and further exercise the Mercury Worldwide Network and mission support forces and to establish their suitability for an extended manned orbital mission. All objectives were successfully accomplished.

Analyses of the significant data have 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 MA-8 mission are documented, beginning with delivery of the spacecraft to the launch site and continuing through recovery and postflight examinations.

The first public release of the MA-8 mission results was made (ref. 4) as a continuation of a NASA policy to provide the technical community-at-large with preliminary information at an early date. The detailed scientific and engineering analyses in this report therefore supersede and add to the information presented in cursory form in reference 4.

Lift-off time for the MA-8 mission was 07:15:11. 84 a. m. eastern standard time (e. s. t.), and all times in this document are given in ground elapsed time (g. e. t.) 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-8 report supports the text, a complete presentation of all MA-8 time-history data has been compiled for technical reference purposes.

[1]Since renamed Kennedy Space Center.

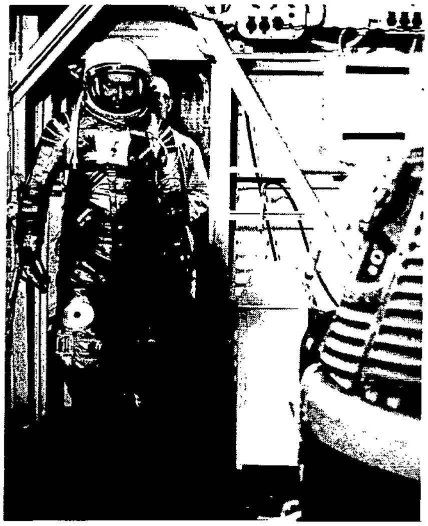


Figure 1. - Pilot Schirra prior to insertion into spacecraft.

Figure 2. - Pilot Schirra on the deck of the recovery aircraft carrier after the MA-8 mission.

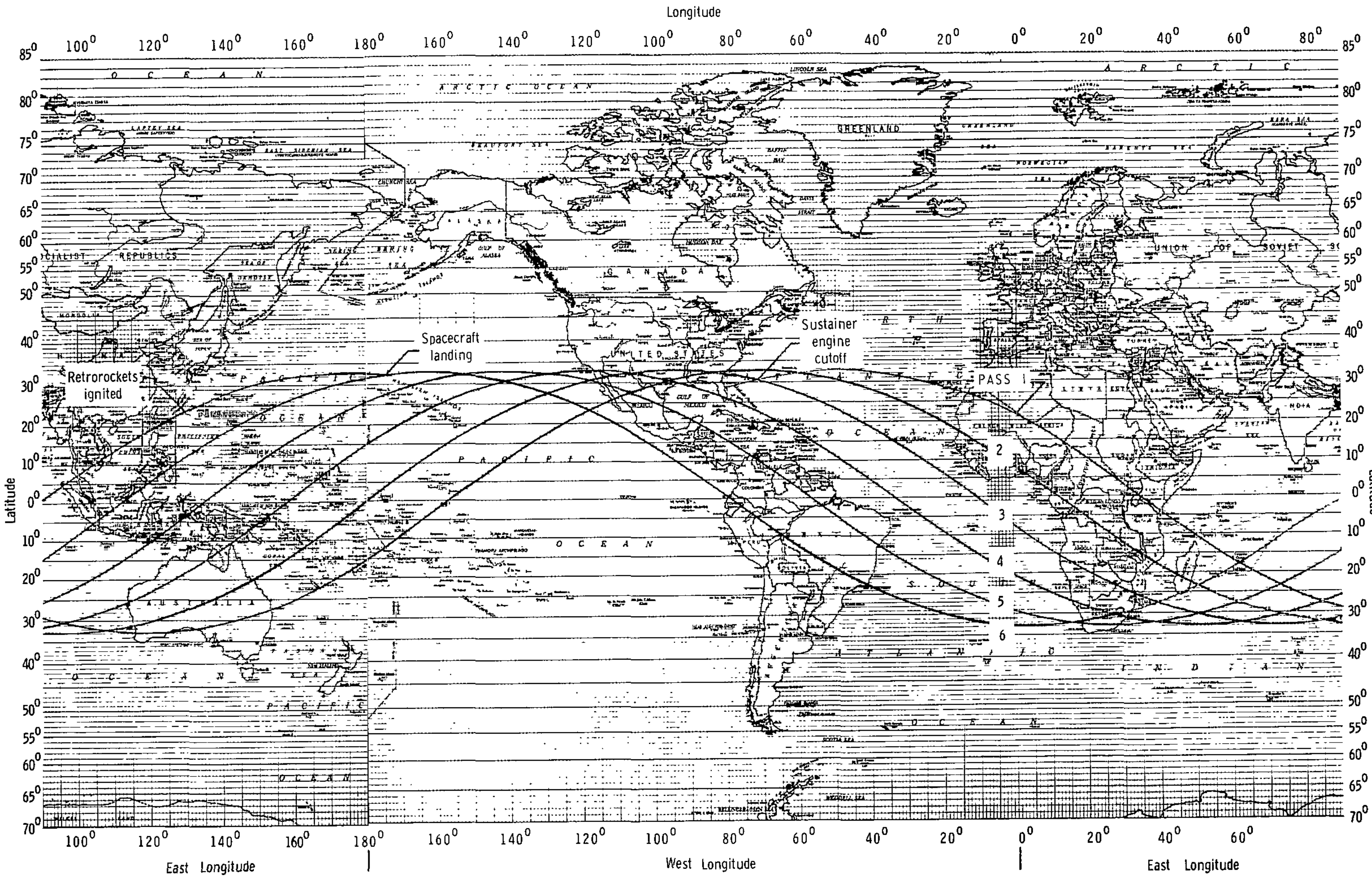


Figure 3. - Ground track for the MA-8 orbital mission.

SPACE-VEHICLE DESCRIPTION

The MA-8 space vehicle, consisting of a Mercury specification spacecraft and an Atlas D launch vehicle, is shown at lift-off in figure 4. The spacecraft and the launch vehicle used in the MA-8 orbital mission were very similar to those used in the MA-6 and MA-7 orbital missions. The MA-6 space vehicle is described in reference 1 and compared with the MA-7 space vehicle in reference 2. The more significant differences between the MA-8 and MA-7 vehicles are presented in the following paragraphs.

SPACECRAFT DESCRIPTION

Spacecraft 16 (fig. 5) was employed for the MA-8 orbital mission and was basically the same as spacecraft 18 utilized for the MA-7 mission (ref. 2). The reference axis system for the spacecraft is depicted in figure 6. However, a number of changes were made in the configuration to increase reliability, to save weight, to aid in fuel conservation, and to provide additional tape-recording capability. To provide a convenient reference, all of the changes are listed according to the major spacecraft subsystem.

Electrical and Sequential

1. The Zener diode package was removed.

2. The flashing recovery light was powered by a standby bus rather than by a separate battery.

3. A standby inverter position was added to the ac voltmeter selection knob.

4. The hold-power circuits were eliminated.

5. Postlanding cutoff circuits were made, independently of the squib bus power.

6. The auxiliary battery of the maximum-altitude sensor was removed, and the sensor was powered from the main 24-volt dc squib bus only.

7. The power source for automatic abort circuits (May-day relays) was changed from the isolated squib bus to the main squib bus.

8. Provision was made to assure that the launch-abort sequence was not disarmed before spacecraft separation from the launch vehicle.

9. An arm-disarm switch and bypass relay were added to the pyrotechnic part of the retrofire circuit.

10. The retroattitude telelight indication was changed to function during the retrosequence period.

11. The 21 000-foot barostats for drogue-parachute deployment were wired in series and powered from the main bus.

12. The 10 000-foot barostats for main-parachute deployment were wired in series and powered from the main bus, with an alternate source of power from the isolated bus.

13. The attitude-control, fuel-jettison, and main-parachute-disconnect fuses were changed to switch fuses.

14. The 6-, 12-, and 18-volt external-power diodes were removed from the spacecraft and incorporated into ground-support-equipment circuitry. The 6-, 12-, and 18-volt supplies for the spacecraft were monitored in the launch blockhouse.

15. Two of the four cabin floodlights were removed.

16. Provisions were made for more comprehensive testing of inverters during hangar checkout.

17. One series diode was added to each catastrophic-failure circuit from the launch-vehicle abort sensing control unit (ASCU).

18. The landing-system control barostat, located in the cabin for the MA-7 mission, was removed.

19. An arm-disarm switch and a 10 000-foot bypass were added to the pyrotechnic segment of the recovery system.

20. Panel switches for suit fans, control-system-mode select, and cabin lights were replaced with more reliable types.

21. The retrofire warning-light time-delay relay was changed from 20 to 15 seconds.

22. The sustainer-engine cutoff (SECO) signal was locked out of the spacecraft until tower separation. Previously, the spacecraft could accept a premature SECO signal immediately after separation from the launch vehicle.

23. The automatic retrojettison switch was changed to allow interruption of the squib circuits to the jettison bolt, retroumbilicals, and the new high-frequency (hf) antenna coaxial cutters.

24. The emergency reserve-parachute-deployment fuse switch, emergency landing-bag fuse switch, and periscope fuse switch were replaced with fuses.

25. Squib circuits were added to effect deployment of the hf orbital dipole antenna at 60 seconds after spacecraft separation from the launch vehicle.

Environmental Control System

1. A retainer pin was added to the bellcrank spring for the emergency-oxygen rate valve.

2. A maximum leakage rate of 600 cc/min for the spacecraft cabin was specified.

3. An additional 15 pounds of coolant water were added to the existing tank.

4. Instrumentation was revised to aid in monitoring cabin and suit heat-exchanger performance by replacing the heat-exchanger steam-vent-temperature measurements with heat-exchanger dome-temperature measurements.

5. Insulation was added to the suit environmental circuit.

6. The cabin-pressure relief valve was replaced with a type that did not include a mechanical lock in the closed position.

7. The four Freon check valves were replaced by a newer type.

8. Squibs were removed from the cabin inlet and outlet valves.

9. The suit-inlet hose was shortened from 38 to 18 inches.

10. The oxygen-supply transducer was changed from a 7500- to a 10 000-psia range.

11. The coolant-water pressure bottle was removed, and pressure was supplied by the suit or cabin.

12. A panel indicator was added to permit monitoring of cabin-oxygen partial pressure.

Automatic Stabilization and Control System

1. The operating band for the orbit mode of the automatic attitude control system was changed from 3.0° to 5.5° and the second pulse shortened to 0.075 second.

2. The cover for the pitch horizon scanner was modified to provide better thermal protection during the launch phase.

3. An attitude-select switch was added to permit normal automatic-control-system operation at 0°, 0°, 0° attitude.

4. Rate gyros were normally unpowered during automatic orbit-mode operation until 10 minutes prior to retrofire, but a switch was added to power rate gyros during orbit-mode operation at the discretion of the pilot.

Reaction Control System

1. A high-thruster arm-disarm switch was added to the fly-by-wire (FBW) mode with automatic enable at retrofire.

2. A thruster-solenoid current monitor was added to aid malfunction detection.

3. Improved nitrogen and hydrogen peroxide relief valves were incorporated.

4. The fuel-warning switch was replaced with an improved type.

5. A modification was made to prevent premature hydrogen peroxide jettison as a result of a single-point failure.

6. All thruster heat sinks were removed.

Instrumentation System

1. The pilot-observer camera slow-frame-speed mode was deleted.

2. The vernier clock and the mixing of events on the clock channel were deleted.

3. The oxygen-flow sensors were removed.

4. The Z-calibration for horizon-scanner output was deleted.

5. The R- and Z-calibrations for the respiration sensor were deleted.

6. The lip transducer was changed to a chest impedance pneumograph for respiration sensing.

7. Time-since-retrofire instrumentation was added, and the integrating accelerometer and 4- and 8-minute timers were deleted.

8. Magnetic recording tape was changed to a thin-base type to provide an 11-hour total recording capability.

9. A temperature-survey indicator and a 12-position rotary switch were added to monitor seven hydrogen peroxide B-nut temperatures, the cabin heat-exchanger air outlet temperature, three inverter temperatures, and the right retrorocket temperature.

10. A boresight yaw-navigation device was added.

11. Two Goddard radiation packs were substituted for two of the four standard Schaeffer radiation packs.

12. An automatic 5-second hold provision was added to the blood-pressure measuring system (BPMS) start-button circuitry.

13. A switch was added to the cutoff correlation-clock edge lighting.

14. The BPMS assembly was located on the spacecraft structure rather than on the leg restraint.

15. The BPMS cuff hose incorporated a right-angle adapter.

16. The cabin-pressure audio-tone warning and tone switch were removed (cabin-pressure switch and warning light remaining).

Communications System

1. One command receiver-decoder was removed, and the remaining receiver-decoder was powered from the standby bus.

2. The hf orbital voice transmitter-receiver was rewired to operate after landing.

3. The hf rescue voice transmitter-receiver was removed.

4. An hf dipole antenna was installed on the retropackage.

5. An antenna switch was added to permit selection of either dipole, bicone, or whip antenna for hf voice.

6. Improved microphones were installed in the pilot's helmet.

7. An extension cord was added to allow operation of the spacecraft communications system from outside the spacecraft after landing.

8. Shielding was added to the audio center to eliminate interference from the auxiliary rescue, search and rescue and homing (SARAH), beacon.

9. A hand-held voice transceiver was added to the survival kit.

Mechanical and Pyrotechnic Systems

1. The retrorocket heater blankets were removed.

2. The sound fixing and ranging (SOFAR) bomb (2500 feet) was added to the main-parachute riser.

3. Dye markers were added to the antenna canister to aid in postflight recovery of the canister.

Heat Protection System

1. The heat-shield center plug was bolted to the heat-shield structural laminate to retard warping upon landing.

2. Experimental ablation samples were bonded and thermocouples added to the beryllium shingles.

3. A triangular, three-color paint patch was added to the spacecraft exterior for postflight thermal evaluation of the paint samples.

4. A rectangular white-painted patch was added to the spacecraft to evaluate the effect on spacecraft shingle temperatures.

Personal Equipment

1. The Polaroid window filter was removed.

2. Leg restraints were deleted; and knee, heel, and toe supports were added.

The weight and balance data for spacecraft 16, according to actual flight usages, are summarized in table I.

LAUNCH-VEHICLE DESCRIPTION

The MA-8 launch vehicle, an Atlas 113 series D (113-D) missile, was modified (as on previous Mercury-Atlas missions) for the mission.

The Atlas 113-D launch vehicle underwent no major modifications for the MA-8 mission. A summary of minor configuration changes from the MA-7 launch vehicle, the Atlas 107-D (ref. 2), follows.

1. The fuel-tank insulation bulkhead was removed at the factory.

2. Baffled injectors were installed in the two booster-engine thrust chambers for improved combustion characteristics (fig. 7).

3. At ignition, the booster engines were started by hypergolic instead of pyrotechnic igniters (fig. 8).

4. No hold-down delay was programed between main-engine completion and start of the release sequence because of the expected improvement in combustion characteristics resulting from the use of baffled injectors.

5. The programer staging backup time was changed from T + 136 to T + 132.3 seconds.

6. Closed-loop guidance steering was planned to start at 24 instead of 25 seconds after booster-engine cutoff (BECO).

7. Sustainer pitch-program time duration was planned for 16.5 instead of 20 seconds.

8. The range-safety command receivers had circuit changes to eliminate the possibility of initiating an inadvertent destruct signal should power to the receivers be momentarily interrupted during external-internal power switching.

9. The rough combustion cutoff (RCC) capability was removed, but the RCC monitoring instrumentation was retained.

10. A redundant head-suppression solenoid control circuit was incorporated in the engine-relay box to improve reliability.

11. The hydraulic instrumentation and sensing lines for the abort sensing and implementation system (ASIS) in the thrust section were rerouted, and the insultation was improved to prevent possible freezing in the cryogenic environment.

12. The telemetry package was modified to include instrumentation for improved temperature measurement in the boattail area.

TABLE I. - SPACECRAFT 16 WEIGHT AND BALANCE DATA

Mission phase	Parameter						
	Weight, lb	Center-of-gravity station, in.			Moment of inertia, slug-ft^2		
		X	Y	Z	I_Z	I_X	I_Y
Launch	4324.55	167.97	-0.13	-0.11	353.2	7865.9	7872.9
Orbit	3028.89	121.03	-.20	-.07	286.8	650.7	659.0
Normal reentry	2732.50	124.45	-.23	.02	275.3	571.6	578.8
Main-parachute deployment	2602.32	122.24	-.18	.14	271.1	459.0	466.3
Flotation	2441.43	119.63	-.52	.05	264.0	386.2	390.5

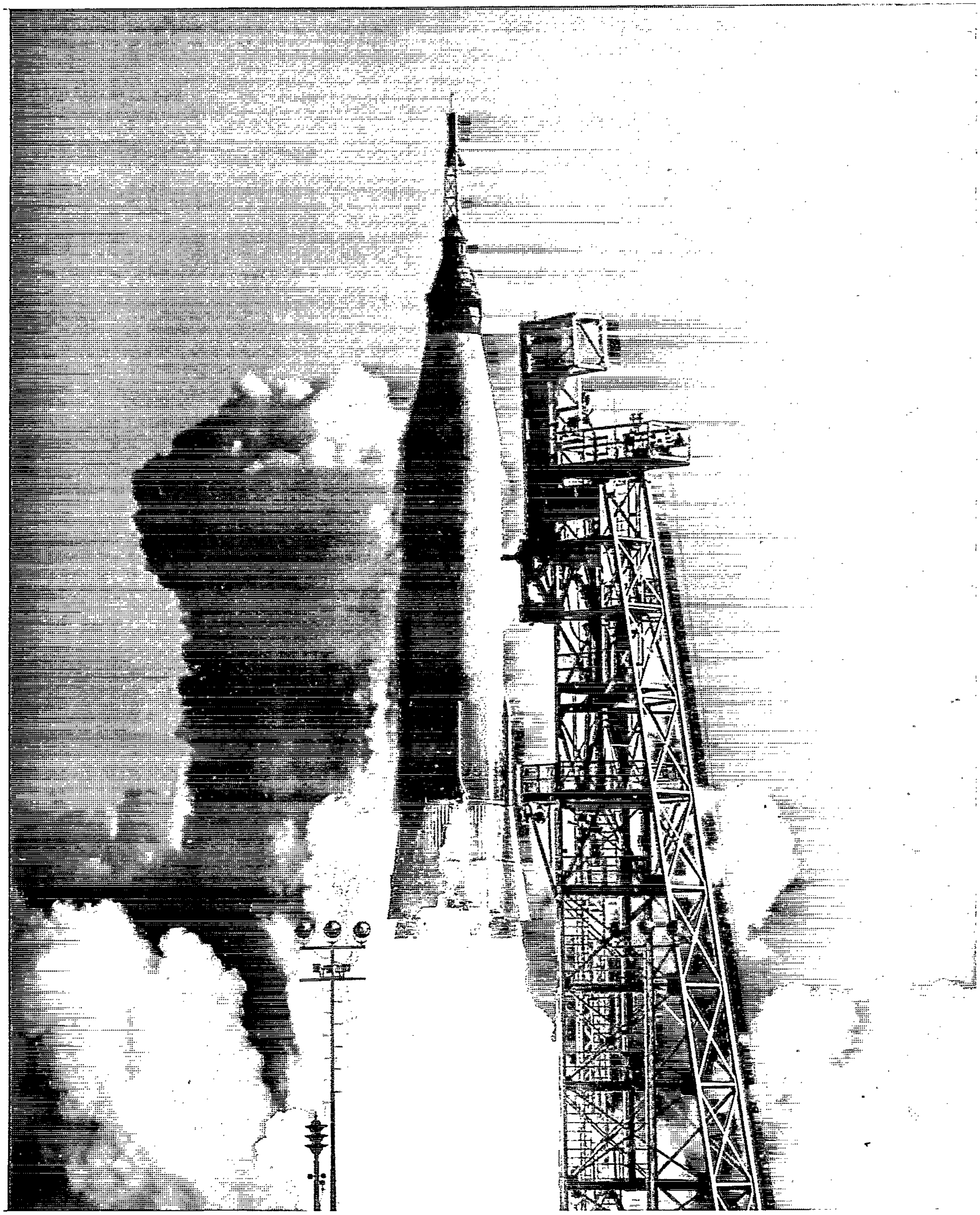


Figure 4.- MA-8 lift-off configuration.

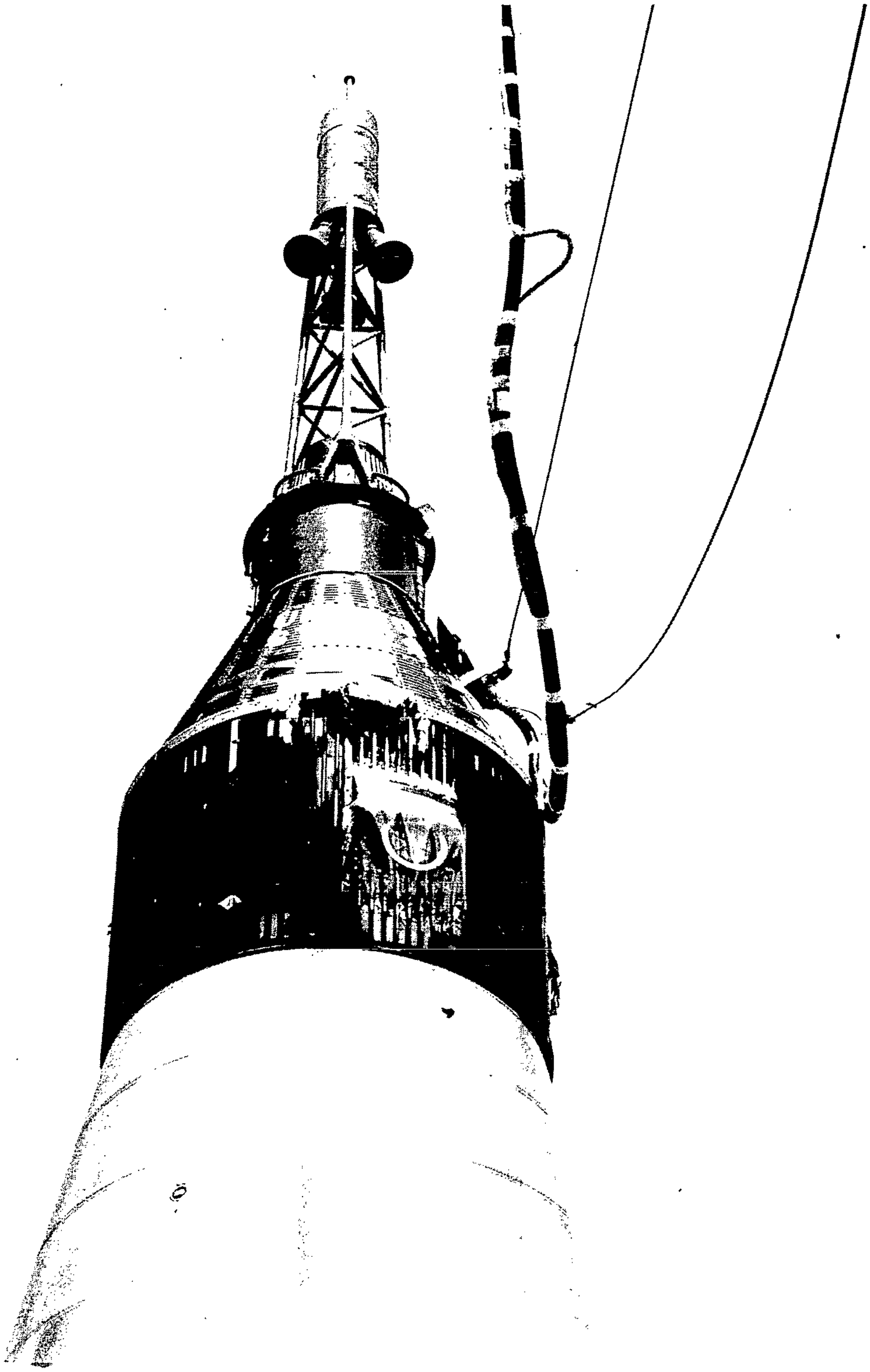


Figure 5. - MA-8 spacecraft and adapter prior to lift-off.

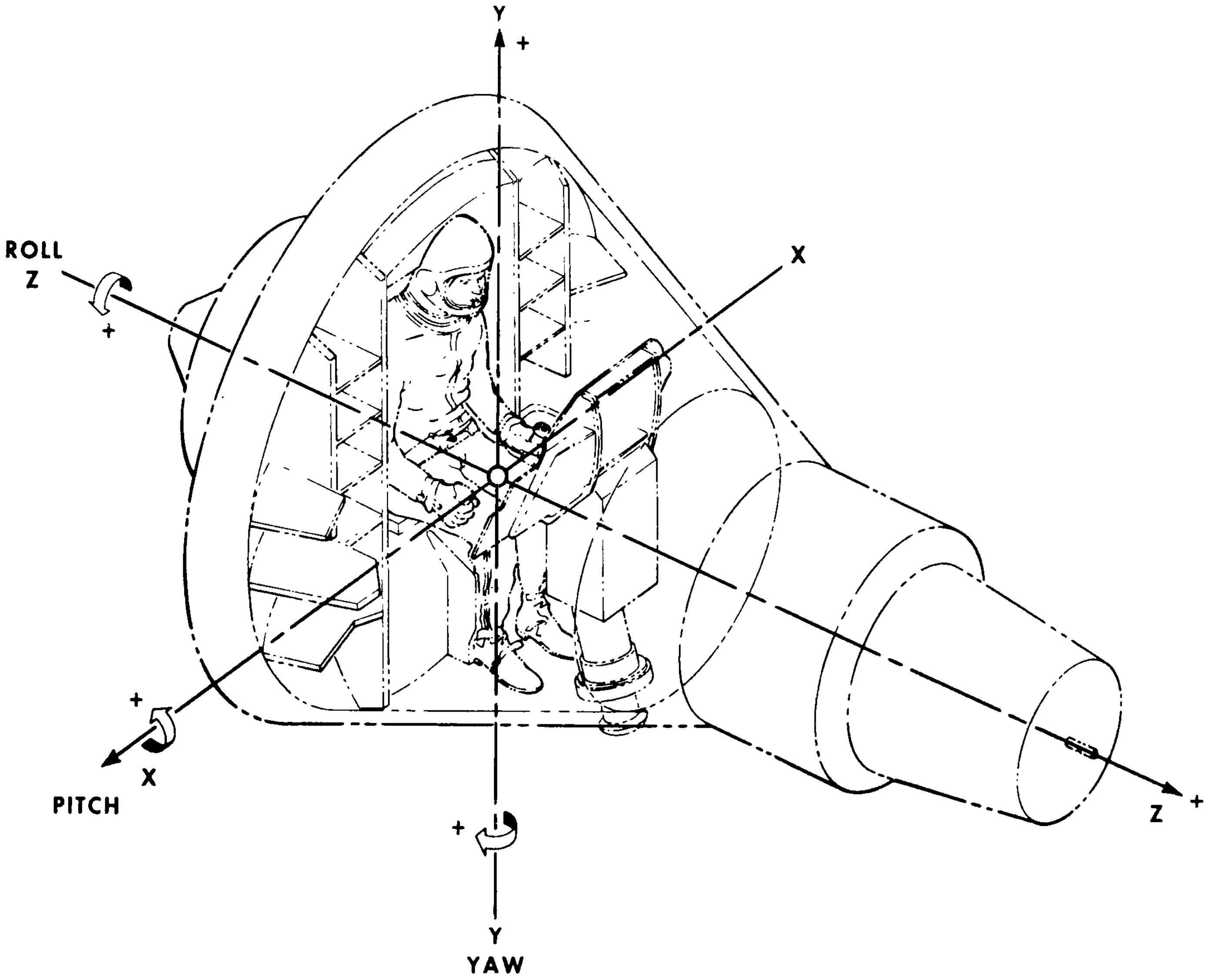


Figure 6. - MA-8 spacecraft axis diagram.

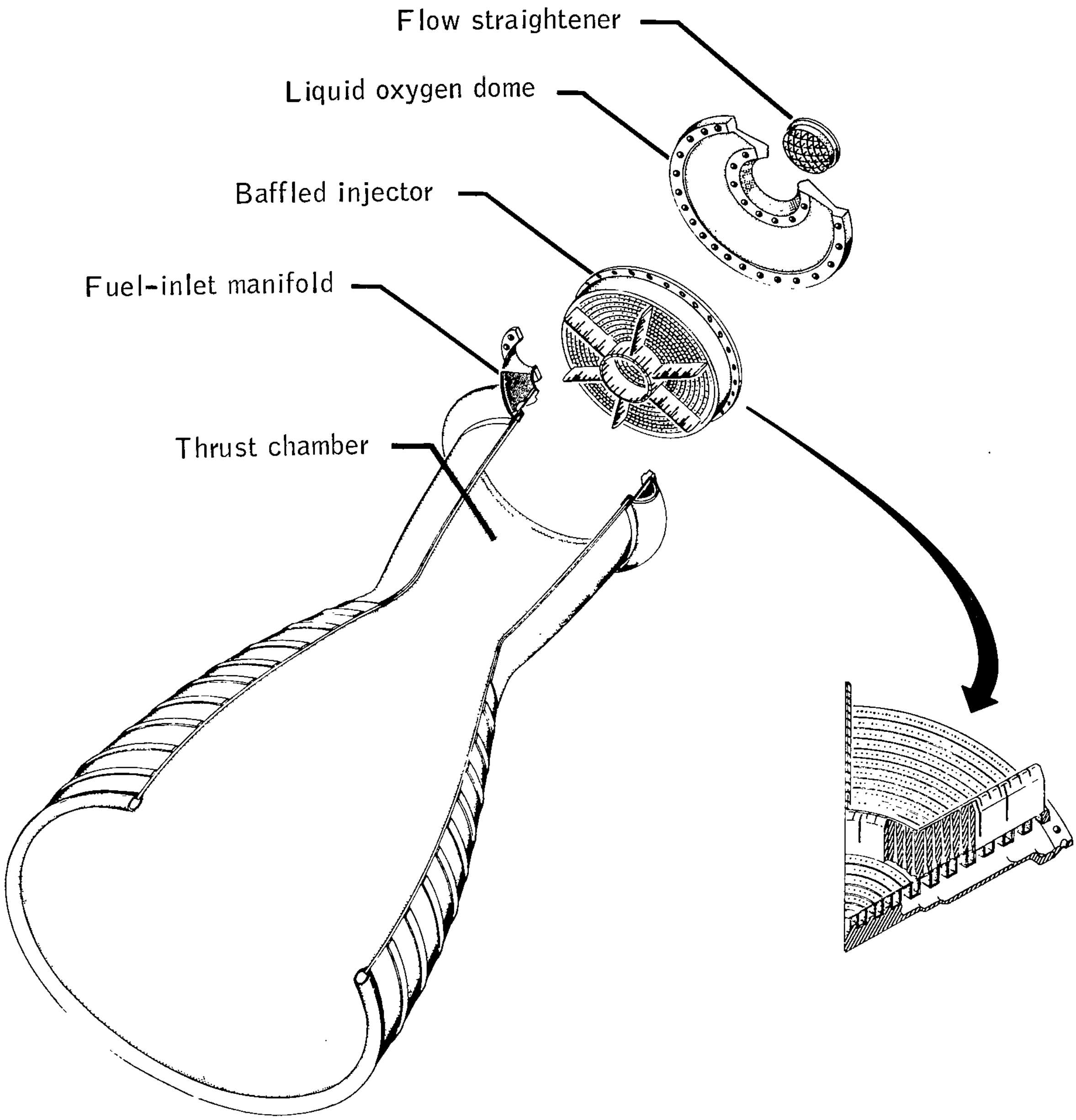
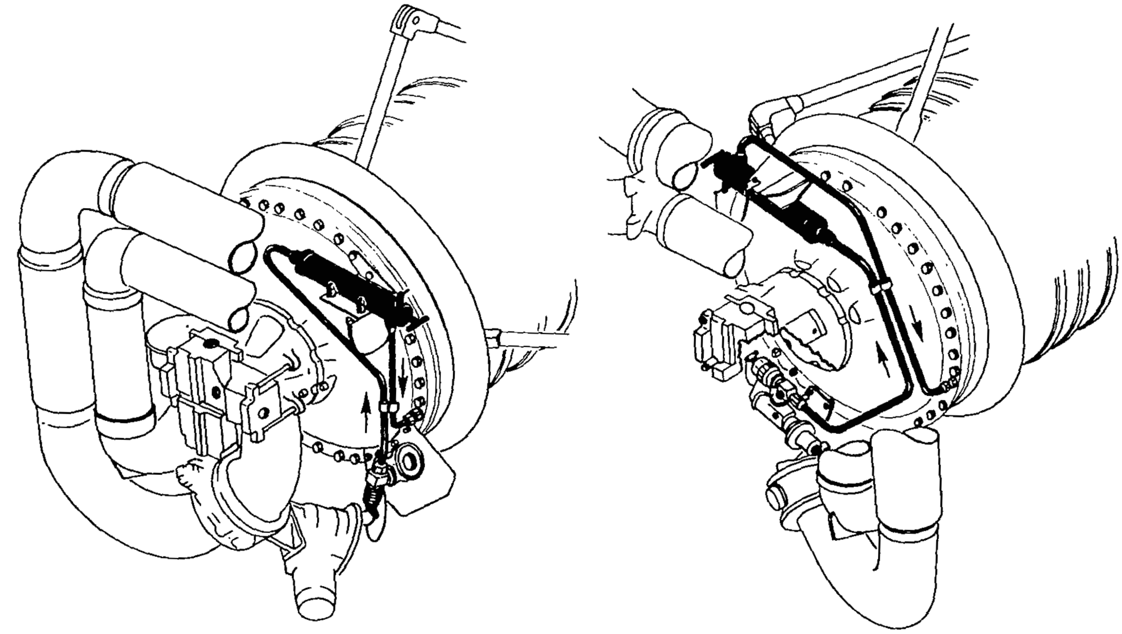
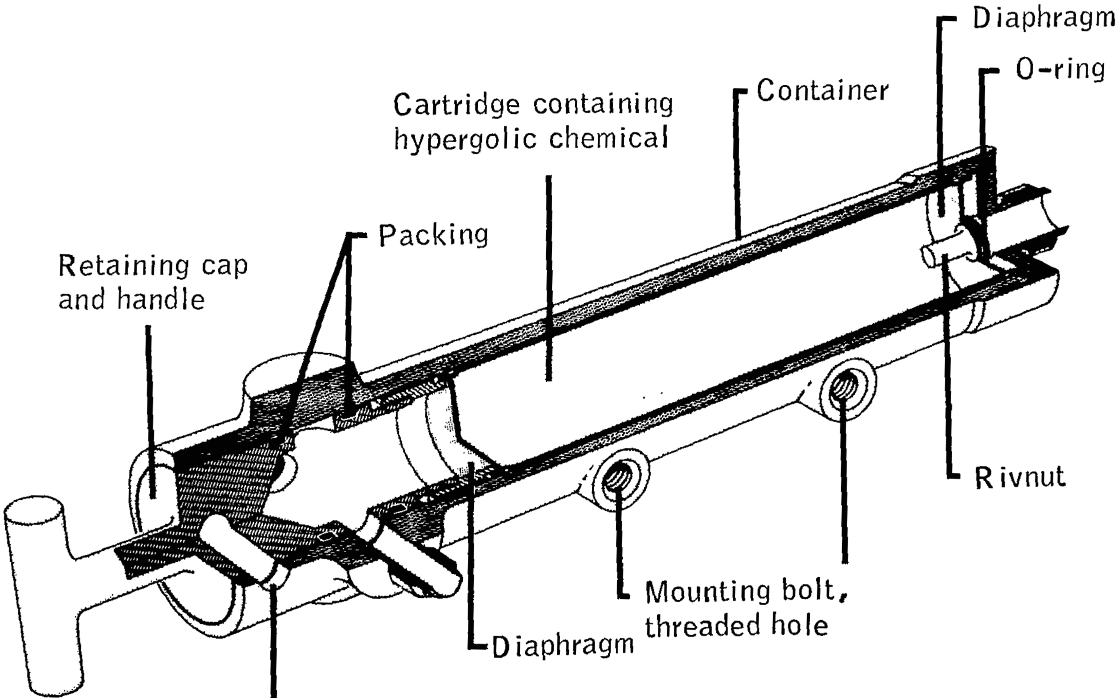


Figure 7. - Booster-engine baffled injector.



(a) Igniter locations.



(b) Igniter configuration.

Figure 8. - Booster-engine hypergolic igniter.

MISSION OPERATIONS

The various ground operations required to support a Mercury orbital mission were grouped according to appropriate mission phases, that is, prelaunch, launch, orbital flight, and recovery. The prelaunch operations included preparations necessary to bring the pilot, spacecraft, launch-vehicle, and ground-support personnel up to flight-ready status. The launch operations commenced with the countdown, when all flight systems and flight-control stations were checked for readiness, and concluded with insertion of the spacecraft into its orbital trajectory. The orbital phase of the mission entailed the flight-monitoring and data-acquisition operations of personnel stationed along the Mercury Worldwide Network. The recovery operations began when a landing point was predicted by appropriate network stations and involved 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 consisted of training the pilot for a specific flight, conducting preparations at the launch site for the spacecraft and the launch vehicle, and conducting flight-safety reviews. Although each pilot had received training after his introduction into Project Mercury, special training was required for the mission involved. The training involved participation in a series of mission simulations to present realistic operational situations which required assessment and action. The simulations were often conducted in conjunction with the detailed checkout operations for the spacecraft, launch vehicle, and the Mercury Worldwide Network.

Program-management personnel attended 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 pilot safety throughout the mission. The following paragraphs outline the operations required for prelaunch.

Pilot Training

The pilot-training program for Project Mercury was divided into six basic categories which were essentially dependent on the training devices used. The categories were academics, static training, environmental familiarization, dynamic training, egress and survival training, and specific mission training. The first five categories were discussed briefly in the report on the MA-6 mission (ref. 1). A discussion about specific training for the MA-8 mission follows.

Preflight operations schedule. - During the preflight preparation period, the MA-8 pilot was involved in a diversity of activities which often required considerable travel and resulted in a crowded schedule. The pilot spent a large portion of his time in briefings and meetings concerning every aspect of the mission, but managed to complete such training requirements as recovery training, survival-pack exercises, acceleration refamiliarization on the centrifuge, and review of the celestial sphere at the

Morehead Planetarium. Table II summarizes all preflight activities of major importance in which the MA-8 pilot participated.

Spacecraft checkout activities. - Participation in the spacecraft preflight activities enabled the pilot to become familiar with the MA-8 spacecraft and launch-vehicle systems. In particular, the involvement of the pilot in the activities permitted the pilot to manipulate and evaluate his flight equipment, along with the various systems and switching-procedure modifications peculiar to the MA-8 spacecraft. The checkout activities, along with other events, are listed in table II. The pilot spent 31 hours 27 minutes in the spacecraft and many additional hours before and after each checkout operation in preparation, observation, troubleshooting, and discussion. In addition, the pilot spent approximately 45 hours in the MA-7 spacecraft, which added to his general knowledge of the Mercury spacecraft and launch-vehicle systems.

Training activities. - An important area of pilot-preparation training was to maintain proficiency in high-performance fighter aircraft, since the pilot must make rapid and accurate decisions under true operational conditions. Aerial flights complemented static trainers by emphasizing the need and consequences of decisions, which kept the pilot alert and aware of the operational mission requirements. The pilot logged approximately 30 hours during the period from August 11, 1962, to 4 days prior to the mission.

The pilot received three series of formal systems briefings which were oriented to the operational requirements of the mission. In addition, the pilot spent many more hours with various systems and operations specialists to establish mission operational procedures. The pilot spent more than 100 hours in reviewing spacecraft systems during the last 2 months of his preflight preparation period.

Table III summarizes the training activities in the Cape Canaveral procedures trainer from August 20 to October 1, 1962. The table does not include the 28 hours spent in the Cape Canaveral procedures trainer during the MA-7 preflight period, or the 8 hours spent in the Langley Research Center procedures trainer during June 1962 to practice manual control of the reentry-rate oscillations and to evaluate flight-plan control tasks. During the MA-8 training period at Cape Canaveral, the pilot spent 29 hours 15 minutes in the trainer accomplishing 37 fast-time simulated missions, 40 simulated turnaround maneuvers, and 68 simulated retrofires and experiencing 68 simulated failures of spacecraft systems. The pilot consumed almost as much time in the briefing and debriefing periods associated with each formal training session as was spent during training.

The main emphasis during the simulations was on the basic operational aspects of the mission because of their relative importance and because the procedures trainer was best equipped to accomplish these requirements. The pilot, therefore, spent the majority of his time during the sessions on the detection and correction of systems failures, on mission anomalies which usually require an abort during the launch phase of the mission, and on overall systems monitoring and management. Also, the pilot devoted a few sessions to attitude control, control-mode switching, maneuvering flight, and other inflight activities specified in the flight plan. The pilot also participated in several launch-abort and network simulations during which the mission rules were rehearsed and discussed.

Training analysis. - The pilot achieved a high level of skill in the procedures trainer in performing such maneuvers as the turnaround and retrofire maneuvers. Use of the transparent gyro simulator and an understanding of the spacecraft control systems and their operation prepared him for inflight activities such as control-mode switching, flight maneuvering using external reference, and the gyro-realinement procedures that cannot be meaningfully simulated in the procedures trainer.

Pilot preflight preparation included familiarization with emergency procedures, responses to mission anomalies, and egress and recovery procedures. Since the mission proceeded normally, evaluation of the effectiveness of these training activities under actual emergency conditions was not possible. However, the pilot reported during postflight briefings that he believed his preparation in these areas was adequate. A training activity which could not be accomplished during the final preparation period was manual control and damping of simulated reentry-rate oscillations. The pilot had practiced the maneuver on the Langley procedures trainer during June, prior to relocation of the trainer at Houston, Texas. However, the pilot would be required to damp the reentry-rate oscillation manually only if both the auxiliary damping and rate-command systems failed. The pilot reported during debriefing that practice in damping reentry-rate oscillations just before the mission would have been desirable, but the procedures trainer at Cape Canaveral had not been mechanized in time for reentry simulations.

The pilot exerted maximum effort in learning the various spacecraft systems and flight hardware. Particular concentration was placed on resolving the best procedures for smoothly accomplishing maneuvering flight and control-mode switching with minimum fuel usage. The approach of the pilot in preparing for the mission was to practice the activities in the trainers and in the spacecraft only after he thoroughly knew each system and its operation. The practice permitted the pilot to make rapid progress in preparing for the mission with a minimum of time spent in the procedures trainer and in the spacecraft.

As a result of experience gained from previous Mercury missions, the pilot was able to prepare for the mission in a more efficient manner. Consequently, the flight plan was more flexible and was finalized at an earlier date, operational requirements were emphasized, and the number of last-minute flight requirements was reduced. Thus, the pilot had additional time to become more familiar with the spacecraft and launch-vehicle systems.

Spacecraft Prelaunch Preparation

Prelaunch preparations for spacecraft 16 were basically the same as the preparations for spacecraft 13 and 18 used in the MA-6 and MA-7 missions, respectively. These preparations are described in the MA-6 mission report (ref. 1). Major changes and modifications made on spacecraft 16 prior to launch are presented chronologically in the following spacecraft history.

Spacecraft History

Spacecraft 16 arrived at hangar S, Cape Canaveral, January 16, 1962. Preparation activities for the spacecraft and the onboard systems consisted of final installations, systems checkouts, and configuration changes. Actual work days in the hangar totaled 185 days which included 43 days spent on tests, but which did not include 4.5 days that the spacecraft was returned to the hangar during launch-pad operations. There were 691 mission preparation sheets, which authorized required work, and 481 discrepancy reports, which described items that required rework, as of September 28, 1962.

The spacecraft was transported to the launch site September 10, 1962, but was returned to the hangar September 21 for replacement of the reaction control system (RCS) manual-system selector valve as a result of high pull forces and subsequent leakage encountered during prelaunch tests. RCS tests, normally performed 4 days prior to launch at the launch complex, were performed in the hangar S RCS cell following the valve change. The spacecraft was returned to the launch complex and remated to the launch vehicle September 26, 1962.

The prelaunch tests performed, major changes, and preflight events in the history of spacecraft 16 at Cape Canaveral are shown chronologically in table IV.

Launch-Vehicle Preparation

Prelaunch preparations for the Atlas 113-D launch vehicle were basically the same as those for the Atlas 107-D and 109-D launch vehicles, which were used in the MA-7 and MA-6 missions, respectively. The preparations are described in the MA-6 mission report (ref. 1).

Flight-Safety Reviews

Flight-safety and mission review meetings were held to determine the flightworthiness of the spacecraft and launch vehicle and to ascertain the readiness of all supporting elements for the MA-8 mission.

Spacecraft. - Two spacecraft 16 review meetings were conducted. The first meeting was held September 20, 1962, to discuss spacecraft history while at the Atlantic Missile Range (AMR) and the corresponding status of the spacecraft systems. A faulty manual-system selector valve in the RCS was discovered September 21, 1962. In order to replace the valve, the spacecraft was demated and returned to hangar S. The subsequent mating with the launch vehicle was conducted September 26, 1962. The second review meeting was held September 28, 1962. All systems were approved as ready for flight, pending the successful completion of the final simulated flight test, which was satisfactorily completed the following day.

Launch vehicle. - Two meetings were held to determine the status of the Atlas 113-D launch vehicle. The first meeting was conducted September 27, 1962, to brief NASA Manned Spacecraft Center (MSC) management regarding the decision to off-load liquid oxygen and fuel in an amount equivalent to that previously consumed during the 2-second hold-down at launch. If the launch vehicle was not off-loaded, an indefinite combination of regulator action and ullage volume could cause an undesirable longitudinal oscillation near lift-off, which might compromise the structural integrity of the intermediate bulkhead. The amount of off-loaded propellant only reduced the extra fuel margin at SECO and did not affect the orbital-insertion probability.

The second meeting, which was termed the Booster Review, was held September 28, 1962, and launch-vehicle systems were approved ready for flight, pending successful completion of the simulated flight previously noted.

Mission. - The MA-8 mission review meeting was held September 30, 1962. All elements of the flight were adjudged to be ready. The X - 1-day Flight-Safety Review Board met October 2, 1962. The board was advised that the Status Review Board had met at 8:30 a. m. that morning and had determined the launch vehicle to be ready for flight. The Flight-Safety Review Board then approved both the spacecraft and launch vehicle for flight.

LAUNCH OPERATIONS

The launch operations discussed in the following paragraphs include the launch procedure, weather conditions, and photographic coverage. The section on "Launch Procedure" 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 and Pacific recovery areas. The photographic section presents a summary of the launch-site photographic coverage 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 560-minute split countdown with a scheduled 17.5-hour hold at T - 390 minutes for spacecraft RCS fuel and pyrotechnic servicing. To provide additional assurance that the projected launch time of 7:00 a.m. e.s.t., October 3, 1962, could be met, a 90-minute built-in hold was scheduled at T - 140 minutes.

The second half of the split countdown was started at 11:00 p.m. e.s.t., October 2, 1962. Launch occurred at 07:15:11 a.m. e.s.t., October 3, 1962, after one hold of 15-minute duration at T - 45 minutes. The sequence of major events which occurred in the minutes of countdown are as follows:

Start of second half of countdown	T - 390
Pilot insertion into the spacecraft	T - 140
Spacecraft hatch closure started	T - 108
Spacecraft hatch secured, shingle installation started	T - 96

Spacecraft shingle installation complete	T - 88
Service tower (gantry) removal started	T - 64
Hold to repair Canary Islands radar	T - 45
Liquid oxygen pumping started	T - 38
Liquid oxygen overfill probe reached	T - 20
Liquid oxygen topping at 2500 pounds below overfill	T - 14
Launch	T - 0

Weather Conditions

Weather conditions in the launch area were satisfactory for operations several days prior to and on the day of the launch. However, several tropical storms caused some concern because of their proximity to planned recovery areas. On the day prior to scheduled launch, Atlantic recovery area 3-1 (section on "Recovery Operations") was shifted 213 nautical miles down the orbital path in a southeasterly direction because of tropical storm Daisy. On launch day, Daisy was located about 400 miles north-northeast of Puerto Rico at approximately longitude 24.5° N latitude 67.5° W, which was between recovery areas 3-1 and 4-1. These recovery areas were planned to be used only in the event of a contingency; therefore, the probability of their use was sufficiently low to justify assuming the risk of the remotely located storm.

In the Pacific, Typhoon Emma was located 750 miles east-southeast of the Pacific Command ship. In addition, Typhoon Frieda was forming 500 miles east of Guam. Simultaneously, Typhoon Dinah, which had been of some concern earlier, had moved into the vicinity of Hong Kong and was far removed from the orbital ground track. At recovery time, there were no disturbances in the planned end-of-mission recovery area 6-1.

Weather observations at the launch site at launch time (taken at 7:17 a.m. e.s.t.) were as follows:

Total cloud cover[a] (horizon to horizon)	5/10
Wind direction	From 150° (SSE)
Wind velocity, knots	2
Visibility, miles	10

[a]The cloud cover consisted of high cirrus clouds at 30 000 feet, some low cumulus clouds with a base at 2200 feet, and some strato-cumulus clouds with a base at 4500 feet on the eastern horizon.

Pressure, sea level, in. Hg	29.99
Temperature, °F	80
Dewpoint, °F	75
Wet bulb temperature, °F	76.3
Relative humidity, percent	85

A plot of the launch-site wind direction and velocity for altitudes up to 60 000 feet is shown in figure 9.

Weather conditions in the planned terminal landing area (recovery area 6-1) were reported at the time of recovery from the aircraft carrier U.S.S. Kearsarge as follows:

Cloud cover[a] (horizon to horizon)	6/10
Wave height, ft	3
Wind velocity, knots	11
Wind direction	110° (ESE)
Sea direction	90° (E)
Visibility, miles	10
Temperature, °F	78
Pressure, sea level, in. Hg	30.15
Wet bulb temperature, °F	71
Dewpoint, °F	75.5
Relative humidity, percent	92
Water temperature, °F	80

[a]The cloud cover consisted of cumulus clouds with a base at 3000 feet and altocumulus clouds at 14 000 feet.

Photographic Coverage

Photographic coverage obtained by the AMR facilities, including quantity of instrumentation committed and data obtained during the launch phase, is shown in table V.

Additional coverage was obtained by the recovery forces at the landing site. Launch-phase photographic coverage was good, and adequate data were available for a detailed photographic evaluation had it been necessary. Coverage of the mission in other respects was also good. The photographic coverage discussed in the following sections was based on film available for evaluation during the postlaunch reporting period.

Metric film. - Metric film from 15 cameras was processed, and the results were tabulated by the AMR. The data were not required for evaluation by NASA MSC, since the power-flight phase was normal.

Engineering sequential film. - Engineering sequential coverage of the launch phase is shown in figure 10, which indicates the time interval when either the launch vehicle or the exhaust flame under reduced visibility was visible to the tracking camera. Optimum coverage was achieved as a result of good weather conditions at the launch site. Fifteen films were reviewed, including 16- and 35-mm film from four fixed cameras and 11 tracking cameras. Fixed-camera coverage with respect to exposure, focus, and film quality was good. Two fixed cameras indicated normal liquid oxygen (lox) boiloff, umbilical disconnect, periscope retraction, and umbilical-door closure. The two other fixed cameras were positioned to show any spacecraft and launch-vehicle displacement prior to lift-off. The quality of the tracking-camera coverage was good, with the exception of two items which were slightly underexposed and three items which were grainy. Six tracking cameras showed launch-vehicle ignition and lift-off. All tracking cameras indicated normal launch-vehicle staging and tower separation. Three of the tracking camera films which were reviewed indicated an irregular launch-vehicle roll rate and rapid vernier engine gimbaling at lift-off. Refer to the section on "Launch-Vehicle Performance" for details of these irregularities.

Documentary film. - Documentary coverage used for engineering evaluation of the mission was provided by 16- and 35-mm motion picture film and 8- by 10-inch still photographs. Four aerial motion picture films of the launch sequence were received. One aerial motion picture camera tracked the space vehicle from lift-off through staging. The film showed excellent tracking, focus, and film exposure, but was inadequate for detailed evaluation because of camera vibration which produced a blurred image. The remaining three aerial films recorded no usable data. A film copy of the Boston University television coverage, as recorded at Patrick Air Force Base, was reviewed and indicated good tracking from after lift-off through tower separation. A large image size was maintained, but quality was restricted by the limitations imposed in reproducing from television tape to photographic film. One motion picture film of recovery operations was available for review. The film showed aerial and shipboard coverage of the spacecraft while on the main parachute, the spacecraft landing in the water, pararescue personnel activities in the water, spacecraft retrieval from the water by the recovery aircraft carrier, removal of the spacecraft hatch, pilot egress from the spacecraft, and shipboard coverage of the pilot during his physical examination.

Documentary coverage of the mission by still photography was good in both quality and quantity. Still photographs of prelaunch activities included views of pilot preparation at hangar S, insertion of the pilot into the spacecraft, and securing for launch. Also included were prelaunch photographs of the spacecraft, separately and mated with the launch vehicle. Flight and recovery coverage provided several views of the launch sequence, views showing the spacecraft and recovery personnel in the water before retrieval by the recovery ship, the spacecraft on board the carrier after pickup, removal of the hatch, pilot egress, physical examination of the pilot, and closeup views of the spacecraft after recovery. Also available were numerous engineering still photographs showing closeup views of the spacecraft during the postflight inspection at the launch site.

FLIGHT-CONTROL OPERATIONS

The preparation of the flight-control team and the Mercury Worldwide Network followed the same procedure used for the MA-6 and MA-7 manned orbital missions. Simulations carried out prior to the mission were considered to be one of the most important steps in the preparation of the flight controllers and the pilot for the mission, particularly in view of the extended mission duration intended for the MA-8 mission. The process of flight-control simulation and support preparation was essential to the safety of the mission.

Prelaunch Period

Network operations began September 14, 1962. Flight-control teams were cleared for departure to their respective network stations between September 14 and 18. The flight-control team to staff the Mercury Control Center was on station September 17, 1962.

Command signal tests at remote sites and preparations for launch simulations were performed September 18 and 19, 1962. Ten launch simulations were performed with the mission pilots while exercising the Mercury Control Center and Bermuda flight-control teams. A series of MA-8 mission reentry simulations was performed September 20, 1962. The simulations involved the Canton, Hawaii, California, and Guaymas stations; the Mercury Control Center; and the Goddard Computing and Communications Center. The simulations were conducted to familiarize appropriate network stations with reentry-decision techniques when faced with various spacecraft problems. A network simulation was performed September 22, 1962, which began with a full launch countdown and continued in real time (actual time intervals) from lift-off to 3 hours 20 minutes elapsed time. The computers were fast timed from that point until 7 hours 10 minutes, and the mission simulation then continued in real time until termination during the sixth orbital pass. The fast-time procedure was utilized for all of the six-pass orbital simulations. Additional six-pass mission simulations were performed September 28 and October 1, 1962.

Approximately 50 percent of the network flight controllers had never participated in a Mercury mission. The Kano, Zanzibar, and Woomera stations were staffed entirely by new capsule communicators (Cap Coms) and systems monitors. The majority of the remaining stations had at least one new flight controller. The Texas site was again, as in the MA-7 mission, used as a training facility for the MA-8 mission, and three new flight controllers were trained at the site.

The documentation for the mission was good. A total of 24 instrumentation support instructions were generated during the prelaunch preparation period, which was a significant reduction over those required for previous missions. The majority of the documentation required only one revision during the prelaunch period. The spacecraft configuration and flight plan were firmly fixed several weeks prior to launch; and only minor changes were made to the data-acquisition plan, countdown, and flight plan. A major revision was written for the mission rules (primarily concerning the Bermuda Mercury Control Center Standard Operations Procedures) for the use of command remoting functions. The contractor document, which contained the spacecraft systems schematics used by flight controllers, was also revised.

Launch Phase

The launch and network countdowns proceeded smoothly, and no major discrepancies were noted. The confidence summaries transmitted by the network to verify site calibrations were good. No major discrepancies were noted in network voice communications, although stations affected by the day-night frequency transition were not as good as had been experienced during previous missions.

At approximately T - 45 minutes, a 15-minute hold was instituted for repairs to the Canary Islands radar equipment. After the countdown was resumed, it was continued without further holds. Minor calibration discrepancies between pilot and telemetry readouts were reported from the blockhouse and were noted on the meters in the Mercury Control Center. Messages were sent to network stations advising them of the calibration changes.

Powered flight was normal, although air-to-ground (A/G) communications were poor to unreadable at the launch-vehicle staging. The communications rapidly improved and were satisfactory during the remainder of powered flight. BECO occurred early; consequently, SECO occurred late. The ports-open indication from the missile telemetry monitor occurred at approximately 10 seconds of powered flight remaining and caused some concern. The event normally occurs about 10 seconds before lox depletion.

The launch-vehicle guidance data became noisy during the last 15 to 20 seconds of powered flight, but the computer was able to make the go — no-go recommendation without difficulty. The cutoff conditions measured at this point were very close to the final orbit, as was determined from later radar tracking information.

Orbital Phase

Following turnaround and checkout of the various spacecraft control systems between Bermuda and the Canary Islands, the suit-inlet temperature began to increase. The pilot increased the suit comfort-control valve (CCV) setting to a value greater than the lift-off setting of 4. The dome temperature of the suit heat exchanger was approximately 80° F and indicated unsatisfactory cooling by the suit circuit. The suit-inlet temperature, as indicated by ground read-out, continued to rise and reached a value of 89° F over Muchea. From the time the spacecraft passed over Muchea until it passed over Canton, the ground read-out showed a tendency to suit-inlet temperature to decrease. The dome temperature of the suit heat exchanger remained at an 80° to 81° F level during the period. By the time of contact with Canton, the pilot had increased the suit setting to 7.5, and he felt that the system was beginning to cool the suit properly.

Upon contact with Guaymas, the pilot reported that he was feeling warm, but not uncomfortable, and that the suit cooling system had begun to decrease the suit temperature. He also reported that all other systems were performing perfectly, and ground read-outs confirmed his report. Based on these considerations, the decision was made to continue for another orbital pass. The environmental systems monitor requested the pilot to reduce the suit valve setting to position 3 to examine the response of the suit dome temperature. The valve reduction was made shortly after the beginning of the second pass, and when the dome temperature rose rapidly, the valve was reset to 7.5. By the time the spacecraft reached Woomera on the second pass, the suit-inlet temperature had decreased to 72° F and appeared to have stabilized. The suit-inlet temperature continued in the vicinity of 70° F for the remainder of the mission, and the pilot was apparently quite comfortable.

Because of the excellent performance of the pilot and the spacecraft; the flight-control task became one of monitoring, gathering data, and assisting the pilot with his flight plan. After the go decision at the end of the first pass, the remaining orbital go decisions were made without hesitation, but with one exception. The loss of communications between the Indian Ocean ship and the Pacific Command ship at the end of the fifth orbital pass required the Pacific Command Ship to make the go decision without an input from the Mercury Control Center. There was no question that the mission should be continued, but had an emergency situation developed, the loss of communications would have caused concern.

In spite of the smoothness of the mission, the ground communications were inferior to that of previous missions because of propagation effects. However, sufficient information was available at all times, either by voice or teletype circuits, to maintain proper surveillance of the mission.

The remote-site flight controllers queried the pilot and obtained any information needed. The network data presented on the summary messages were excellent. The average tolerance on all telemetered parameters was approximately 2 percent. No gross deviations were noted in summary data, and it is believed that these good data were the result of the new verification procedures and confidence tapes that were prepared specifically for the mission. The postpass analysis by network stations provided many useful real-time inputs to the Mercury Control Center, and no difficulty existed in determining the exact status of the spacecraft, pilot, and mission at any time.

Retrofire and Reentry Phases

The retrofire maneuver, which took place over the Pacific Command ship, appeared to be nearly perfect, except for an apparent 2-second delay in retrofire (section on "Electrical and Sequential"). The attitudes of the spacecraft were held extremely well by the attitude-control system, as indicated by both the pilot and ground telemetry and as verified by the subsequent landing accuracy. Other than voice communications with the pilot and some telemetry data obtained from the Watertown radar ship, no further trajectory information was received. The Watertown Cap Com gave the Mercury Control Center the initial time of communications ionization blackout during reentry, and the information provided confirmation of the time of retrorocket ignition and spacecraft attitudes at retrofire.

Relay communications between the aircraft in the sixth-pass recovery area and the Hawaii station worked well and provided communications with the pilot almost continuously from the end of ionization blackout to landing. Thus, the Mercury Control Center had absolute confidence that the reentry phase had been completed successfully.

The MA-8 mission was the best coordinated effort in Project Mercury to date and was a result of the experience gained in previous missions. The large number of new flight-control personnel, who acted as Cap Coms, medical monitors, and systems monitors for the first time, performed well and reflected effective training to the time of deployment to their stations. The cooperation between the MA-8 mission and backup pilots and flight-control personnel was a major contributing factor in making the MA-8 mission a successful operation.

RECOVERY OPERATIONS

The MA-8 recovery operations discussed in the following paragraphs include the recovery plans, recovery procedure, and postlanding aids. The section on "Recovery Plans" contains a descriptive and graphical presentation of the planned recovery areas and the associated recovery forces. The section on "Recovery Procedure" shows in chronological order the significant events pertinent to the actual recovery operation. The section on "Recovery Aids" summarizes the effectiveness of the spacecraft equipment, which was utilized to assist recovery forces in the location and retrieval of the spacecraft after landing.

Recovery Plans

Figure 11 shows the areas in the Atlantic and Pacific Oceans where recovery ships were positioned. The locations of recovery vehicles were not fixed because some of the ships and aircraft changed position during the course of the mission to provide a location and retrieval capability for more than one landing site. Areas A through F were available, if it became necessary, to abort the mission during powered flight. Recovery forces were distributed to provide for recovery within a maximum of 3 hours after landing in area D; a maximum of 6 hours in areas A, C, E, and F; and a maximum of 9 hours in area B. Periodic landings from orbit were provided during each orbital pass. Areas 2-1, 3-1, and 4-1 were available for landings in the Atlantic Ocean at the beginning of the second, third, and fourth orbital passes, respectively. Areas 4-2, 5-1, and 6-1 were available for landings in the Pacific Ocean near the end of the fourth, fifth, and sixth passes, respectively. Recovery forces were distributed to provide for recovery within a maximum of 3 hours in these areas. A total of 16 ships and 13 aircraft were on station in the Atlantic recovery areas, and 7 ships and 4 aircraft were on station in the Pacific recovery areas. Additional search aircraft were available to back up the aircraft on station in the recovery areas. Also, helicopters, amphibious surface vehicles, and small boats were positioned for recovery support near the launch complex.

Locations of staging bases are shown in figure 12. Contingency recovery aircraft were on alert status at these bases to provide support, if a landing were to occur at any place along the orbital ground track. The aircraft were equipped to locate the spacecraft and to provide emergency onscene assistance if required.

Recovery Procedure

All recovery forces were in their proper positions at the appropriate times during the mission. Weather forecasts on the morning prior to launch indicated that Hurricane Daisy could cause adverse recovery conditions in recovery area 3-1, which at that time was located at latitude 29°39' N longitude 62°00' W (section on "Weather Conditions"). Therefore, the recovery ships assigned to area 3-1 were instructed to relocate down range along the ground track to an area with more favorable weather. As a result, the center of area 3-1 was moved 213 nautical miles down range to a position located at latitude 26°25' N longitude 58°18' W. All recovery forces assigned to area 3-1 were shifted down range without difficulty. At launch time, weather conditions were favorable for location and retrieval in all planned Atlantic and Pacific recovery areas, and conditions were good in most contingency recovery areas along the spacecraft ground track.

A communications network linked the deployed recovery forces to the Recovery Control Center located in the Mercury Control Center at the launch site. Recovery communications were satisfactory throughout the operation, and the recovery forces were given information regarding mission status during the launch, orbital, and reentry phases.

During the sixth orbital pass, recovery units in area 6-1 were alerted to expect a landing in their area. At the elapsed time from lift-off of 08:53:00 g. e. t. (20 minutes prior to landing), area 6-1 recovery forces were informed that the retrorockets had ignited normally, and the landing position had been predicted as nominal. Recovery units in area 6-1 made contact with the descending spacecraft before any calculated landing predictions based on reentry tracking were available from the Mercury Worldwide Network support. At 09:05:00 g. e. t., the aircraft carrier U. S. S. Kearsarge, positioned in the center of area 6-1, made radar contact with the spacecraft at a slant range of 178 nautical miles and held contact until the spacecraft descended to an altitude of 1200 feet.

At 09:08:00 g. e. t., the destroyer U. S. S. Renshaw, positioned about 80 nautical miles up range from the center of area 6-1, reported a sonic-boom noise. A contail was observed by personnel aboard the U. S. S. Kearsarge, and at 09:10:00 g.e.t., the U. S. S. Kearsarge reported visual sighting of the spacecraft at a range of 5 nautical miles. A few personnel on board the carrier observed drogue-parachute deployment, and many observed main-parachute deployment and subsequent spacecraft landing (fig. 13). Personnel on the aircraft carrier also reported that two almost-simultaneous sonic-boom noises occurred 10 seconds prior to main-parachute deployment. The spacecraft landed at 09:13:15 g. e. t. at the location of latitude 32°05' N and longitude 174°28.5' W, which was 4 nautical miles down range of the landing point (fig. 14).

The pilot reported at 09:14:00 g. e. t. that conditions were normal, that he was comfortable, and that the spacecraft was dry and floating upright. Helicopters were launched from the aircraft carrier at 09:17:00 g. e. t. and established communications with the pilot. Helicopter crews reported that the spacecraft flotation attitude was never more than 20° from the vertical. A team of three swimmers, with a spacecraft auxiliary flotation collar (fig. 15), was deployed from a helicopter at 09:19:00 g. e. t., and 4 minutes later the spacecraft was secured within the collar. At 09:21:00 g. e. t., the pilot reported that he preferred to remain in the spacecraft and to be retrieved by the aircraft carrier U. S. S. Kearsarge. The aircraft carrier approached within 400 yards of the spacecraft, and a motor whaleboat from the carrier towed a lifting line to the spacecraft. The shepherd's crook on the end of the lifting line was attached to the spacecraft at 09:50:00 g. e. t.

At 09:54:00, the spacecraft was lifted clear of the water (fig. 16); and at 09:56:00 g. e. t., the spacecraft was secured on deck. The pilot actuated the side-hatch explosive mechanism at 09:59:00 g. e. t. (46 minutes after landing) and 2 minutes later (fig. 17) was clear of the spacecraft. The pilot remained on board the U.S.S. Kearsarge for a 72-hour period of rest and debriefing.

The antenna canister and drogue parachute landed 300 yards from the spacecraft and were retrieved by helicopter at 10:00:00 g. e. t. The following information at the time of retrieval was reported by the U. S. S. Kearsarge:

Position of pickup	32°05.5' N 174°28.5' W
Winds, velocity and direction, knots	13 from 120° true
Waves, height and direction, ft	3 from 130° true
Water temperature, °F	80
Air temperature:	
Wet bulb, °F	71
Dry bulb, °F	78

The spacecraft was transferred from the U. S. S. Kearsarge to a tug near Midway Island on the morning of the day after launch. The spacecraft was transferred at Midway from the tug to a C-130 aircraft for delivery to Cape Canaveral. The spacecraft arrived at Cape Canaveral 2 days after the day of launch.

At the time of recovery, the spacecraft appeared to be in excellent condition. The swimmers who attached the spacecraft auxiliary flotation collar reported that none of the stainless-steel straps attached to the heat shield were broken, and the damage to the landing bag consisted of five small holes and a 6-inch slash. The heat-shield center plug remained in place. The experimental ablation materials appeared to be intact at landing and were protected from damage during spacecraft handling by a covering of foam rubber. The antenna canister appeared normal, and there were no rips or tears in the drogue parachute or the parachute risers. The main parachute, normally jettisoned upon landing, was not recovered.

Recovery Aids

All spacecraft recovery aids appeared to function normally, although no reports of high-frequency directional-finding (hf/DF) beacon reception were noted, and it was reported that the flashing light ceased to operate shortly after landing. Prior to being extinguished, the light was sighted by a helicopter pilot at a range of one-half mile. The green dye from the spacecraft dye marker was sighted by a search-aircraft pilot at a range of 9 miles.

A C-54 search aircraft reported contact with the Super SARAH recovery beacon at a range of 105 nautical miles. Three JC-130B search aircraft reported receiving the SARAH recovery beacon at ranges of 60, 60, and 280 nautical miles, respectively, but their detection equipment did not have the capability of discerning between the code A of the Super SARAH beacon and the code C of the Mercury SARAH beacon. Four JC-130B aircraft from the 6594th Recovery Control Group at Hickam Air Force Base, Hawaii, were utilized as search aircraft for areas 4-2, 5-1, and 6-1. The aircraft were capable of locating the spacecraft by homing in on the spacecraft ultrahigh-frequency (uhf) recovery beacons. The aircraft also tracked the spacecraft telemetry signal during the second through the sixth orbital passes and provided DF bearings on the spacecraft. The aircraft lost the telemetry signal during the communications blackout period, but reacquired the signal and provided reliable DF bearings on the spacecraft until landing.

The SOFAR bomb signal was received, and a quick fix location was provided 20 minutes after spacecraft landing. A final location fix was provided 45 minutes after landing. Both of the fixes, shown in figure 14, were within 2 miles of the spacecraft retrieval position.

TABLE II. - PILOT PREFLIGHT PREPARATION HISTORY

Date	Day	Activity
July 11	Wed.	Flight-plan meeting, flight-film meeting
July 12	Thurs.	Flight-plan review
July 13	Fri.	Scheduling meeting
July 14	Sat.	Flying (T - 33)
July 16	Mon.	Flight-plan review
July 17	Tues.	Scientific panel meeting
July 18	Wed.	Mission rules review; flying (T - 33)
July 20	Fri.	Camera and onboard equipment briefing
July 23	Mon.	A. m.: Flight activities discussion, scheduling meeting P. m.: TV interview (Telstar)
July 24	Tues.	Blood-pressure cuff discussion, systems briefing (ASCS)(automatic stabilization and control system)
July 25	Wed.	Systems briefing (ASCS and reaction control system (RCS))
July 26	Thurs.	Systems briefing (sequential)
July 27	Fri.	Flight-plan presentation
July 28	Sat.	Flying (T - 33)
Aug. 1	Wed.	A. m.: Systems briefings (communications and environmental control system) P. m.: Ultraviolet camera briefing
Aug. 2	Thurs.	A. m.: Systems briefing P. m.: Weather briefing
Aug. 3	Fri.	Geology briefing (terrestrial photography)
Aug. 4	Sat.	Flying (F - 106)
Aug. 6	Mon.	Scheduling meeting, flying (T - 33)
Aug. 8	Wed.	Flying (T - 33)
Aug. 10	Fri.	Review of contractor documents
Aug. 11	Sat.	Systems test
Aug. 12	Sun.	Systems tests concluded
Aug. 13	Mon.	Sequential system checks
Aug. 14	Tues.	Sequential system checks concluded
Aug. 15	Wed.	Survival equipment meeting, flying (F - 106)
Aug. 16	Thurs.	Recovery training
Aug. 17	Fri.	Weight and balance
Aug. 20	Mon.	Mercury procedures trainer, flying (F - 106)
Aug. 21	Tues.	Survival-pack exercise
Aug. 22	Wed.	A. m.: Flight-plan activities meeting P. m.: Mercury procedures trainer
Aug. 23	Thurs.	Mercury procedures trainer
Aug. 24	Fri.	Johnsville centrifuge Atlas g refamiliarization
Aug. 25	Sat.	Morehead Planetarium celestial review
Aug. 27	Mon.	Meeting on checklists
Aug. 28	Tues.	Mercury procedures trainer, flying (F - 106)
Aug. 29	Wed.	A. m.: Mercury procedures trainer P. m.: Scheduling meeting
Aug. 30	Fri.	Flight-plan meeting
Sept. 1	Sat.	Flying (T - 33)
Sept. 4	Tues.	Flight-controller briefing
Sept. 5	Wed.	Flying (T - 33)
Sept. 6	Thurs.	Systems briefings (ASCS and RCS)
Sept. 7.	Fri.	A. m.: Systems briefings (electrical and sequential) P. m.: Launch-vehicle meeting
Sept. 8	Sat.	Mercury procedures trainer
Sept. 10	Mon.	Mercury procedures trainer
Sept. 11	Tues.	A. m.: Simulated flight no. 1 P. m.: Briefing of the President of the United States; Mercury procedures trainer
Sept. 12	Wed.	A. m.: Readiness examination P. m.: Mercury procedures trainer
Sept. 13	Thurs.	Flight-plan activities review, checklists review, flying (F - 102)
Sept. 14	Fri.	Simulated flight no. 2 and flight acceptance test, A/G communications check
Sept. 15	Sat.	Mercury procedures trainer
Sept. 17	Mon.	Questionnaire review, A/G communications check, flying (F - 102)
Sept. 18	Tues.	Bermuda Mercury Control Center simulation
Sept. 19	Wed.	Flight configuration sequence and aborts
Sept. 20	Thurs.	A. m.: Mission review P. m.: Mercury procedures trainer
Sept. 21	Fri.	Launch simulation and radio-frequency compatibility, flying (F - 102)
Sept. 22	Sat.	Network simulation
Sept. 24	Mon.	Training facilities meeting (Houston), Flying (T - 33)
Sept. 25	Tues.	Mercury procedures trainer
Sept. 27	Thurs.	A. m.: Flight-plan discussion, mission review P. m.: Mercury procedures trainer
Sept. 28	Fri.	Launch simulation and radio-frequency compatibility, flying (F - 102)
Sept. 29	Sat.	Simulated flight no. 3
Sept. 30	Sun.	Mission review
Oct. 1	Mon.	A. m.: Mercury procedures trainer P. m.: Physical examination
Oct. 2	Tues.	Pilot briefing, study
Oct. 3	Wed.	Launch

TABLE III. - PILOT TRAINING SUMMARY IN THE MERCURY PROCEDURES TRAINER NO. 2 (CAPE CANAVERAL)

[68 simulated failures, 40 turnaround maneuvers, 53 retrofire attitude control maneuvers]

Date, 1962	Type of training	Time, hr:min	Number of missions	Failure number and type (a)						Special training activities (b)
				ECS	RCS	SEQ	ELEC	COMM	Other	
Aug. 20	New switch function familiarization	01:30	1	--	--	--	--	--	--	1,4,5
Aug. 23	One-orbital-pass mission	01:30	1	--	--	--	--	--	--	1,4,5,6
Aug. 28	Flight-plan familiarization, simulated systems failures	01:45	1	--	--	1	1	--	--	3,4,6
Aug. 29	Flight-plan familiarization	00:35	1	--	--	--	1	--	--	1,4,6
Sept. 8	Simulated systems failures	03:00	4	--	1	3	3	1	1	1,2,3
Sept. 10	Simulated systems failures	01:35	3	--	1	3	3	--	--	1,2,3,6
Sept. 11	Simulated systems failures	01:30	3	1	--	2	3	--	3	2,3,4
Sept. 12	Simulated systems failures	01:15	4	3	--	2	1	--	1	2,3,4,5
Sept. 15	Simulated systems failures	02:25	3	2	--	5	1	1	--	2,3,6
Sept. 18	Bermuda Mission Control Center simulation	03:35	4	1	2	2	2	3	2	2,3
Sept. 19	Bermuda Mission Control Center simulation	00:30	1	1	--	--	--	--	1	2
Sept. 20	Simulated attitude-control-system failure	02:30	4	2	1	1	--	--	3	1,2,3,4,5
Sept. 22	Network simulation	01:00	1	--	--	--	--	--	--	1,4
Sept. 25	Flight-plan work	02:00	1	--	--	--	--	--	--	1,4,6
Sept. 27	Simulated attitude-control-system failure	01:05	1	--	--	--	--	--	--	1,5,6
Oct. 1	Network simulation, simulated systems failures	03:30	4	--	--	3	--	--	--	1,2,4
Total		29:15	37	10	5	22	15	5	11	

[a]System abbreviation key:
- ECS — Environmental control system
- RCS — Reaction control system
- SEQ — Sequential system
- ELEC — Electrical system
- COMM — Communications system

[b]Training activities key:
1 — Normal launches and reentries
2 — Launch aborts
3 — Orbital and reentry emergencies
4 — Turnaround maneuvers
5 — Retrofire attitude control
6 — Flight-plan activities (equipment manipulation, control-mode switching, yaw maneuvering, et cetera)

TABLE IV. - MODIFICATIONS AND TESTS MADE TO SPACECRAFT 16

Modification or test	Completion date, 1962
Checkout of spacecraft electrical power systems	Feb. 23
Checkout of spacecraft instrumentation system	Feb. 26
Checkout of spacecraft sequential system	Feb. 28
Checkout of spacecraft communications systems	Mar. 3
Replacement of 7500-psi oxygen-supply pressure transducers with 10 000-psi transducers	Mar. 7
Checkout of spacecraft environmental control system	Apr. 2
Altitude-chamber test of spacecraft	Apr. 17
Removal of maximum-altitude-sensor battery	May 16
Disablement of retrorocket heater wiring	June 13
Wiring of parachute-system barostats in series	June 14
Checkout of spacecraft RCS	June 18
Spacecraft communication system radiation test	June 21
Installation of A-11-type amplifier-calibrator in the automatic control system	June 22
Removal of photographic lights	June 25
Addition of volts to the heat-shield center plug	June 25
Addition of the low-thrust-only select switch to the FBW control mode	June 29
Addition of wiring for the time-from-retrofire signal	July 9
Removal of squibs from the cabin snorkel valves	July 13
Addition of a liferaft communication hardline	July 13
Addition of a temperature display and associated selector switch	July 24

TABLE IV. - MODIFICATIONS AND TESTS MADE TO SPACECRAFT 16 — Continued

Modification or test	Completion date, 1962
Addition of an automatic-solenoid malfunction detector	July 24
Addition of retrofire and recovery-squib-arm switches and automatic bypass relays	July 25
Removal of the Zener diode panel	July 26
Addition of temperature pickups to the dome location of the suit and cabin heat exchangers	Aug. 3
Replacement of the Freon check valves with a more reliable type	Aug. 16
Simulated flight in hangar S	Aug. 14
Test of automatic control system	Aug. 18
Installation of beryllium shingles with advanced ablative material bonded thereon	Aug. 23
Alinement of retrorockets and conduct of spacecraft weight and balance measurement	Aug. 27
Addition of the hf orbital antenna to the retropackage	Aug. 28
Spacecraft moved to launch site and mated with launch vehicle	Sept. 10
Simulated flight no. 1	Sept. 11
Electrical mate and abort tests	Sept. 12
Simulated flight no. 2	Sept. 14
Flight configuration sequence and abort tests	Sept. 19
RCS proof pressure test. Spacecraft demated and returned to hangar S to replace manual RCS selector valve	Sept. 21
Spacecraft returned to launch site and remated to launch vehicle	Sept. 26

TABLE IV. - MODIFICATIONS AND TESTS MADE TO SPACECRAFT 16 — Concluded

Modification or test	Completion date, 1962
Simulated flight test no. 1 (repeated)	Sept. 27
Launch simulation	Sept. 28
Simulated flight no. 3	Sept. 29
Electrical interface test	Sept. 29
Launch countdown and lift-off	Oct. 3

TABLE V. - ATLANTIC MISSILE RANGE OPTICAL LAUNCH COVERAGE

Film type	Station	Number of items committed	Number of items obtained
Metric	1	15	15
Engineering sequential	1	47	46
Documentary	1	102	99

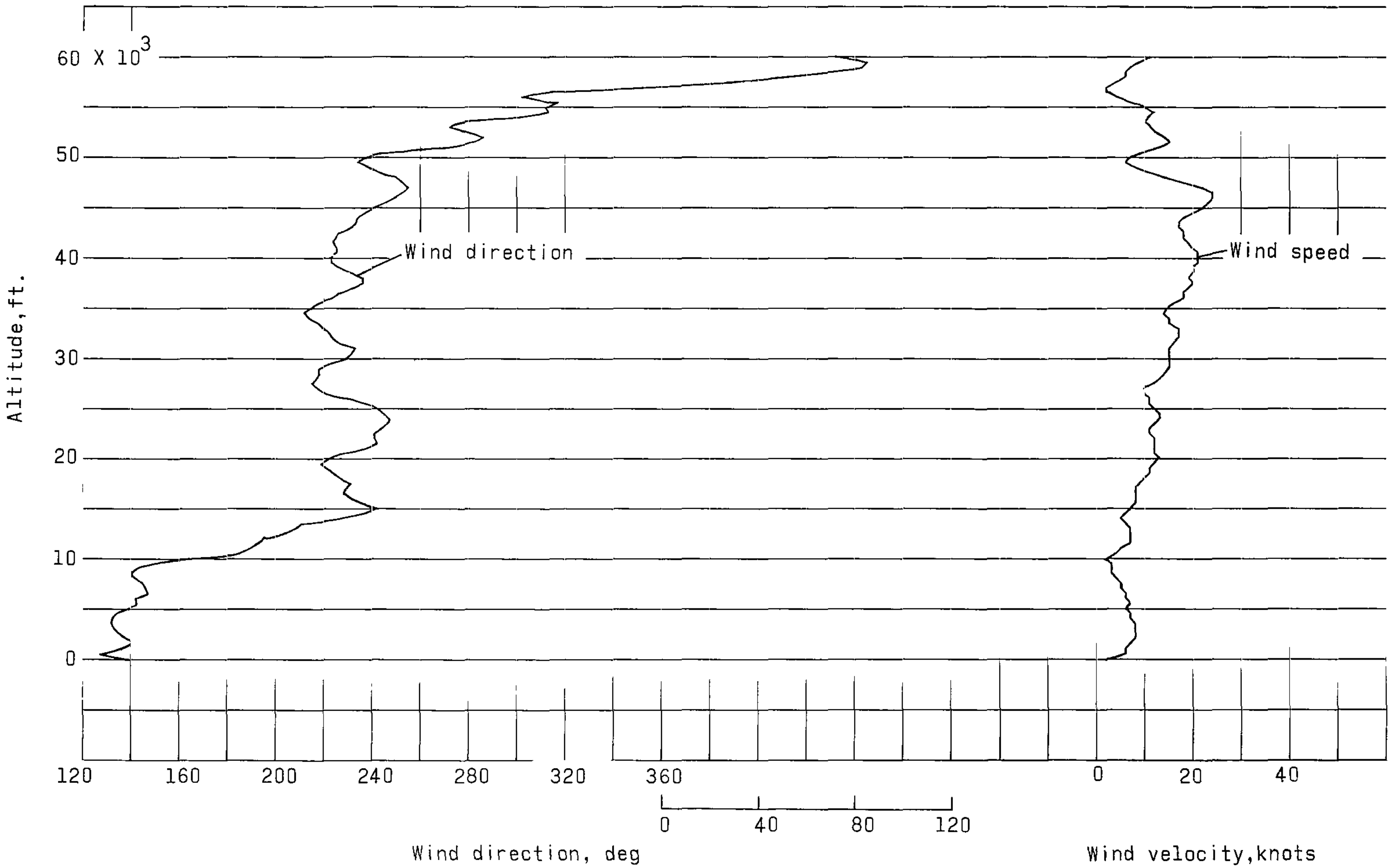


Figure 9. - Wind direction and velocity at the launch site.

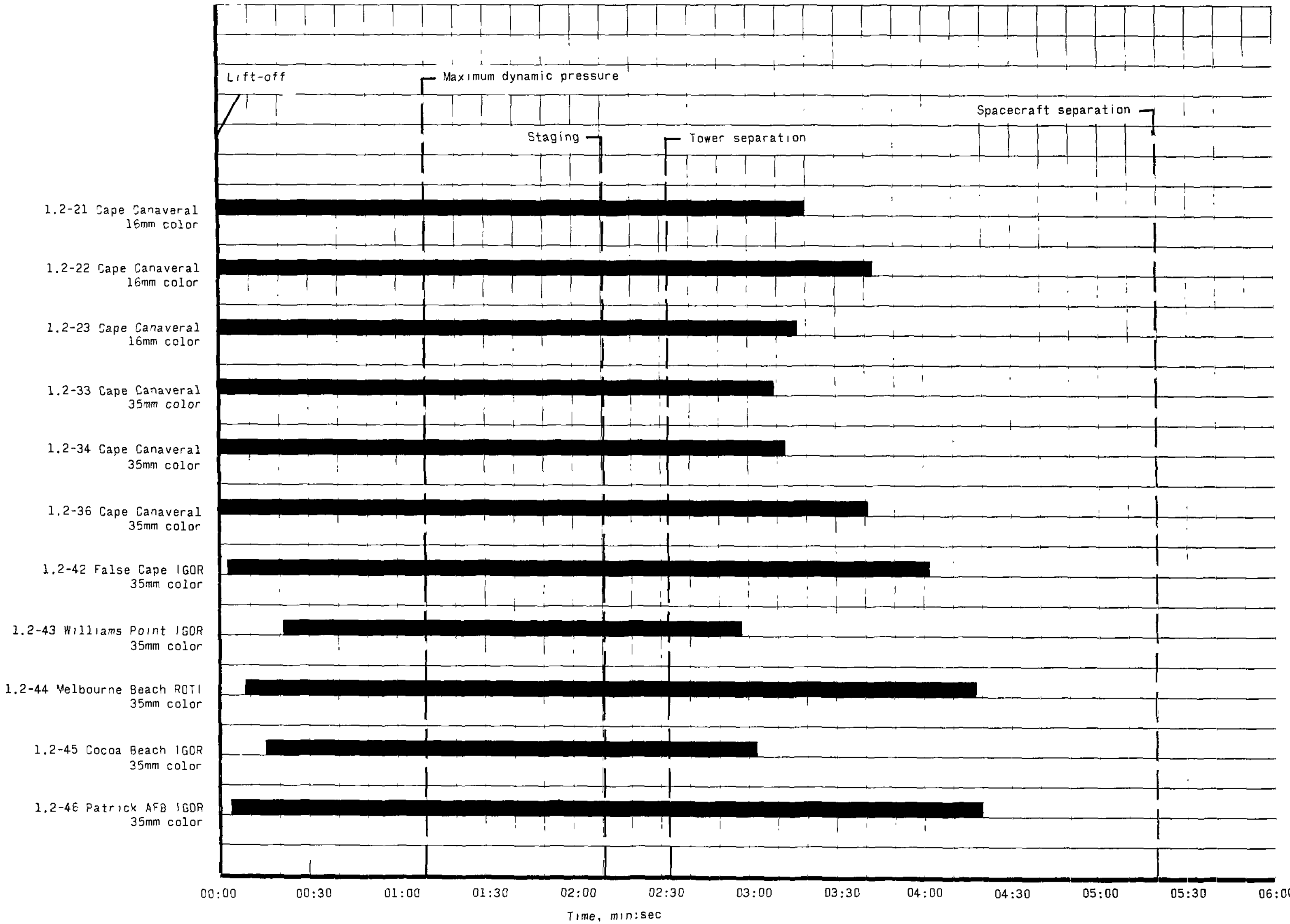
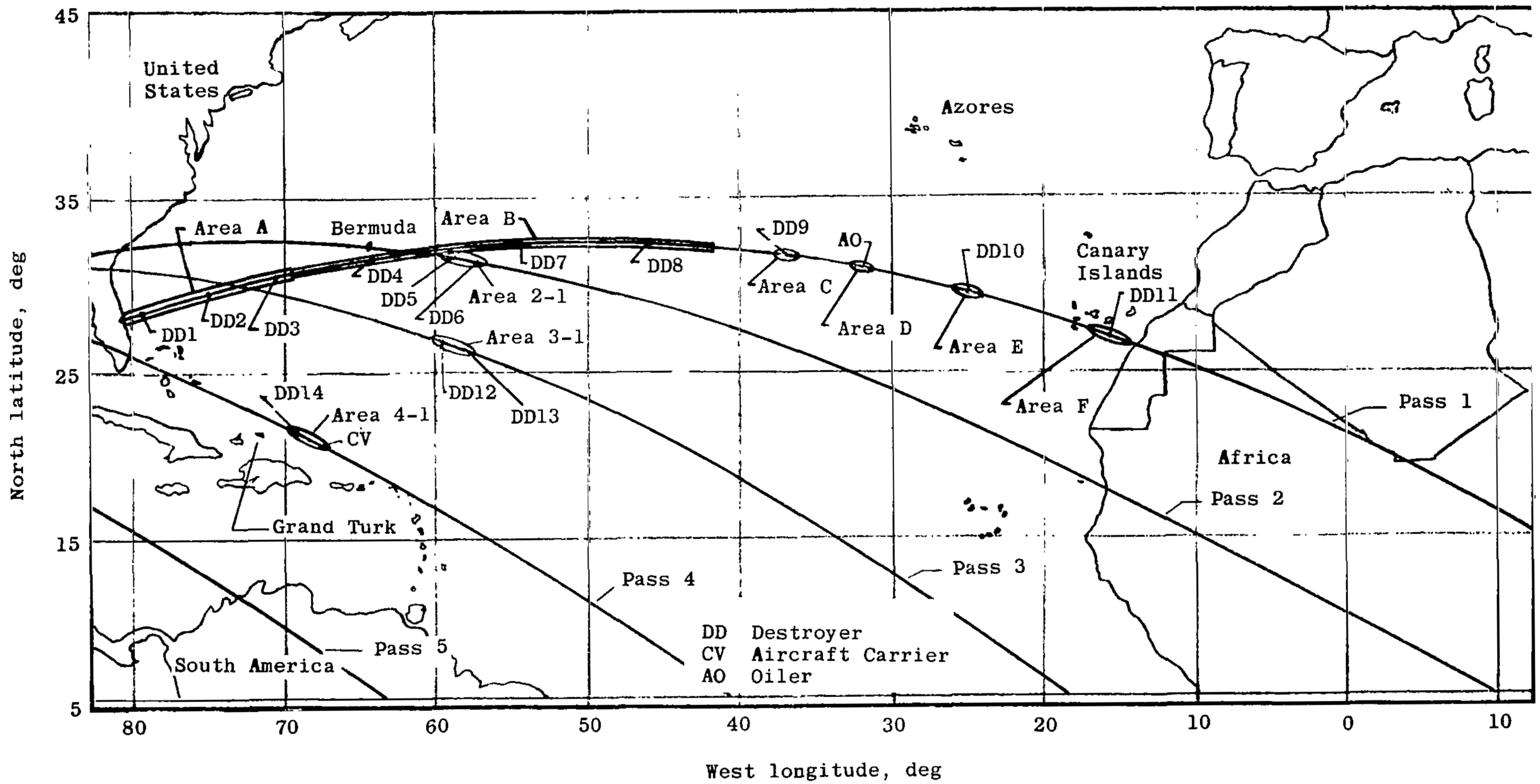
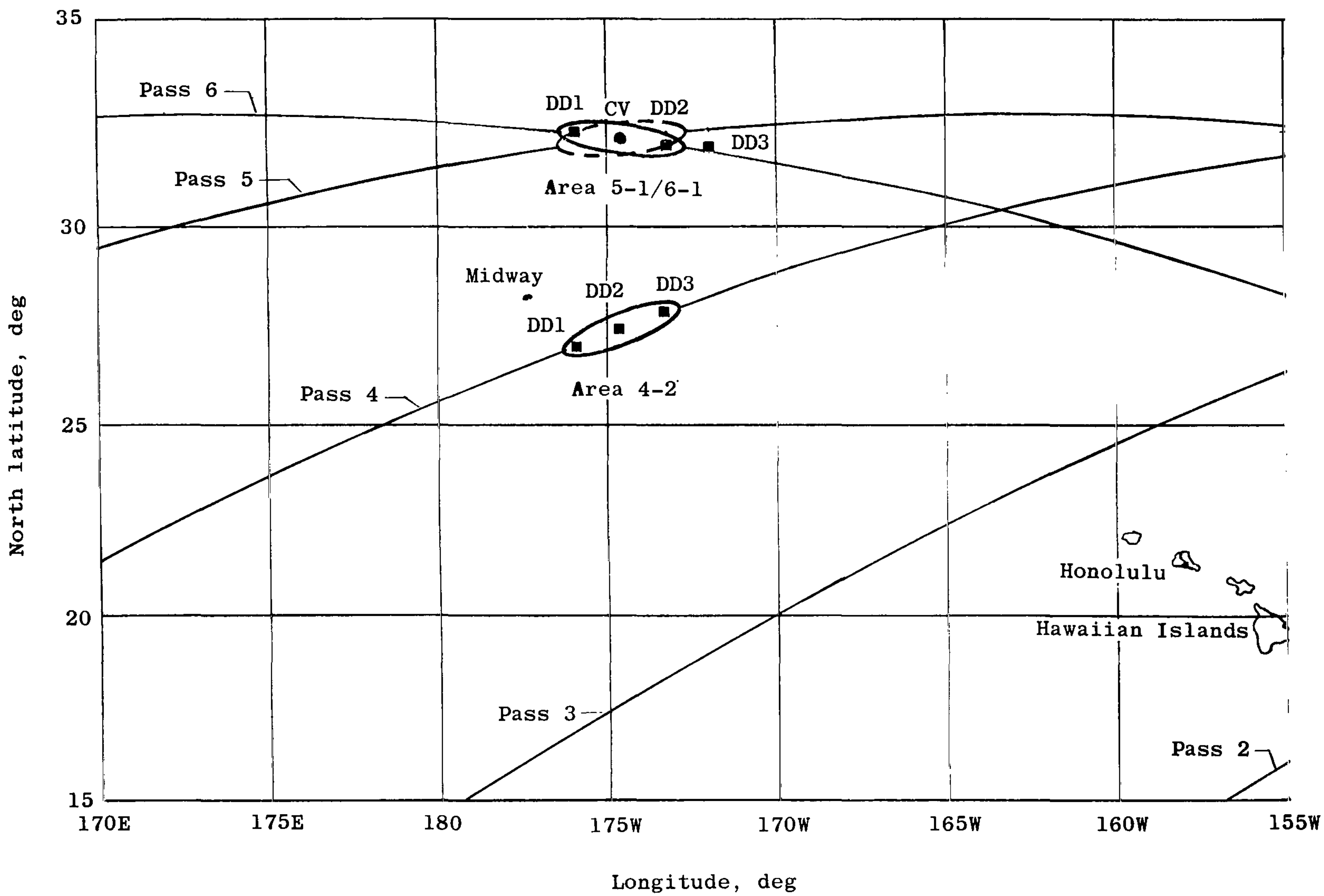


Figure 10. - AMR engineering sequential tracking camera coverage.



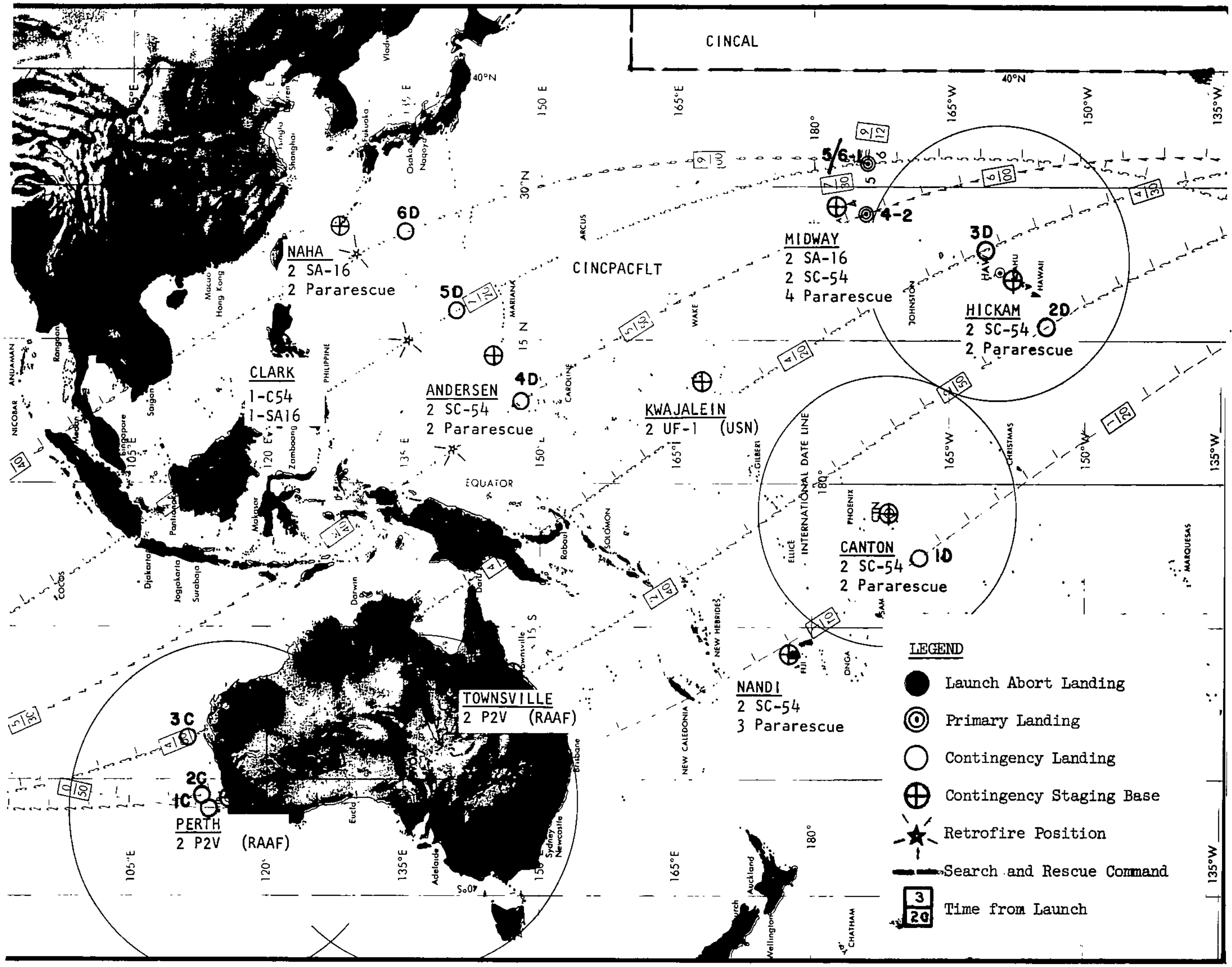
(a) Atlantic Ocean.

Figure 11. - Recovery areas and ship locations.



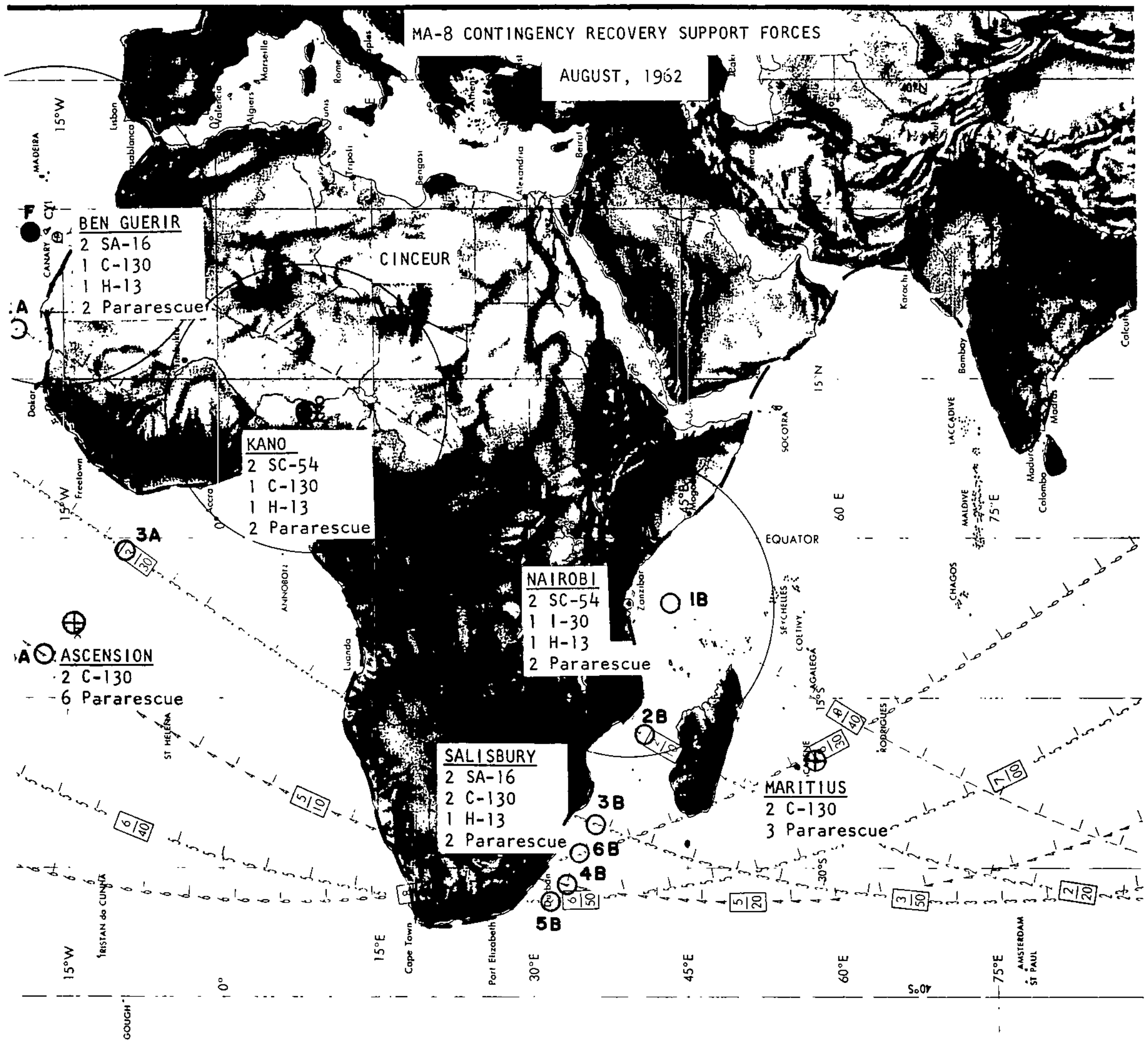
(b) Pacific Ocean.

Figure 11. - Concluded.



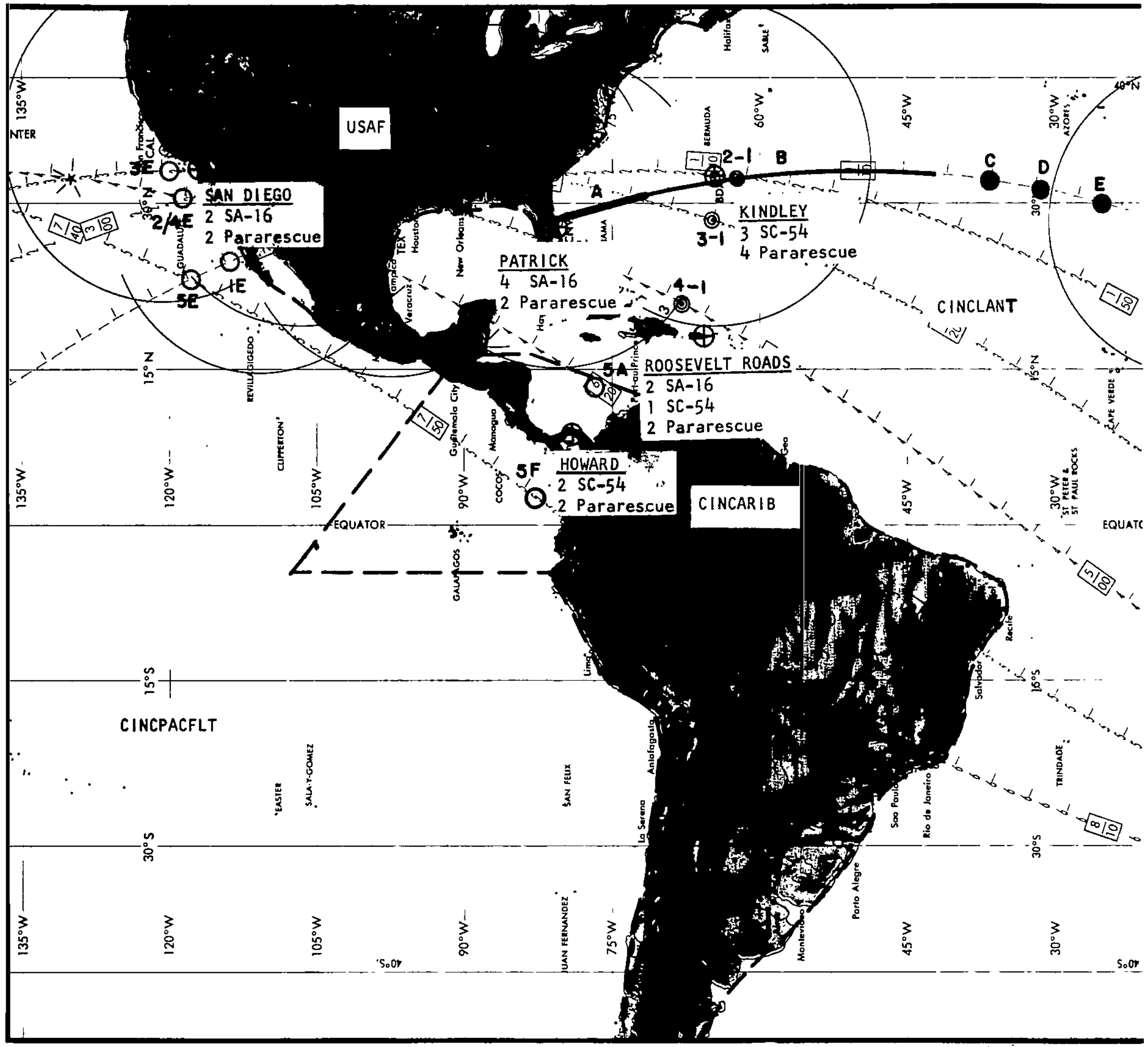
(a) Australia and Western Pacific Ocean.

Figure 12. - MA-8 contingency recovery support forces.



(b) Eastern Atlantic Ocean, Africa, and Indian Ocean.

Figure 12. - Continued.



(c) Eastern Pacific Ocean, the Americas, and Western Atlantic Ocean.

Figure 12. - Concluded.

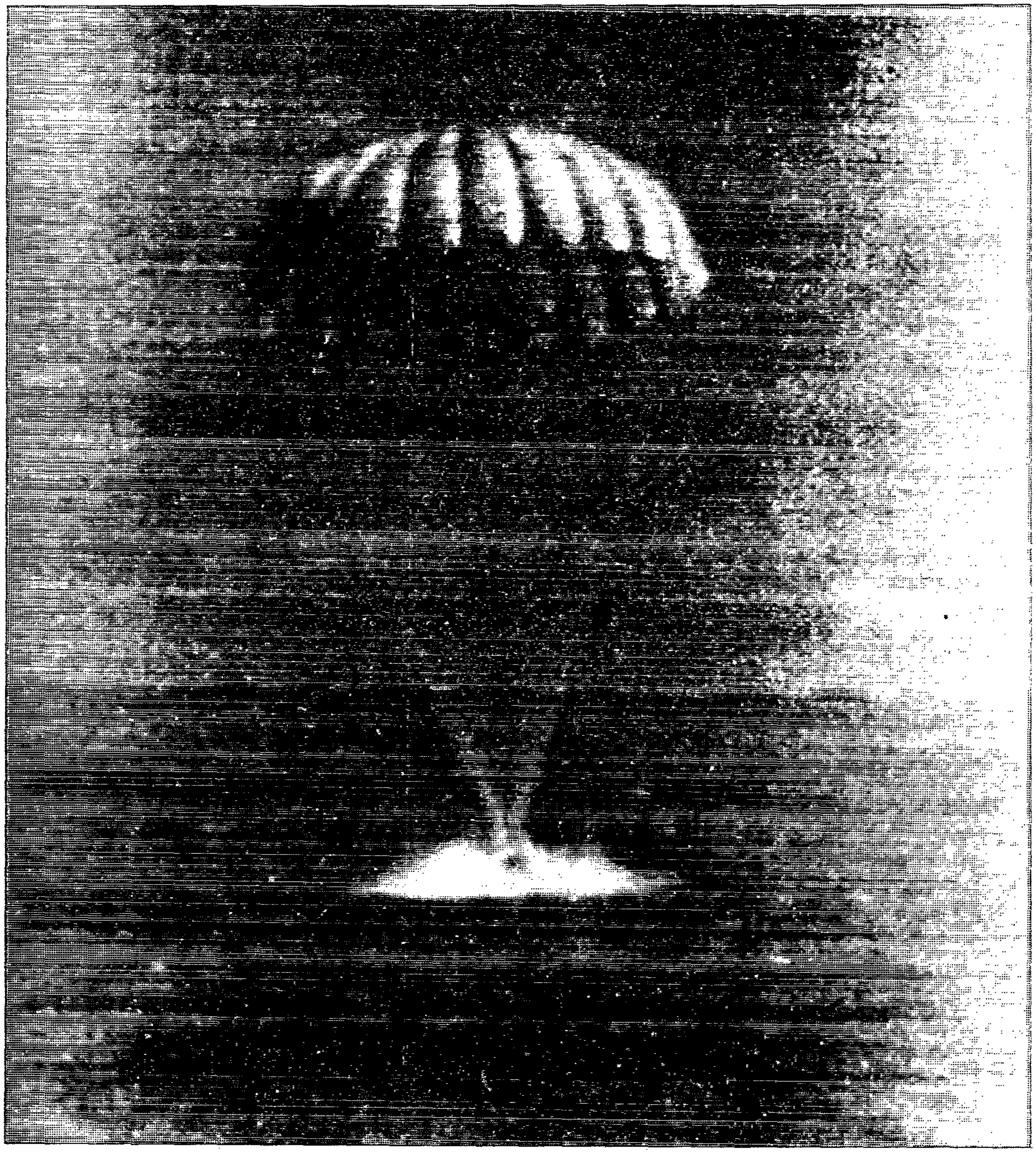


Figure 13. - MA-8 spacecraft at landing.

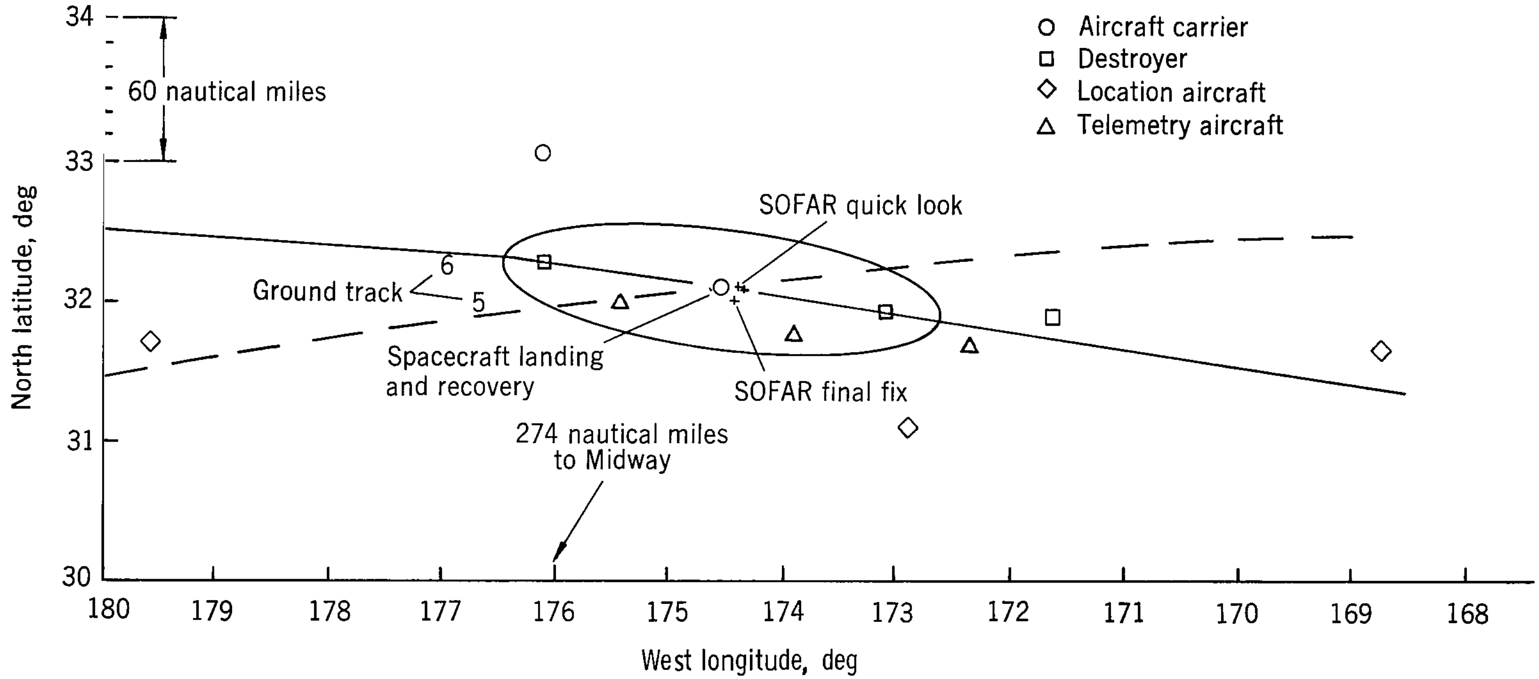


Figure 14. - Details of landing area 6-1.

Figure 15. - MA-8 spacecraft in auxiliary flotation collar with motor whaleboat personnel attaching line from recovery aircraft carrier to spacecraft.

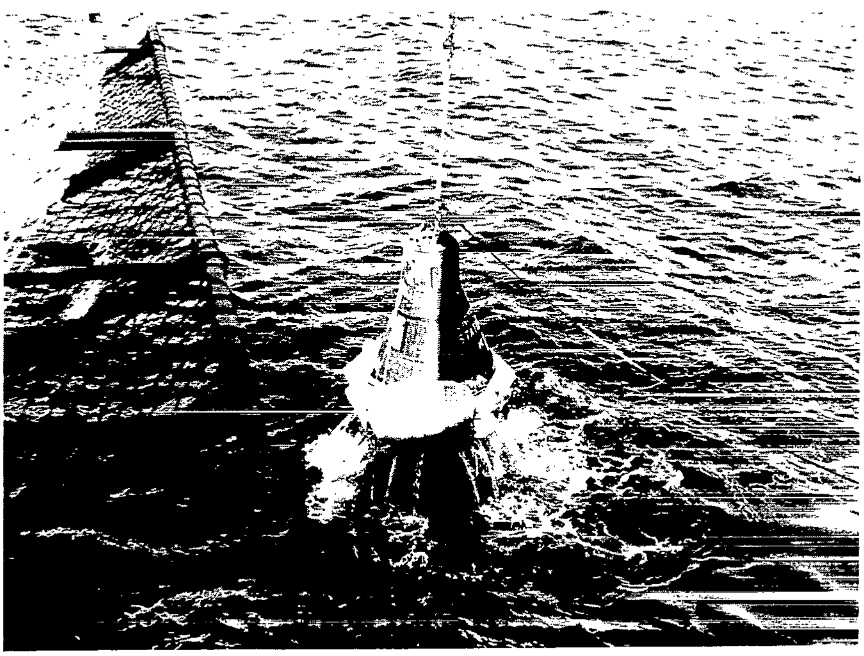


Figure 16. - MA-8 spacecraft being lifted on board recovery aircraft carrier.

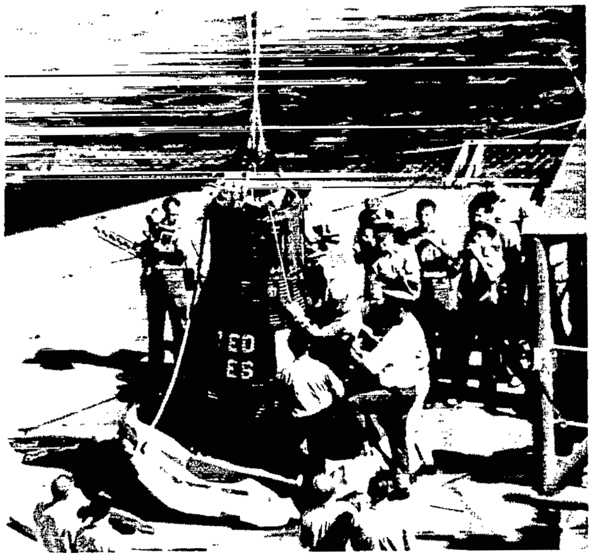


Figure 17. - Pilot egressing from the MA-8 spacecraft after activating side hatch.

MISSION PERFORMANCE

The technical results of the MA-8 mission and analyses of the flight data are presented. The performance analyses are grouped into the following major areas: spacecraft performance, aeromedical analysis, pilot flight activities, pilot flight report, launch-vehicle performance, trajectory and mission events, and Mercury Worldwide Network performance. In addition to discusssons of each major spacecraft subsystem, the section on "Spacecraft Performance" contains details of the postflight inspection and the performance of scientific equipment installed in the spacecraft. A postflight meteoroid-impact analysis is included as a part of the postflight inspection. The sections on "Aeromedical Analysis" and "Pilot Flight Activities" discuss the well-being of the pilot, his activities, and the personal narrative of his flight experience. The section on "Launch-Vehicle Performance" is a brief synopsis of Atlas systems operation, while the section on "Trajectory and Mission Events" showing computed and measured flight parameters. Finally, the Mercury Worldwide Network is analyzed in the specific performance areas of trajectory computation, command, and tracking and in the areas of telemetry and voice communications.

SPACECRAFT PERFORMANCE

The entire MA-8 spacecraft performed exceptionally well; the only significant systems irregularity was the inability to adjust the suit-circuit cooling level rapidly at the outset of the mission. When the adjustment was accomplished satisfactorily during the second orbital pass, the mission continued in a routine fashion and was described later by the MA-8 pilot as of "textbook" quality. Other minor irregularities were experienced and are discussed in the discourses on specific subsystems which follow, but they were not sufficient to jeopardize the success of the mission. Flight data and measurements are generally not shown, other than to support or otherwise clarify the analysis presented. Reference 1 provides a more detailed systems description.

Spacecraft Control System

All spacecraft control-system components functioned normally throughout the MA-8 mission. At various times during control-mode changes from the automatic stabilization and control system (ASCS) orbit mode to FBW, short-duration voltage transients were noted across the solenoid coils of the 24-pound automatic thrusters. The magnitudes of the transients were insufficient to actuate the solenoid valves and produce thrust, but they were retained by the memory in the flight telemetry circuits.

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

1. ASCS with secondary choices of orientation, orbit, and auxiliary damping modes

2. FBW with pilot choice of high and low thrusters or low thrusters only

3. Manual proportional (MP)

4. Rate stabilization control system (RSCS)

Modes 1 and 2 employed the automatic RCS thrusters, while modes 3 and 4 used the manual RCS thrusters. Each RCS had its own fuel supply and was independent of the other systems. Combinations of modes 1 and 3, 2 and 3, or 2 and 4 were available to provide double authority at the discretion of the pilot.

To eliminate inadvertent fuel usage, the circuitry of the FBW mode was modified to contain a special thrust-select switch which permitted the pilot to disable the FBW high thrusters, with an automatic return to normal occurring at the time of retrofire. Because of the change, the operation of the normal FBW mode differed from that of the MA-7 spacecraft in that the MA-8 automatic low thrusters continued to operate during periods of high-thruster actuation.

The amplifier-calibrator employed was the A-11 model. The changes from the previous model (A-9) are shown in table VI. The orbit-mode operation is outlined in table VII.

The changes were intended to conserve fuel by increasing the time period of spacecraft oscillation between attitude-limiting maneuvers. An attitude-select switch was provided in the ASCS orbit mode to give the pilot a choice of either -34° or 0° as a fixed attitude in pitch, with an automatic return to retroattitude at the beginning of the 30-second retrosequence period. The attitude-select switch used in conjunction with the gyro free-normal switch also provided an autopilot operation with a spatial reference at any spacecraft attitude. All other control-system components were identical to those employed in the MA-7 spacecraft.

Performance analysis. - Operation of the spacecraft control system was satisfactory throughout the mission. Some discrepancies were noted and are discussed in the following paragraphs, but the discrepancies did not compromise the success of the mission. The pitch and roll scanners became enabled at tower separation, and slaving of the gyros was effective from that point throughout the mission. At completion of the turnaround maneuver, the outputs of the gyros and the scanners matched within 2°.

A 0.5-deg/min rate of disparity between the roll scanner and the roll gyro was evident during a period of 27.5 minutes, beginning at about 07:20:00 g.e.t. The spacecraft was in ASCS orbit mode at the time with gyros free, and since a misalinement in yaw can produce a precession of the roll gyro, this possibility was investigated. For example, if the spacecraft were at a yaw heading of 90°, then the roll horizon would revolve at the orbital precession rate of 4 deg/min. At any other yaw heading, the precession rate of the roll scanner w_s is

$$w_s = (4 \text{ deg/min}) \frac{\sin \psi}{\cos \theta}$$

where ψ is the yaw attitude and θ is the pitch attitude. By assuming a constant pitch attitude, an average yaw attitude of 6° would be required to produce a precession rate of 0.5 deg/min. The roll discrepancy noted was eliminated by the pilot at 07:47:36 g. e. t.

The ASCS orbit mode, with the new pulse widths and attitudes, operated in conjunction with the interim-thruster configuration and did not produce a spacecraft limit cycle within ±5.5° as predicted. While the fuel consumption was extremely nominal, two or three pulses were required for rate reversal, and the limit cycle about all axes averaged approximately ±8°. The deviation was further increased by the effects of scanner slaving. Therefore, it was concluded that pulse durations were not as long as expected and were insufficient to meet the limit-cycle requirements.

Small-voltage transients appeared across the solenoids of the 24-pound automatic thrusters when the pilot switched from ASCS orbit mode to the FBW-low mode, but the transients were insufficient to operate the solenoid valves and produced no effect on spacecraft attitudes. The transients were duplicated in postflight testing and did not significantly affect the ASCS operation.

Replacement of the three-position mode-select switch prior to flight with a more reliable two-pole center-off unit required the addition of an extra relay to duplicate the original circuit operation. The operating time of the relay was then added to that of the auxiliary-damper relay, which permitted the amplifier-calibrator to revert to the orientation mode for approximately 3.8 milliseconds during the switching operation from ASCS orbit mode to ASCS auxiliary damper. The increased orbit-mode attitude limits previously described permitted the amplifier-calibrator orientation-mode logic to command high thrusters whenever the switching occurred at attitudes in excess of ±5.5°.

The voltage transient was detected and remembered by the high-speed capacitive network in the telemetry channels for the 24-pound automatic thrusters. Similar low-thruster commands were not seen with mode changes at attitudes of less than ±5.5°, since the amplifier-calibrator returned immediately to the orbit mode prior to receiving its auxiliary-damper command.

Control-system utilization. - The spacecraft separation signal, which was received by the amplifier-calibrator at 0:05:17 g. e. t., initiated automatic damping. Three seconds later the pilot switched to auxiliary damper and then to FBW low to execute the turnaround manually. By 0:12:51 g. e. t., sustainer-stage tracking was completed, and the spacecraft was placed in the ASCS orbit mode of control. This mode was employed for approximately 80 percent of the time when the spacecraft power was on prior to reentry, and its use resulted in a significant decrease in fuel usage when compared with the previous missions when the control modes were primarily manual. Utilization of other control modes was confined to the minimum time necessary to accomplish the scheduled maneuvers.

Four short periods of double-authority control were noted, that is, when more then one control mode was in operation. At 2:06:09 g. e. t., while utilizing manual proportional control, the FBW mode was inadvertently selected approximately 17 seconds before the MP mode was removed. At 6:28:13 g. e. t., the pilot selected ASCS with the spacecraft at -34° pitch and the attitude-select switch in reentry. The resulting pitch-up command was promptly removed by utilizing the FBW system combined with 31 seconds of rate command for faster response. At 7:45:14 g.e.t., during the gyro free check, the pilot was advised of discrepancies between the roll gyros and scanners; the pilot elected to realine the spacecraft with the MP system while remaining in ASCS orbit mode. The fourth period of double authority occurred during the firing of the retrorockets. The pilot selected MP control to backup the automatic control system if it failed to control the spacecraft attitudes properly during the event.

Atttiudes at retrofire were maintained by the ASCS, with MP as a backup, and the attitudes were held to within ±1° for the retrofire period. The pilot commanded reentry attitude manually with the FBW mode and then switched to RSCS at 9:00:27 g.e.t. to obtain the 0.05g roll rate with pitch and yaw damping. Reentry was normal except for some slight yaw oscillations which occurred at 9:05:07 g.e.t. These minor oscillations probably resulted from a dynamic imbalance in the control-stick mechanism, coupled with the inherent neutral stability characteristics of the Mercury spacecraft under certain Mach number regions.

Reaction control system. - The RCS was of the standard configuration except for thrust-chamber modifications similar to those used in spacecraft 18 (MA-7 mission). In comparison with spacecraft 18, there were no heat sinks attached to the automatic and manual roll thrust-chamber assemblies. The pilot reported no malfunctions in the RCS and this was substantiated by the onboard recorded data. Fuel-consumption rates were appreciably lower than for the MA-6 and MA-7 missions. The low fuel usage was consistent with the lack of FBW high-thruster action and frequency and duration of low-thruster activity. The amount of fuel used during the mission is shown in table VIII. The angular accelerations imparted to the spacecraft by the 1-pound thrusters were near the nominal value of 0.5 deg/sec^2, consistently throughout the mission, and were substantiated by the onboard data.

Propellant feedline temperatures were measured during the mission, and the following are the maximum temperatures recorded:

Thruster position (low automatic)	Maximum temperature of solenoid B-nut, °F	Approximate time of measurement, hr:min
Yaw, left	103	01:36
Yaw, right	117	02:25
Pitch, up	111	01:12
Pitch, down	106	02:26
Roll, counterclockwise	127	08:20
Roll, clockwise	117	08:17

Environmental Control System

The environmental control system (ECS) consisted of equipment which provided for and controlled the environment of the pilot's pressure suit and the spacecraft cabin. The ECS provided 100 percent oxygen for the metabolic requirements of the pilot and maintained cabin pressure at a nominal value of 5.1 psia by supplying oxygen to compensate for cabin leakage. Heat loads resulting from pilot metabolism, operation of spacecraft equipment, and solar radiation were removed to maintain comfortable temperature and specific-humidity levels in the pressure suit and to maintain a temperature level in the cabin suitable for efficient equipment operation.

The above-normal suit-inlet temperature during the first 2 hours of flight was the only ECS problem during the mission. The temperature increased during the first hour of flight and remained at an elevated level until a gradual advance of the control valve by the pilot permitted adequate coolant water to flow to the suit heat exchanger at approximately 2 hours after launch. The suit-inlet temperature then decreased to a normal level and was maintained in this condition for the remainder of the mission.

System description. - The suit circuit was a recirculatory gas-flow system which provided a livable environment for the pilot. Metabolic carbon dioxide was removed by a chemical reaction with lithium hydroxide and was replaced with gaseous oxygen (stored on board initially at 7500 psi) by a demand pressure-regulating valve. The cabin pressure was maintained at 5.1 psia. The suit-inlet pressure was referenced to and maintained at a level slightly above cabin pressure. In the event of cabin decompression, the suit pressure would have been maintained at 4.6 psia.

Heat was removed from the suit and cabin circuits by forced-convection, water-evaporative heat exchangers. Water was supplied to the heat exchangers from an on-board supply, and the flow was regulated to the respective heat exchangers by comfort-control valves which were adjustable by the pilot. The water CCV was designed to pass a minimum of 4.5 pounds of water per hour in the full-open position. The valve stem turned through an arc of 310° from the full-closed to the full-open position. The normal operating range was approximately 100° of the stem-turning arc, with each 10° increment of turn varying the flow between 0.05 to 0.1 lb/hr. Water evaporated in the heat exchanger at approximately 35° F and exhausted into space. The process of evaporation required approximately 1000 Btu per pound of water evaporated. The heat was absorbed from the gas side of the heat exchangers and, thus, provided cooling in the separate suit and cabin circuits. Metabolic perspiration and respiration water was condensed in the suit heat exchanger and was transported by the gas stream to an absorption sponge. The sponge was periodically squeezed by a plunger, and the condensate was stored in a collection tank.

The ECS for spacecraft 16 (MA-8 mission) was essentially the same as that for spacecraft 18 (MA-7 mission). The following minor changes were made:

1. The water sealing device which was incorporated in the cabin-pressure relief valve of previous spacecraft was removed.

2. The coolant quantity indicating and pressurization system was removed.

3. The coolant-water tank was pressurized from the cabin.

The real-time determination of the coolant water remaining during the mission was dependent upon the preflight calibration of the comfort-control valves and pilot reports of CCV settings.

The most significant change in the ECS was the relocation of the temperature-monitoring point from the steam exhaust to the domes of the suit and cabin heat exchangers. These temperatures were sensed on the exterior surface of the heat exchanger between the first and second pass of the evaporating water. An extensive heat-exchanger testing program indicated that temperature at this position was most representative of heat-exchanger operation and that the highest efficiency of the heat exchanger was obtained when the temperature was 55° ± 5° F. Further, the conclusion from these tests was that a sudden drop in dome temperature below 45° F indicated excessive waterflow.

Analysis and results. - The data used in this section were obtained from the onboard voice transcript, onboard recorded data, and postflight testing and inspection. The CCV positions, heat-exchanger dome temperatures, and cabin heat-exchanger gas-outlet temperatures appear only in the onboard voice transcript. The suit-inlet and cabin-air temperatures given in the following discussion were obtained from the recorded data from the low-frequency commutator. The data derived from spacecraft instrument read-outs, the onboard tape record, and real-time range telemetry did not agree concerning suit-inlet temperature. Postflight calibration of the spacecraft instrument read-out and the two telemetry channels for this parameter at relatively low cabin temperatures indicated that the telemetry channels operated within ±2.5° F of the actual temperature. The spacecraft instrument read-out deviated from 4° to 9° F below telemetry-channel values. It was concluded that the variation in cabin temperature affected the spacecraft instrument calibration without influencing the telemetry value of suit-inlet temperature.

Prelaunch phase: Following pilot insertion, the suit-inlet environment was maintained at a temperature of approximately 60° F, and the cabin environment was maintained at 85° F. Preflight cooling was accomplished through evaporation of the ground-supplied refrigerant flowing through the heat exchangers and inverter cold plates at a rate of about 34 lb/hr. The refrigerant was turned off at T - 7 minutes in accordance with normal operating procedures. The metabolic oxygen consumption rate of the pilot during the prelaunch phase was 1.17×10^{-3} lb/min (373 cc/min at 32° F, 14.7 psia). In comparison, the metabolic rate during the launch simulation was 0.94×10^{-3} lb/min (300 cc/min at 32° F, 14.7 psia). Both rates were computed from the pressure decay of the oxygen storage tanks. After cabin purge, the cabin-oxygen partial-pressure measurement was 1.0 psi below cabin pressure. This measurement was confirmed as inaccurate by a prelaunch chemical analysis, which indicated 98 percent oxygen. The cabin-oxygen partial-pressure measurement was erratic and remained lower than cabin pressure throughout the mission.

Launch phase: During the launch phase of the mission, the cabin-pressure relief valve ceased relieving at a differential cabin pressure of 5.9 psi above ambient. The pressures were at the upper limits of design tolerances, but they indicated proper functioning of the relief valve during the launch phase.

Orbital phase: The suit-inlet temperature increased at a rate of approximately 0.5° F/min during a portion of the first hour of the mission, but was reasonably stable at 86° F during the second hour (fig. 18). During this time, the pilot increased the suit CCV setting by one-half-position increments every 10 to 15 minutes from the preflight position 4 to position 8 at 01:58:20 g.e.t. The dome temperature of the suit heat exchanger rose from 75° F at launch to 81° F and began a downward trend when the CCV was set to position 8. At 01:50:00 g. e. t., the suit CCV was reduced to position 3 by the pilot, on request, and a marked increase in the dome temperature of the suit inlet and suit heat exchanger resulted. The increase indicated that the water flow rate at position 3 was inadequate for proper cooling; consequently, the valve was reset to position 8. At an elapsed time of 2 hours, the dome temperature of the suit heat exchanger dropped to 70° F and remained at this temperature for most of the mission. The suit-inlet temperature began a downward trend at 2 hours elapsed time and indicated 70° F at 3 hours after launch. At 4 hours elapsed time, the suit heat-exchanger dome temperature dropped rapidly to 45° F. The CCV was reset to position 7.5, and the dome temperature rose rapidly to the control range of 55° ± 5° F. This performance was in agreement with the heat-exchanger tests previously described, and it was concluded that optimum heat-exchanger operation occurred at a CCV setting between positions 7.5 and 8.0.

The pilot adjusted the comfort-control valves in accordance with the preflight briefing and, thus, demonstrated that the suit temperature could be adequately controlled in flight.

Preflight calibration data had indicated that the suit CCV should be set at position 4 to obtain the required flow rate of 0.72 lb/hr. Postflight testing of the valve as flown revealed that a shift in the valve calibration had occurred so that the flow-rate average of four tests at position 8 was 0.705 lb/hr, (fig. 19).

As was experienced in previous missions, the cabin temperature cycled as a result of the radiation in solar heating at sunrise and sunset. Electrical equipment power-down and power-up caused the trend of the cabin temperatures to decrease and increase (fig. 20). The dome temperature of the cabin heat exchanger was maintained between 45° and 55° F during the mission, and the heat-exchanger outlet-gas temperature indicated 40° to 45° F. The cabin CCV was set at position 4 at launch, but it was reduced to position 3 at 01:03:00 g. e. t. to provide assurance that freezing in the heat exchanger would not occur.

The total water expended for cooling the suit and cabin circuits and the inverter cold plates was 12.82 pounds, determined in postflight tests. The quantity of condensate collected was 168 cc, which was approximately the same amount for the 9-hour flight as was collected on each of the two previous 4.5-hour orbital missions.

The cabin-leakage rate determined during preflight tests was 570 cc/min at 19.7 psia. The cabin-leakage rate during flight was 0.72×10^{-3} lb/min, based on an average pressure of 5.3 psia, which would correspond to 630 cc/min at 19.7 psia. The inflight leakage was calculated from the time interval between cabin-pressure seal-off (5.9 psia) and cabin-pressure regulation (4.8 psia), which began at approximately 07:20:00 g. e. t. After this time, the total oxygen-usage rate was 1.7×10^{-3} lb/min. Cabin leakage calculated from oxygen supply-pressure decay was equivalent to 475 cc/min at 19.7 psia. The pilot oxygen was calculated to be 1.14×10^{-3} lb/min (364 cc/min at 32° F, 14.7 psia) during the first 7 hours of flight. The oxygen-usage and the cabin-leakage rates were within the acceptable range determined before the mission.

Reentry phase: The performance of the ECS during reentry was normal. The system was changed to the postlanding mode of operation at 09:07:48 g. e. t., when the pilot manually opened the suit-inflow and cabin-outflow valves. The oxygen emergency-rate flow was initiated automatically at this time, which conformed to normal procedures.

Summary of system performance: The MA-8 mission was the first manned orbital mission during which positive control of the suit temperature was demonstrated. The pilot experienced no discomfort from humidity as reported by the MA-6 and MA-7 pilots. The coolant-water usage during the mission agreed more closely with expected usage rates than those encountered in previous missions. The improved performance was attributed to the use of the heat-exchanger dome temperature as the control parameter, rather than the temperature at the steam-exhaust port.

Pilot comfort: Prior to the MA-8 mission, a series of tests was conducted using flight-configuration heat exchangers by NASA at Houston and by the contractor at St. Louis to develop an effective method of monitoring the heat-exchanger performance and to allow the pilot to utilize the maximum cooling provided by the heat exchanger. The tests yielded two significant results: (1) Monitoring of the temperature of the heat-exchanger dome provided a more positive and rapid response method of controlling the heat-exchanger performance, and (2) as water-flow rates were increased beyond optimum values, the cooling effectiveness did not increase. The results supported the hypothesis that partial freezing occurred in the heat exchanger during the MA-6 and MA-7 missions, where an excessive amount of cooling water was used and difficulty was experienced in obtaining satisfactory cooling.

As a result of the series of tests, a recommendation was made to the pilot that he insert into orbit with the suit CCV set at position 4 and increase the setting by one-half-position increments at 10-minute intervals if the suit-inlet temperature warranted a change. The position 4 setting, using preflight calibration data for the flowrate valve, corresponded approximately to the theoretical flow rate needed and corresponded to the valve position established for adequate cooling in one of the two altitude-chamber tests of spacecraft 16. The setting was used by the pilot during the early part of the mission, but it was found to be too low for adequate cooling. As discussed previously, postflight tests showed the valve-flow passage to be restricted by foreign material, thus requiring a higher-than-anticipated setting.

Conclusions. - The initial difficulty encountered with the elevated suit-inlet temperature was indicated after the mission by a shift in the previously calibrated flow for the suit CCV. The four postflight calibration tests of the CCV in the flown condition presented a significant envelope of variation for flow rates at a given valve setting (fig. 19). The valve was disassembled, and inspection of the valve components revealed flakes of dried lubricant on the valve stem and in the valve seat. The flakes were large enough to cause restriction of the flow through the valve. The valve was cleaned by ultrasonic methods, and the 0-rings and the male threads of the valve body were relubricated. Three calibration tests of the cleaned suit CCV showed that the calibration had returned to almost the preflight values. The flow rates of the cleaned valve were relatively consistent and were predictable for any setting. Postflight testing of the cabin CCV and inverter CCV did not reveal a significant calibration shift.

Evidence of the comfort of the pilot during the mission was reflected by the 168 cc of condensate collected, which was a measure of the perspiration experienced. During the two previous three-pass missions, which involved a duration of approximately one-half that for the MA-8 mission, the pilots experienced high specific humidity and excessive perspiration; consequently, the same approximate magnitude of condensate was collected. A low specific humidity at the suit heat-exchanger outlet was indicative of a properly functioning suit-cooling system.

A high cabin temperature was experienced on all orbital missions. The cabin heat exchanger for the mission was known to be efficient, as evidenced by the 40° F gas-outlet temperature. However, increased heat loads (since the design of the cabin-cooling circuit) relaxed the initially acceptable temperature limits, and the MA-8 system performed within current acceptable ranges.

Communications Systems

Performance of the spacecraft communications systems was satisfactory for the MA-8 mission. Major modifications to the systems since the previous mission included the removal of one of the two command receiver decoder units, the removal of the hf recovery transceiver, and the addition of a new hf dipole antenna. For additional information relating to the performance of the communication systems, refer to the section on "Mercury Worldwide Network Performance."

The dipole antenna was installed to improve hf voice performance during the orbital phase. The dipole antenna was mounted on the retropackage (fig. 21) and consisted of two elements, one of which is shown in figure 22. The extendable portion of the antenna was made of specially treated beryllium copper tape; and each side, when deployed by the firing of a squib, measured 14 feet long and five-eighths inch in diameter. A coaxial switch was added to allow the selection of either the bicone antenna or the dipole antenna for orbital communications and for the selection of the whip antenna after landing.

A miniaturized uhf transceiver operating at the frequency of the low-link telemetry was added to enable the pilot, when in the liferaft, to establish voice contact with the recovery forces. In addition, an extension cable was provided for use of the spacecraft voice equipment from the liferaft. To reduce the helmet microphone size and to reduce the sensitivity of the microphone to head motion, a miniaturized microphone replaced the larger two-unit microphones previously used.

Voice communications. - During powered flight, the increased background noise caused keying of the spacecraft transmitter when in the voice-operated switch (VOX) mode of communications. The keying was apparently the result of increased sensitivity and fidelity of the new microphones. After powered flight, the performance of the voice-communication equipment was good.

High-frequency reception and transmission range was improved considerably over that of previous missions. During the first orbital pass, good-quality hf transmissions from the spacecraft were continuously received by the hangar S communications station from the time the spacecraft was near Guaymas until the spacecraft was near Bermuda. However, voice reception at the Mercury Control Center was poor at times when transmissions were patched into the Goddard conference loop. Ultrahigh-frequency communications were normally line of sight. The pilot reported that communications to the spacecraft from the ground stations were exceptionally good. The ground stations reported good-quality hf and uhf reception from the spacecraft. The hf and uhf voice equipment was tested after the mission and was found to be in satisfactory condition. No conclusive reason for the inferior hf voice reception by the Mercury Control Center could be given.

Radar beacons. - Performance of the C- and S-band radar beacons was satisfactory. As in previous missions, amplitude and slight frequency modulation was experienced on the C-band beacon. The condition was not significant and was caused by the phase shifter (wobbulator) and, at times, by the drifting mode of the spacecraft, which resulted in poor antenna orientation.

Location aids. - Recovery forces reported that transmissions from all recovery aids, except the hf rescue beacon (SEASAVE), were received. After landing, hf communications were received, thus indicating that the spacecraft whip antenna was extended and operating electrically. The SEASAVE beacon was tested after flight and found to be satisfactory. Reasons concerning why SEASAVE signals were not received after landing cannot be given.

Command receivers. - The command receivers operated normally during the launch and orbital flight phases. However, at 09:08:21 g. e. t., shortly after antenna fairing separation, an all-events-channel indication with a signal strength of 3 microvolts was noted. Attempts to duplicate this anomaly during rigorous postflight testing were not successful, and no cause for its occurrence could be found.

Electrical and Sequential Systems

Electrical system. - The MA-8 spacecraft electrical system was essentially the same as the MA-7 system. The system operated satisfactorily throughout the mission, and voltage and current profiles were as expected. Some minor modifications made to the system that were not present in spacecraft 18 (MA-7 mission) were as follows:

1. The Zener diode bus regulators and associated fuses were removed from the main and isolated 24-volt dc buses.

2. The internal battery for the flashing recovery light was removed. The unit was powered from the 6-volt dc standby bus.

3. The capability to monitor standby-inverter voltage was added to the ac voltselector switch for the voltmeter.

4. The maximum-altitude sensor was powered from the main 24-volt dc squib bus only. The special auxiliary battery and associated relays were removed prior to flight.

5. The command receiver was powered by the standby 18-volt bus.

There were no problems associated with inverter temperatures. The temperature for both inverters at lift-off was 90° F. The temperature of the 150-volt-ampere inverter increased to 100° F in 20 minutes and then stabilized at approximately this temperature until reentry. This observation indicated that the 150-volt-ampere cold plate was effective. At landing, the temperature was 120° F, which was caused by the increased cabin temperature during reentry and by the loss of cooling effectiveness at lower altitudes. The 250-volt-ampere inverter matched its load profile by increasing temperature whenever the inverter was powered and by decreasing temperature when the inverter was not powered. The maximum temperature for the 250-volt-ampere inverter was 175° F at the end of the orbital mission, indicating that the 250-volt-ampere cold plate was not functioning properly. Postflight tests confirmed that the cold plate was providing only a small fraction of its preflight cooling capacity.

Sequential system. - The sequential system for spacecraft 16 was substantially modified as a result of a study of nonredundant components and subcircuitry (single-point-failure analysis). All modifications are listed in the section on "Spacecraft Description." The major modifications are as follows:

1. The orbit-attitude relay circuit was revised to assure that the launch and abort sequence would not be disarmed before spacecraft separation.

2. The SECO signal was locked out until tower separation. Previously, a premature SECO could have been accepted immediately after booster-stage separation.

3. A retrofire arm switch and a bypass relay were added. In conjunction with the retrorocket fuse switches, these additions would reduce the possibility of premature retrorocket ignition while retaining the automatic ignition capability.

4. The 21 000-foot barostats were wired in series to reduce the possibility of premature parachute deployment.

5. The two 10 000-foot barostats for main-parachute deployment were wired in series and were provided with an automatic crossover if either the main or the isolated squib bus failed.

The Pacific Command ship reported that retrofire occurred 2 seconds late. However, the flight data show that retrosequence started at the proper time called for by the satellite clock. The start of retrofiring occurred 30.5 seconds later, which was within 0.1 second of the 30.4-second timeout time expected from the MA-8 retrofire time-delay relay.

The flashing recovery light was reported to have stopped flashing during recovery operations. Although the procedure specified that the wiring to the light was to be disconnected during recovery, no confirmation of the wiring disconnection could be made. The reason for the failure of the light to continue operating was not known. Postflight tests showed the flashing light to be operating properly.

The 18-volt isolated bus displayed a pulsating voltage on telemetry which was caused by the indications of satellite clock pulses at the commutator sampling rate. The clock caused a voltage pulse each second, and the commutator sampled the bus every 0.8 second; therefore, every fifth sampling at a period of 4 seconds transmitted the corresponding clock pulse. The transmitted data indicated a voltage drop on the ground. The pulses varied in amplitude because the commutator sampled different portions of the pulse. This pulsating voltage was present during the MA-7 mission and was also observed during postflight testing of the MA-8 spacecraft.

Instrumentation System

The instrumentation system was used to monitor the operation of specific equipment in the spacecraft, and the associated measurement data were either displayed to the pilot or transmitted to the ground, or both. In addition, certain aeromedical data were transmitted and recorded. The more critical portions of the data were transmitted to the ground for flight-control monitoring through the operation of two telemetry transmitters. The pilot-observer camera, mounted on the instrument panel, recorded the activities of the pilot at a programed exposure rate throughout the mission.

System description. - The instrumentation system flown in the MA-8 mission was essentially the same as the instrumentation system flown in the MA-7 mission. Many deletions and changes were made in the MA-7 data format to accommodate new areas of interest. The higher exposure rate for the pilot-observer camera was deleted to extend the coverage of the available film. The vernier clock and mixed events were deleted to provide for monitoring the operation of the automatic-control-system solenoids when in the FBW mode. The modification was accomplished without a format change in the subcarriers. The thermistor previously mounted on the microphone for recording respiration rate was deleted, and an impedance pneumograph was used for measuring respiration. The primary and secondary oxygen transducers were modified to read-out pressure directly in hundreds of pounds per square inch. The BPMS was mounted to the spacecraft structure, since the leg restraints for the pilot had been removed. To accommodate the retrofire clock counter, the commutated control-stick positions were deleted from the high-level commutator. B-nut temperature segments on the pitch-up and pitch-down 1-pound automatic solenoids were substituted for the outer skin-temperature segments.

Additional changes to the instrumentation system for spacecraft 16 included the following:

1. A 5-second time-delay relay was added onto the starting circuit of the BPMS so that the pilot would not have to hold the start-button depress until the system was properly pressurized.

2. The dome temperatures of the suit and cabin heat exchanger were monitored rather than suit and cabin steam-vent temperatures.

3. Thin-base magnetic tape was used in the onboard recorder to provide full coverage of the extended mission.

4. The following temperatures were monitored on the instrument panel by the pilot:

a. Standby inverter

b. Cabin heat-exchanger outlet

c. Roll, left manual B-nut, 1 pound

d. Roll, right automatic B-nut, 1 pound

e. Roll, left automatic B-nut, 1 pound

f. Right retrorocket

g. The 150-volt-ampere main inverter

h. The 250-volt-ampere main inverter

i. Yaw, right automatic B-nut, 1 pound

j. Yaw, left automatic B-nut, 1 pound

k. Pitch, down automatic B-nut, 1 pound

l. Pitch, up automatic B-nut, 1 pound

Only the first three parameters were not monitored on high- and low-link telemetry.

Prelaunch. - A resistance element under thermocouple no. 6 on the low-level commutator, channel 17, was erratic during the preflight launch-complex testing. Extensive analysis showed that the associated spacecraft wiring had a varying resistance of from 2 to 15 ohms. Corrective measures would have required too much time; therefore, the parameter was listed as unnecessary for flight and consequently invalid for postflight analysis.

During the horizon-scanner calibration at the pad, a Z-calibration relay failed in the normally closed position. The relay was wired out of the circuit for flight. The R- and Z-calibration relays were also removed from the respiration-rate circuit. In neither case was the calibration circuit necessary.

During the launch simulation test, the 108-second automatic-stop timer of the BPMS failed to operate to return the telemetry to the electrocardiogram (ECG). The system could still be operated by having the pilot push the stop button. Therefore, the decision was made to proceed with the mission under these conditions. A postflight failure analysis was conducted on the BPMS controller, and it was found that a switching transistor had started, which removed power from the controller after the 108-second time interval. It could not be determined whether this was caused by a transistor failure, or was the end result of some other malfunction.

On the day that the launch precount was started, the high-link body temperature read-out became slightly noisy. A decision was made to continue with the count because the equivalent low-link read-out was yielding good data.

At T - 5 minutes during the launch countdown, body-temperature readings on both links became erratic. The flight surgeon decided to go ahead with the mission because the suit-inlet temperature reading was good. At 01:52:00 g. e. t., both links again indicated normal body-temperature readings and continued to do so throughout the mission. Postflight tests indicated that body temperature on both links was still valid, and more extensive tests failed to determine what caused the erratic behavior at T - 5 minutes.

During preflight static firing of the RCS, the meter for pilot display of the manual-system fuel quantity read 5 percent low. Telemetry for the same parameter indicated a correct reading. The reason for the meter error was determined by postflight testing to have been a shift in the meter calibration. With the exception of the previously noted items, all instrumentation and telemetry were working correctly at lift-off.

Launch. - At lift-off, the telemetry signals were of good quality, with signal strengths of 10 000 microvolts for the high link and 2500 microvolts for the low link. At T - 3 minutes, the high link was -3. 5 kilocycles from center frequency, and the low link was +1. 1 kilocycles from center frequency.

Orbit. - During the mission, a discrepancy was observed between the suit-inlet temperature reading by the pilot and that transmitted via telemetry to the ground. Postflight analysis of the onboard data verified that throughout the mission the average reading of both the high- and low-link telemetry on suit-inlet air temperature was approximately 8° F higher than the readings by the pilot. After 2:00:00 g. e. t., however, the average for the high- and low-link telemetry reading on suit-inlet temperature was 6° F above the reading by the pilot. It was concluded from postflight tests of the instrument-panel read-out that the effects of cabin-temperature variation and improper calibration caused the panel unit to read low. For additional discussion of this discrepancy, refer to the section on "Environmental Control System."

The oxygen partial-pressure read-out behaved erratically during some of the mission. For approximately 15 minutes, starting at 1:14:00 g.e.t., the partial-pressure indications were of no value. After that, occasional erratic readings lasted approximately 30 seconds. Postflight analysis of the behavior was not possible because the instrument sensor dried out.

Summary. - With the exception of the malfunctions in body temperature and oxygen partial-pressure instrumentation, both of which operated satisfactorily before the mission was completed, the performance of the remainder of the instrumentation system was generally satisfactory. The pilot-observer camera operated as programed, and data for most of the mission were recorded on the onboard tape.

Slight discrepancies were also noted between telemetry values and instrument-panel read-outs for cabin temperature, main bus dc volts, and the fan bus ac volts; however, the discrepancies were not significant enough to cause concern. The Z-axis acceleration data appeared erroneous, which could not be explained.

Heat Protection System

The spacecraft heat protection system performed satisfactorily as in past missions. The only anomaly detected during postflight inspection was extensive cracking and bond-line separation of the heat-shield ablation layer.

Heat shield. - As well as could be determined, the materials and construction of the heat shield were the same as for heat shields used on previous orbital missions, with the exception that the center plug was bolted to the structural laminate to prevent loss after reentry. The center plug was found firmly attached to the heat shield during postflight examination.

As on previous orbital missions, the heat shield provided satisfactory thermal protection during reentry. As was expected, the stagnation point appeared to have been very near the center of the shield, and the usual glass droplet streaks extended out from the center (fig. 23).

The minor and major cracks in the ablation laminate are shown in figure 23. The cracks and the separation at the bond line are shown in a cross-sectional view in figure 24. The separation at the bond line, where the ablation laminate was glued to the structural laminate, was found to be extensive over the center portion of the shield and extended approximately to one-half the radius of the shield. The unbonded surfaces were smooth. The cracks in the ablation laminate apparently occurred after reentry heating, as evidenced by a uniform char depth in the cracked and uncracked portions of the ablation laminate.

When the bond-line separation was found in the shield used for the MA-8 mission, a section was cut from the MA-7 shield, and it was found that substantial bond-line separation was also evident, but without major cracks showing at the exterior of the ablation laminate. It was concluded, after a detailed study of heat-shield historical records, that proper quality control, thorough X-ray procedures, and discrete selection of flight items would eliminate substantial bond-line separation for future missions.

A temperature measurement was made at the bond line 27 inches from the geometric center of the shield. The maximum temperature experienced at this point was 450° F and occurred at about the time of main-parachute deployment. This value is in agreement with the maximum temperature of 460° F experienced at the same location on the MA-7 heat shield. During the orbital phase, the heat-shield temperature averaged 60° F.

The heating appeared to be uniform over the shield as indicated by 12 core samples taken at various locations in the shield. Char-depth measurements were normal, varying from 0.3 to 0.35 inch as in previous missions.

The measured weight loss of 17.43 pounds was more than that experienced during previous missions. The MA-7 heat shield lost 13.1 pounds, and the calculated loss was approximately 11 pounds. The measured weight loss for previous missions had been as low as 6.1 pounds. However, the heat-shield drying procedure, used after flight to remove water, was not the same for all missions, thus leading to some uncertainty as to the significance of the apparent differences in weight loss. A summary of the Mercury heat-shield performance for all missions, including the MA-8 mission, is contained in reference 5.

Afterbody. - Temperatures experienced by the conical-cylindrical shingles during the launch phase were normal, and postflight inspection revealed no adverse heating effects. The maximum temperature that occurred on the conical section during launch was a normal value of 1184° F near the heat-shield attachment point.

During the orbital phase, the temperatures on the afterbody shingles agreed with the temperatures experienced on previous missions. The temperatures approached repetitive cycles with the outside skin reaching a maximum of 250° F and a minimum of -50° F.

Spacecraft reentry temperatures were typical of those experienced on previous orbital missions. The maximum measured temperature during reentry on the conical section was 975° F. On the cylindrical section, temperatures were measured at three longitudinal stations spaced at 5-inch intervals. The maximum measured temperatures on the center line of the shingle were 631°, 580°, and 481° F, with the lowest temperature being nearest the conical sections.

A total of four inner skin temperatures were measured during all phases of the mission. The average of the measured inner skin temperatures was 100° F during the orbital phase of the mission, and the maximum temperature experienced during reentry was 145° F.

White-paint patch. - During the launch phase, the temperature of the oxidized shingle was a maximum of 410° F higher than the adjacent shingle area with white paint. During the orbital phase, the oxidized shingle was approximately 130° F hotter in the sunlight just before darkness. While the spacecraft was in darkness, the oxidized shingle was approximately 70° F hotter.

During the early (low-temperature portion) part of reentry, the temperature of the oxidized shingle was approximately 300° F hotter, but later in reentry (high-temperature portion), the oxidized shingle became 110° F cooler than the white-painted area. A similar test was made in the MA-7 mission, but the data were questionable as to magnitude; however, a similar trend was noted. The higher temperature of the oxidized shingle during exit and at the start of reentry was apparently caused by the lower emissivity of the oxidized shingle at lower temperatures. The lower emissivity resulted in less radiation of aerodynamically induced thermal energy with an accompanying higher temperature of the shingle. At the higher temperatures during reentry, where the oxidized shingle emissivity was higher, the oxidized shingle radiated more energy and thus became cooler than the white-painted area. The results of the calculations were in reasonable agreement with the measured temperature differences.

Green-glow effect. - The MA-8 pilot observed a green glow in the area of the beryllium shingles during reentry. The MA-7 pilot also reported a greenish glow in the area during reentry. Nine of the 12 beryllium shingles on the MA-8 spacecraft had experimental ablation materials attached, and the materials could have contributed to the green glow. However, a possible explanation for the green-glow effect was that during assembly, the beryllium shingles were lubricated with a compound which contained copper. Copper compounds, when heated in a flame, cause the flame to exhibit a green color. Because of the high temperatures experienced by the cylindrical afterbody, the heating of the copper compound was believed to have been a major contributory cause of the observed green glow.

Mechanical and Pyrotechnic Systems

The only known anomaly which occurred in the mechanical system during the MA-8 mission was a slight tearing of the main-parachute deployment bag. The rocket and pyrotechnic systems performed satisfactorily throughout the mission.

Recovery sequence. - The recovery sequence system differed from that used in the MA-7 mission in two respects: (1) The cabin-mounted control barostat was deleted, and (2) the barostats in the recovery section were wired in series rather than in parallel.

Parachutes. - The performance of the drogue and main parachutes upon deployment was satisfactory. Only the drogue parachute was recovered for postflight inspection, but the pilot reported that both parachutes were deployed cleanly and were undamaged during descent. A single variant encountered in the parachute system was three small tears in the main-parachute deployment bag. The tears were about 1 inch in length and approximately 6 inches below the top of the bag (fig. 25). The drogue parachute was deployed manually at a pressure altitude of 39 400 feet (standard conditions) with the planned altitude intended for approximately 40 000 feet. The main parachute was deployed automatically at a pressure altitude of 10 600 feet (standard day conditions). This altitude is coincident with the nominal specification value. Since there were no known instances of broken shroud lines in previous missions or test programs under normal deployment conditions, it was concluded that the dangling line reported by the pilot during descent on the main parachute was probably the reefing-cutter line.

Rockets and pyrotechnics. - A postflight examination of the spacecraft and an analysis of the pertinent data indicated that all rockets and pyrotechnics functioned normally. It cannot be determined whether or not certain pyrotechnics (such as redundant clamp-ring bolts and the tower-jettison igniter) actually ignited since the available information shows only that the resulting function was satisfactory.

Explosive-actuated hatch. - The explosive-actuated side hatch was opened after the spacecraft was placed on board the recovery ship. The hatch actuated normally, although the pilot injured his hand slightly during the procedure.

Landing-shock attenuation system. - The landing-shock attenuation system was unaltered from the MA-7 configuration. The landing bag deployed at a pressure altitude of 9800 feet, and the system performed normally, according to statements by the pilot and from postflight examinations. The postflight examination of the bag showed some small tears and rips of a minor nature. The straps and cables were not damaged beyond that normally experienced in previous missions.

The ablation shield appeared intact, although the circumferential cracks appeared larger and more numerous than usual. The fiber-glass protective shield was penetrated by the heat-shield lugs, indicating that recontact occurred. The automatic roll shutoff valve on the RCS showed evidence of contact with the heat shield, and a primary hydrogen peroxide line had been dented. The main pressure bulkhead did not exhibit any visible damage. The indications of recontact were slightly more noticeable than in the MA-7 mission.

Flotation. - Reports and photographs from the recovery forces indicated that the spacecraft righted itself quickly and floated at the proper attitude.

Postflight Inspection and Meteoroid Analysis

Spacecraft 16 underwent the normal postflight inspection and conditioning procedure. A thorough visual inspection was made of the external and internal areas of the spacecraft in the as-received condition. The immediate postflight inspection procedure included removal of the heat shield, landing bag, and conical and beryllium shingles for inspection of the pressure-bulkhead and internal skin areas. A photographic record was made of the inspection process.

A desalting washdown, tank drainage, and a flushing procedure, as applicable, were accomplished, and safeguards against deterioration were taken. The detailed inspection results of individual spacecraft structural systems are discussed in the following paragraphs.

Structure. - The conical-section shingles showed the usual bluish and orange tinge, and the cylindrical-section shingles which had no ablative material attached showed the usual dark yellow-grey appearance. Both discolorations were caused by aerodynamic heating. Nine of the cylindrical-section shingles had samples of ablative material bonded to their surfaces. The temperature-sensitive paints showed that temperature had varied with location around the periphery of the cylindrical section during reentry. The hatch-seal area on the conical section was warped and distorted as a result of explosive hatch actuation.

Ablation shield. - Two of the heat-shield retaining lugs were found to be sheared off and one was bent. One of the sheared-off lugs was found imbedded in the fiber-glass protective shield. Refer to the section on "Heat Protection System" for additional discussion.

Landing bag. - The landing bag had a few small tears and several punctures that probably occurred when the heat shield recontacted with the bottom of the spacecraft on landing. All the landing-bag straps were intact, although they were buckled and twisted. One of the landing-bag cables had a few broken strands near the ablation-shield attachment fitting.

Recovery compartment. - The interior of the compartment was undamaged, and the appearance was normal. The butterfly antenna atop the spacecraft was corroded, and both extension arms were broken. The whip antenna was missing from its housing, since standard recovery practice was to sever the antenna.

Antenna canister. - The destabilizing flap on the antenna canister showed normal heating effects, but the fiber-glass scanner cover attached to the flap was burned off. The flap still rotated easily about its hinge, and the flap spring was in working order.

The face of the pitch scanner was discolored. The parachute hold-down foot shaft was bent, and one rivet head had pulled through the fiber-glass disk. All 10 of the rivet heads, which attach the fairing to the center post, had pulled through the lower conical section of the antenna fairing.

Main pressure bulkhead. - The fiber-glass protective shield was gouged in seven places, and some of the RCS lines were damaged as a result of recontact by the heat shield on landing. Landing damage also included bending of the mounting brackets for the heat-shield release valve and the roll manual push-pull valve. Two corrosion pits of approximately 0.018 inch were noted on the hydrogen peroxide tank for the automatic system.

Spacecraft interior. - The interior of the spacecraft was in good condition, as was expected. A quantity of from 20 to 25 cc of liquid was found under the pilot couch. A postflight chemical analysis showed the liquid to be a mixture of salt water and recovery-dye marker. As a result of the explosive hatch actuation, the hatch springs were completely straightened. The right-hand filter on the viewing window was broken as a result of being latched open when the hatch was actuated. A considerable number of paint chips was discovered throughout the spacecraft interior.

Micrometeoroid analysis. - The investigation of spacecraft 16 for evidence of meteoroid impingement consisted of both preflight and postflight microscopic examination of the René 41 afterbody shingles. Limitations were imposed on the examinations by the spacecraft exterior finish. The shingles had an oxidized exterior surface with a measured surface finish of 25 to 30 microns root mean square. Thus, the presence of minute impingements on the order of 10 microns could be masked by these surface finishes. A detailed examination of the René shingles of spacecraft 13 (MA-6 mission), which employed optical and electron microscopes and X-ray diffraction, indicated the existence of an oxidation change to the surface. The effect undoubtedly occurred during the aerodynamic heating phases and made the search for evidence of meteoroid impacts difficult.

The number of impacts on the spacecraft conical section could be predicted from theory, since the particle flux at a given surface could be related to a statistically derived flux-mass distribution. Using a modified penetration equation, a 10^{-7} gram particle with a velocity of 30 km/sec would penetrate a conical-section shingle (ref. 6).

Preflight examination: Prior to the MA-8 mission, the entire exterior surface of the spacecraft was examined under 5X magnification, and some small surface areas were examined under 12X magnification. The examinations revealed many flecks of paint, minute surface scratches, and small metal particles. Because of the high density of the imperfections, no attempt was made to microscopically map the surfaces of the spacecraft. The examinations also revealed no hemispherical dents.

Postflight examination: Following the MA-8 mission, the surface of the spacecraft was examined under 12X magnification. A preliminary examination revealed seven possible impacts. The impacts were then viewed by using 40X magnification, and they were larger but similar to impacts found on shingles not exposed to flight conditions. The postflight examination revealed that the number of points of brilliance resulting from oblique particle impingement had increased considerably over that noted in the preflight examination. A more detailed microscopic investigation, however, failed to reveal any surface imperfections which could conclusively be attributed to in-flight meteoroid impingement.

Scientific Experiments

Four research experiments planned for the MA-8 mission utilized equipment and materials extraneous to the normal spacecraft operation. The experiments were concerned with (1) a light-visibility exercise, (2) general interest photography, (3) an experiment involving reentry-heating effects on various ablation materials, and (4) an investigation of nuclear-radiation phenomena in space. The results of the experiments are discussed in the following paragraphs.

Light-visibility experiment. - Visual sightings of high-intensity ground lights were attempted on the MA-8 mission on the first orbital pass at Woomera, Australia, and on the sixth orbital pass at Durban, South Africa. The objectives of the sightings were to measure the ability of the pilot to acquire a ground light and to determine his level of dark adaptation at the time of the light-visibility experiment. The pilot was provided with a standard light source of approximately 10^6 candlepower (fig. 26) and an extinction photometer (fig. 27). The photometer was identical physically to the photometer carried for the MA-7 mission, but a photographic process instead of the aluminum vapor was used for the variable-density wheel. Four flares, each with an intensity of 10^6 candlepower, were ignited at Woomera. The first two were ignited at 00:58:40 g. e. t., and the remaining two were ignited when the first flares burned out. The reported weather conditions at flare ignition were an 8/10 broken-cloud cover with light rain. Extensive lightning was also reported in the area. The pilot reported the lightning but was unable to identify the flares. Under clear atmospheric conditions and at the point of closest approach, the flares should have appeared as bright to the pilot as a star of the first magnitude.

A high-intensity xenon light was illuminated at Durban at 08:23:00 g. e. t. for a period of 3 minutes on the sixth orbital pass. Based on the power consumption and the generally specified conversion efficiency of this type of xenon lamp, it was estimated that the light produced a maximum luminous intensity of 2.2×10^6 equivalent candlepower. Under clear atmospheric conditions, a light with this luminous intensity at the point of closest approach should have appeared to the pilot at least as bright as a first-magnitude star. Again, the pilot was unable to see any light source that he could identify as coming from this source, although he did report observing what appeared to be a city in the general area. Weather conditions at Durban were reported as heavy cloud cover with rain. Weather conditions at both sites, as in the two previous missions, were unfavorable for observation of the high-intensity ground lights; therefore, positive results could not be obtained.

General photographic study. - The general photography included two areas.

Weather bureau photographs: Photographs for the weather bureau were intended to measure the spectral-reflectance characteristics of cloud, land, and water features on the surface of the Earth by photographs taken from the spacecraft using wide band-pass color filters. The measurements were intended to show the following:

1. The variation of photographic contrast with the wavelength of visible light

2. The radiance values of clouds, land, and water as a function of wavelength when viewed from outside the atmosphere

3. The relative variation of the light scattering in the atmosphere with wavelength

The measurements were used to select a filter for television cameras in the Nimbus Weather Satellite which was under construction. The information also assisted in the design of equipment for future weather satellites and in the investigations of atmospheric physical properties.

The photographs for the experiment were taken with a Hasselblad camera, model 500-C, with a film aperture of 2-1/4 by 2-1/4 inches and an f/2.8, 80-mm, six-element lens with a UV-17 lens cover (fig. 28). Kodak experimental Plus-X serial film, type SO-102, coated on Estar thin base (0.025 inch) was a panchromatic film with red sensitivity extending to about 720 millimicrons and had a daylight exposure index of 64. The film, used generally for high-altitude photographs, was contained in the detachable magazine shown in figure 29. The magazine held film for 45 exposures.

Six gelatin filters were mounted in vertical strips (fig. 30). This assembly was installed in the film-magazine slide opening just ahead of the film plane. The filters were assembled from left to right as follows:

Number	Color	Wratten number	Neutral density
1	Blue	W-475 and W-96	0.1
2	Green	W-61 and W-96	.1
3	Neutral	W-96	.2 and 0.9
4	Yellow	W-15 and W-96	.9
5	Red	W-25 and W-96	.6
6	Far red	W-70 and W-25	

Neutral density was added to each color filter to produce nearly equal film densities when exposed to a grey target. The photographs were taken at a shutter speed of 0.008 second with a lens opening of f/5.6.

To determine the radiance of objects in the picture, the spectral transmittance of all optical materials in the light path must be known. Spectrophotometric curves of the spacecraft window, the camera lens, and the color filters were obtained.

During the MA-8 mission, a total of 15 frames were exposed for the experiment. The first four pictures were taken over the South Atlantic (between 06:35:00 and 06:38:00 g. e. t.) near the twilight line on the Earth. In the photographs, long cloud streaks and patches of thin cirrus were visible. Two photographs of the Moon were taken with the filter mosaic removed. The last nine pictures were taken in sequence over an area of very extensive cloud cover near Brazil (between 08:00:00 and 08:02:00 g. e. t.). Because the reflected light was greater than anticipated, the negatives were overexposed; however, some excellent photographs of well-developed thunderstorms were obtained in the latter sequence.

Analyses of the photographs indicated that contrast was higher through the yellow and red filters than through the blue, green, and neutral filters (fig. 31). The blue and neutral filters showed the lowest contrast, which confirmed that aerosols in the atmosphere scatter predominantly blue light. The scattering is evident at the line of the horizon, which becomes more diffuse in the neutral and yellow filters than in the blue or green filters.

The pilot reported a residue, experienced in previous missions, on the outside of the spacecraft window after the escape tower was jettisoned. The residue introduced an unknown variable into the experiment, which necessitated reporting radiance measurements of minimum values, since the spectral transmittance characteristics of the window at the time the pictures were taken could not be determined precisely.

Terrestrial photographs: A series of color terrestrial photographs were taken on the MA-8 mission for two purposes: (1) to aid in building up a catalog of space photographs of various terrestrial physiographic features, such as folded mountains, fault zones, and volcanic fields and (2) to obtain cloud photographs for comparison with Tiros results. The photographs were also taken using the Hasselblad camera with a second film magazine containing a color reversal film having an American Standards Association number of 160. The film magazine contained about 11 feet of film with a 45-exposure capability. To aid in setting the camera, the pilot was provided with the automatic wide-angle-view exposure meter shown in figure 32. A total of 14 photographs were taken during the third orbital pass over the western part of the United States and Mexico and during the sixth orbital pass over South America. No analysis of physiographic features was made of the pictures because of overexposure of several photographs and the extensive cloud cover over much of the terrain.

Nuclear-radiation experiment. - The NASA Goddard Space Flight Center nuclear-radiation experiment was intended to provide a detailed study of the flux and composition of the galactic-cosmic radiation outside the atmosphere of the Earth and to obtain a measurement of the intensity and the energy spectrum of artificially induced electrons at orbital altitudes.

The nuclear emulsion plates were found to be in good condition following the mission. There was a slight tendency for the emulsion to stick together, possibly as a result of the removal of the heat-reflectant aluminum foil during installation. Results from analysis of the plates agreed with the results of previous missions and indicated a very low level of radiation inside the spacecraft.

Ablation-material investigation. - An experiment was conducted during the MA-8 mission which involved a study of the reentry heating effects on various advanced ablation materials; the materials were considered for possible use in the design of future reentry vehicles. Since ground testing in the laboratory could only approximate the effects of an orbital reentry, the mission was intended to yield heating data applicable to that expected on the leeward side of a vehicle reentering at parabolic velocities. Through the experiment, much larger material samples could be tested than was possible with laboratory facilities. A discussion and the preliminary results of the ablation experiment follow.

Materials: Six organizations supplied a total of eight advanced ablation materials for the experiment.

Test configuration: Each ablation panel, which was bonded to a beryllium shingle of the cylindrical section of the spacecraft, was 15 inches long and 5 inches wide. The panel was centered on the shingle and was applied, starting at the juncture of the conical and cylindrical sections of the spacecraft. Preflight photographs of the materials bonded to nine shingles and one blank shingle are presented in figure 33.

Instrumentation: The backface of two oppositely mounted bare shingles were instrumented with iron-constantan thermocouples. In addition to the thermocouples, temperature-sensitive paints were applied to the inside skin of the shingles to which ablation material was bonded. The paints were also applied to a shingle without a sample to offer some comparison. The temperature-sensitivity range for paints was 149° to 644° F.

Preflight qualifications: Tests were conducted to qualify the material samples for the nominal Mercury mission. Included were acoustic, arc-jet, and hydrogen peroxide compatibility tests. None of the tests presented any evidence that the safety of the mission and the protection of the cylindrical section would be compromised in any way.

Test objectives: The objectives of the experiments were to obtain data which could be correlated with supporting laboratory results and which could be applied to future advanced reentry vehicles. The results of the flight experiment, after a thorough and detailed analysis, provided information for selection of the type of material to be used on advanced design concepts for manned spacecraft.

Analysis of flight data: The main sources of information came from postflight observation, from weight and depth measurement of the ablation material, and from the results of the thermocouples and the temperature-sensitive paint. All materials satisfactorily survived the space and entry environments experienced during the MA-8 mission. The section on "Trajectory and Mission Events" shows time histories of the important trajectory parameters for the mission. A close inspection of the panels following the mission revealed evidence of char and cracking, but there was no evidence of delamination.

A probable longitudinal distribution of peak heating rate was determined. Maximum calculated heating rates on the hotter of the two instrumented shingles varied from a low of 4.4 Btu/ft^2-sec at the end of the shingle nearest the conical section to 6.4 Btu/ft^2-sec at the center of the shingle and to 10.7 Btu/ft^2-sec at the aft end of the shingle. The difference in heating rate, higher at the aft end of the shingle, was assumed to apply to all the shingles.

A probable circumferential variation of peak heating rate around the cylindrical section (at the time of maximum heating) was estimated. Heating rates versus time were calculated from temperature-time histories available from four thermocouples on the two instrumented shingles which had ablation material. A third shingle without ablation material showed a maximum temperature at its center of at least 644° F, as derived from temperature-indicating paints. Heating rates versus time were calculated from this case, and assumed a similarly shaped temperature-time curve as for the other thermocouples, with a maximum temperature of 644° F. From an analysis of the instrumented shingles, the highest and lowest heating rates around the cylindrical section were estimated. For an assumed sinusoidal distribution of heating rate around the cylindrical section, the approximate heating rates for the other shingles could, therefore, be approximated. An estimation of spacecraft angle of attack was made from limited aerodynamic data, and probably there was no more than a 2° angle of attack at maximum heating. An estimation of angle of attack was also made from wind-tunnel data, using the effect of angle of attack on the midcylinder circumferential distribution of the heat-transfer coefficient. On this basis, it was determined that the capsule angle of attack at maximum heating was below 5° and probably close to 0°. The circumferential variation of heating around the cylindrical section precluded the opportunity to compare each material panel with all others to assess superior thermal protection and restricted the shingles which could be compared.

All materials showed evidence of ablation in the form of cracking, areas of spallation, areas of discoloration, and char. The materials in the area of higher heating rates showed these symptoms in more severe form. However, no shingle material on the hot side showed superior surface reaction over any material on the cool side.

Detailed observations were made of the intentional and purposeful repairs made by most suppliers. As a group, the elastomeric materials were superior in restricting the gaps in the filled and unfilled cutouts. The appearance of most filled cutouts showed no major dimensional changes from the original. However, severe delaminations, chipping, pitting, cracking, and dimensional changes were present in most unfilled cutouts. Two suppliers reinforced the holes in their material with an epoxy filler to prevent any cracking or erosion.

A comparison of X-ray photographs and postflight surface inspection was made. The purpose of the comparison was to determine if a correlation existed between voids in the bond shown by the X-rays and failing of the material in that area. Only in the case of large voids in the bond did the void, shown by an X-ray photograph, appear to manifest itself in a spallation of the material, and then only in a noncharring material.

Conclusions: The major conclusions that were drawn from the analyses of data on ablation materials tested during the MA-8 mission were as follows:

1. Each material panel could not be compared with all other panels because of an estimated circumferential variation of heating around the cylindrical section. The variation was probably caused by a 2° angle of attack at maximum heating.

2. There was an increase of temperature and char depth and an increase of thickness loss as the aft end of each material panel was approached. The increase was caused by an observed longitudinal variation of heating rate along each cylindrical-section shingle.

3. No serious delamination of any material was found on the MA-8 mission test. All materials held the backface temperature to a level which achieved an acceptable bond strength.

4. No material experiencing a higher heating rate performed better than any material experiencing a lower heating rate; that is, no material performance had overridden the normal-heating distribution. Therefore, as a group, the materials on the hot side showed the poorest surface characteristics and the highest backface temperatures, as determined by the temperature-sensitive paints.

5. The elastomeric materials proved superior to the hard ablation materials in limiting the growth or delamination of the intentional cutouts.

6. The filled cutouts proved superior to the unfilled cutouts in limiting their own growth and delamination.

7. No general correlation was found between voids shown in the X-ray photographs and ultimate spallation of the material in the area. However, in the case of large voids in the bond, shown by the X-ray photograph for a noncharring ablator, the voids showed up as spallations in the material.

8. Surface effects previously shown during ground testing appeared in the post-flight analysis, but to a lesser extent. The use of relatively large specimens to experience the actual space and entry environment could not be duplicated in a ground facility at the time of the investigation.

Preliminary results: A close inspection of the panels following the mission revealed evidence of char and some minor cracking, but there was no evidence of delamination. It was observed from the temperature-sensitive paints and the thermocouple measurements that the backface temperatures varied around the cylindrical section and indicated an asymmetrical thermal load. The heat flux also appeared to have increased longitudinally from the conical section towards the antenna section.

It appeared that the cylindrical-section shingles received little damage from post-flight handling by the recovery crews. On some of the samples, intentional cutouts were included to test the effectiveness of field repairs. Preliminary results indicated that all purposeful repairs were no more affected by the reentry than the unimpaired areas. The repairs did not compromise the protection qualities of the remainder of the sample or the beryllium shingle.

AEROMEDICAL ANALYSIS

The aeromedical studies for the MA-8 mission amplified and extended the program outlined in previous manned space-flight reports. Before the mission, the pilot's state of health and medical fitness for the mission were evaluated continuously. The accumulation of these preflight data familiarized the aeromedical monitors with the normal physiological responses of the pilot and provided a base line with which to compare the in-flight and postflight aeromedical data so that changes resulting from the space flight could be determined. These studies are presented in three classifications: clinical examinations, physiological observations, and special studies.

Clinical Examinations

The clinical examinations consisted of repeated aeromedical histories, physical examinations of the pilot by physicians, clinical laboratory tests, X-rays, and other routine medical procedures, such as an ECG and an electroencephalogram (EEG). The immediate preflight and postflight clinical examinations were accomplished as close together as time permitted in order to detect any physical changes induced by the mission. The postflight physical examination and medical debriefing differed from previous missions in several important aspects. Since recovery was planned for the Pacific Ocean, the decision was made to carry out the entire debriefing on board the recovery aircraft carrier. This procedure permitted a much earlier opportunity to complete some phases of the medical examination, which on previous missions had been postponed for several hours. The actual landing of the spacecraft in the immediate vicinity of the carrier allowed early recovery and, thus, early postflight medical examination of the pilot by a NASA flight surgeon. The aircraft carrier was a satisfactory location for the clinical examination in terms of space and equipment.

Physiological Observations

The physiological observations were based on a comparison of data collected on the ground during preflight activities and during the mission. Physiological data on the MA-8 pilot, Walter M. Schirra, Jr., were obtained from the following sources:

1. Biosensor monitoring during preflight activities
2. Onboard recorded continuous biosensor records
3. Reports from the range medical monitors
4. Voice transmissions
5. Pilot-observer camera film
6. Results of special in-flight tests
7. Postflight debriefing

Special Studies

Special studies for the MA-8 mission consisted of nonroutine medical procedures designed to provide information about selected body functions and sensations in the spacecraft environment during flight.

Biosensor System

The Mercury biosensor system for the mission consisted of two sets of ECG leads, a rectal temperature thermistor, an impedance pneumograph, and the BPMS. Previous postflight reports (refs. 1 to 3) contain most of the details of this system, and only major changes are noted in the following paragraphs.

Electrocardiographic monitoring system. - The continuous ECG monitoring system used during the MA-8 mission was basically the same as the system used for previous missions. Alterations were introduced in the electrode location and the composition of the electrode attachment. The electrode positions were unchanged except for the right-side electrode, which was moved slightly below the right axilla, but remained in the midaxillary line to minimize any muscle artifact. The biosensor harness was modified by the addition of two electrodes for the pneumograph. This lead was of the same design as those leads used for the ECG, but it was located to produce the greatest possible thoracic volume change associated with normal respiration.

The ECG electrodes were attached with double-backed adhesive tape which was cut to fit the rubber ring of the sensor. The sensor paste was changed from the previous bentonite-calcium-chloride material to a combination of carboxypolymethylene and hypertonic Ringer's solution. Carboxypolymethylene is a hygroscopic polymerized carrier for the ions needed to provide electrical continuity. This carrier is more soluble and easier to manage than the bentonite paste. The use of a 10-times-isotonic Ringer's solution provided the necessary amount of conductivity and low impedance and had the added feature of decreased skin irritation after prolonged contact.

Blood-pressure measuring system. - As a result of previous experience with the BPMS, new preflight testing procedures were introduced. A comprehensive engineering evaluation which followed the MA-7 mission suggested a need for improvement in the criteria for adjusting the amplification of the sounds picked up by the microphone located over the brachial artery. The sounds corresponded to those sounds heard with a stethoscope during cuff-pressure decay. Extensive comparisons between standard clinical blood-pressure readings and readings obtained using the BPMS allowed determination of a more nearly optimum controller-gain setting for the MA-8 pilot. As a result, the read-out during the MA-8 mission improved noticeably over the read-out for the MA-7 mission.

The BPMS cuff thickness was decreased without change in bladder size for increased comfort, and the caliber of the hose from the cuff to the suit connection was decreased. The changes did not affect the cuff-filling or bleed-down times, and the basic system was unchanged.

During preflight launch-pad testing, the BPMS automatic timer failed. The failure made it necessary for the pilot to push the manual stop button at cycle completion, which resulted in a return of the telemetry read-out from BPMS to ECG lead II. This manual technique was used throughout the mission.

Body-temperature measurement. - The body-temperature measurement system was unchanged from the previous mission, but the read-out failed 6 minutes before launch with the signal going full scale. At about the middle of the second orbital pass, a nominal reading reappeared, but was intermittent thereafter.

Pneumograph. - The pneumograph produced a signal from impedance across the chest, which was directly proportional to thoracic volume. The thoracic-impedance variation correlated well with spirometer data, although the correlation was not linear. The impedance-pneumograph system consisted of a 50-kilocycle oscillator, a 50-kilocycle amplifier, a detector, and a low-frequency amplifier. The output of the oscillator was applied across the chest through an electrode in each midaxillary line at about the level of the sixth rib. These electrodes, the conductive paste, and methods of attachment were identical to the ECG electrode system described previously. The oscillator output was made variable by means of a potentiometer so that, for all but exceptionally deep breathing, the inspiratory peaks remained on scale on the direct-wiring recorder. Even for cases in which the range was exceeded, the respiratory rate could still be determined unless excessive body movement masked the thoracic-volume changes of respiration. The unit did not indicate instantaneous tidal volume, but it did provide respiration rate and a general indication of chest-volume changes. Inspiration signals were distinguishable even during the thoracic-volume changes which occurred with speaking (fig. 34).

Body movements of the pilot during the mission made the respiratory trace difficult to interpret, but the restrictions imposed by the spacecraft design on pilot movement kept motion artifact to a minimum. The spacecraft environment materially affected the physiological responses of the pilot; therefore, the information presented in the section on "Environmental Control System" complements the discussion of physiological observations.

Preflight Aeromedical History

The pilot spent most of the time between June 1962 and the launch date at Cape Canaveral in preparation for the MA-8 mission. During this period, he chose swimming and waterskiing as his modes of physical conditioning. In the several days immediately prior to flight, he did not participate in direct physical conditioning. The controlled diet, begun September 21, 1962, provided a well-balanced menu. A low-residue diet was consumed for the 3 days before flight. A list of the items for each meal of the low-residue diet appears in table IX. The pilot reported minimal difficulty in becoming accustomed to the diet. As in previous manned missions, breakfast on the morning of the mission consisted of eggs, steak, buttered toast, jelly, orange juice, and coffee. Also, a small amount of the bluefish, which was caught by the pilot on the evening before the mission, was eaten. All of the 325-cc fluid intake on launch morning from awakening to lift-off was at breakfast and consisted largely of orange juice. The pilot reported that shortly before lift-off he was aware of an emptiness in his stomach. This sensation is attributed to the fact that he had not eaten for 5 hours. He voided three times into the urine collection device between the time of insertion into the spacecraft and the launch (a total period of 155 minutes).

The MA-8 aeromedical countdown (table X) differed from the countdowns of previous missions only in the periods allotted for each activity and the time at which the pilot was awakened. Such changes reflected not only the operational requirements to complete certain tasks, but also represented an effort to provide the pilot with a maximum amount of sleep prior to the mission. Without medication, the pilot obtained 5 hours of sound sleep immediately before the mission. The new direct-writing bioinstrumentation package in the hangar S aeromedical laboratory permitted simultaneous biosensor and pressure-suit check-out. Therefore, a separate time allotment was no longer required for each of these activities. All events of the aeromedical countdown preceded the launch-pad countdown insertion time. A comparison of the activities with the activities of previous orbital missions is shown below.

Mission	Pilot awakened, a. m. e. s. t.	Nominal launch, a. m. e. s. t.	Time to nominal launch, hr: min	Actual launch, a. m. e. s. t.	Time to actual launch, hr: min
MA-6	2:20	8:00	5:40	9:47	7:27
MA-7	1:15	7:00	5:45	7:45	6:30
MA-8	1:40	7:00	5:20	7:15	5:35

Preflight Physical Examination

Abbreviated physical examinations were conducted by the flight surgeon prior to each of the preflight activities listed in table XI. A more extensive examination was conducted 15 days prior to the mission. Also, a comprehensive medical evaluation, performed by specialists in internal medicine, neuropsychiatry, opthalmology, radiology, and clinical laboratory and by the flight surgeon, was completed 2 days before the mission. The evaluation included an audiogram, chest X-ray, and ECG. For purposes of postflight comparison, the EEG taken May 17, 1962, was deemed adequate and was not repeated before the mission. All of the medical evaluations revealed a healthy and alert pilot, appropriately prepared for his flight assignment.

Preflight Physiological Data

Base-line physiological data were obtained from the following preflight activities (total observation time, 23 hours 27 minutes):

1. Dynamic tests (treadmill, tilt table, and cold pressor) conducted at the Lovelace Clinic March 1959

2. The Mercury-Atlas three-orbital-pass simulation conducted at the Johnsville Aeromedical Acceleration Laboratory (AMAL) September 22, 1961

3. A simulated flight May 4, 1962, conducted at the launch complex as a part of the MA-7 prelaunch preparation

4. Simulated flights in the hangar altitude chamber conducted with the MA-7 spacecraft at altitude April 17, 1962, and with the MA-8 spacecraft at sea level August 14, 1962

5. Simulated flights at the launch complex September 10 and 14, 1962

6. Records from the hangar preparation area, transfer van, and blockhouse obtained during the countdown October 3, 1962

The base-line data in table XII summarize all available heart- and respiration-rate data. Rates from the dynamic simulation at the Johnsville AMAL were determined for each minute from T - 90 seconds to T + 66 minutes. Other heart and respiration minute rates were obtained by counting 30 seconds every 3 minutes. Rates for the final 10 minutes of the MA-8 launch countdown were determined by counting for 30 seconds every minute. All values were within physiologically acceptable limits. The mean prelaunch heart and respiration rates were similar to rates obtained during other activities prior to the mission. The preflight body temperatures ranged from 97.0° to 98.6° F. Body temperatures varied from 97.1° to 97.9° F during countdown until T - 6 minutes when the reading went full scale.

Examination of the ECG waveform during all prelaunch activities showed only normal sinus arrhythmia, infrequent premature atrial contractions, and rare premature ventricular contractions. During launch countdown, a single premature atrial contraction was detected.

Blood-pressure data are summarized in table XIII. The values in the "Special BPMS test" category were obtained from a series of comparisons between the clinical and the BPMS readings which were derived prior to launch in an effort to determine the best BPMS amplifier gain adjustment. Random clinical determinations were obtained from routine annual physical examinations and from examinations associated with the various preflight activities. The blood-pressure values derived from BPMS and clinical sources prior to the mission were similar and represented normal physiological responses.

Flight Physiological Data

Figure 35 illustrates the in-flight physiological responses, which are summarized in table XII. Minute rates were obtained by counting 30 seconds of each minute from lift-off to 10 minutes g. e. t., and from 08:48 to 09:12 g. e. t., which was approximately the time of biosensor disconnect. Values for the intermediate segment of the mission were obtained by counting for 30 seconds every 3 minutes. The mean in-flight heart and respiration rates were not significantly different from the mean preflight values. The maximum heart rate during the launch phase was 112 beats/min, with a minimum of 102 beats/min. The maximum rate during the mission was 121 beats/min at T + 6 minutes. Thereafter, the heart rate gradually declined (fig. 35) until the slowest rate was 56 beats/min. During reentry, the maximum rate was 104 beats/min. These responses were within the expected physiological ranges. A careful evaluation of individual heart cycles revealed a frequent increase and slowing of heart rate which appeared to be unrelated to activity of the pilot and was of a greater magnitude than his normal sinus arrhythmia.

The maximum respiration rate during launch was 37 breaths/min at T + 5 minutes, when maximum acceleration occurred immediately prior to SECO. During weightless flight, respiration rates were close to the mean value. During reentry at 09:05 g. e. t., the respiration rate reached a maximum of 43 breaths/min associated with maximum reentry acceleration. Thereafter, the rate declined to 20 breaths/min at biosensor disconnect. These values were also within accepted physiological ranges.

From 00:08:00 to 09:02:00 g. e. t., 20 BPMS cycles were obtained periodically (fig. 35) throughout the mission. The systolic levels were clearly evident on all 20 cycles. Premature manual cutoff of the BPMS operation made four of the diastolic points questionable, and these values were not included in the data. All of the values shown in table XIII were similar to the values obtained during preflight and postflight observations. The mean pulse pressure of 57 mm Hg was not significantly elevated from the other values. The in-flight bioinstrumentation record, which included a blood-pressure cycle, is shown in figure 36.

Examination of the ECG waveform of the pilot during the mission showed no change from preflight waveforms. One atrial premature beat, one ventricular premature beat, and one fusion beat were noted in the more than 9 hours of continuous ECG monitoring. The fusion beat is illustrated in figure 37, and the ECG artifacts typical of this mission are shown in figure 38.

During the initial period of the mission, the body-temperature values were unreadable. This parameter suddenly returned to readable levels at 01:52:00 g. e. t. (table XIV). During the remainder of the mission, the read-out varied from 97.7° to 98.5° F with occasional sudden small changes as noted in table XIV. The values were normal, but their accuracy was questionable, since proper operation of the system could not be verified.

Special Studies

The modified caloric test and retinal photography were two special tests performed for the MA-8 mission. The modified caloric test was accomplished 6 days before the mission and 2 hours after landing by the same physician. Both the retinal photography and the modified caloric test, performed after the mission, revealed no significant change from preflight values. The technique for the modified caloric test is discussed in detail in reference 6. In addition to the radiation packs normally installed in the spacecraft, three self-indicating dosimeters were carried on board and placed on the inside of the hatch by the pilot after launch. Two solid-state lithium fluoride dosimeters were placed in the helmet liner at eye level, and three were placed on the inside of the underwear over the chest. The self-indicating dosimeters revealed only a minimal amount of radiation exposure (a dose of radiation of approximately 0.06). Refer to the section on "Scientific Experiment" for a discussion and results of the radiation detection devices carried in the MA-8 spacecraft.

In-flight Aeromedical History

Despite the 3.5-hour increase in the duration of weightlessness over the previous two manned orbital space flights, no untoward sensations were reported by the pilot. Specifically, he was not nauseated nor did he vomit. Although he was never hungry during the mission, the pilot consumed without difficulty peaches and beef with vegetables, which were contained in collapsible tubes. Solid-food cubes were not evaluated since the pilot could not reach them during the mission. He experienced no urge to defecate during the mission. He reported a moderate amount of in-flight flatulence but no eructation. Vision and hearing were normal. The pilot moved his head as required by his assigned tasks during weightlessness, including periods in which the spacecraft was slowly turning in drifting flight, yet he reported neither vestibular disturbance nor disorientation. Bladder sensation and function, as in all previous Mercury missions, were reported as normal. The noise and vibration of powered flight caused no particular problems.

Weightlessness was described as "very pleasant," but there was no exhilaration, euphoria, breakoff phenomenon, or other unusual psychological reactions. Reaching for spacecraft controls was no different from prior experience in the Mercury procedures trainer. As a test, at three specific times during the flight, the pilot closed his eyes and attempted to touch three specific controls or instruments. He recorded his error, if any, on the onboard tape. The errors were few (three on nine trials) and the maximum error was 2 inches in a lateral direction from one of the three targets on the second attempt. There was no tendency to overshoot or undershoot, and his final test was the most accurate.

A few minor problems were encountered in flight. During the fourth or fifth orbital pass, some fluid was deposited onto the inner surface of the helmet faceplate. The vision of the pilot was obscured to some degree by the fluid, and he was forced to turn his head more than usual to look through a clear area of the visor. The fluid was analyzed and conclusively determined to have been perspiration.

The pilot stated that he was warm and perspired moderately during the first orbital pass when the suit-inlet temperature was elevated. However, he said he was not uncomfortably hot during this period. The evaluation by the flight surgeon in the Mercury Control Center concluded that the pilot was physiologically capable of continuing the mission, assuming that the suit-inlet temperature could be brought under control during the next orbital pass. This control was achieved, and during the fifth and sixth passes, the pilot even became "a little cool." Otherwise, he said he was comfortable throughout the mission.

The pilot developed slight nasal congestion during the final two orbital passes. The congestion caused the pilot no difficulty in clearing his ears, and it did not affect his respiration. About 4 hours after recovery, he developed a mild rhinorrhea (nasal discharge). By the next day, the symptoms had almost disappeared.

Postflight Physical Examination

Initial observation of the pilot by a physician occurred about 40 minutes after landing and immediately following the opening of the spacecraft hatch. He appeared active, cheerful, and well coordinated and exited from the spacecraft without assistance. There was no evidence of dizziness or deterioration of gait or station at any time following the mission. He expressed great pleasure at the way the mission had gone with such expressions as: "I feel fine; It was a textbook flight; The flight went just the way I wanted it to." He did not appear unusually fatigued, he was eager to talk, and he took an active part in the postflight physical examination.

Less than 1 hour after landing, the aeromedical examination of the pilot was well underway. Oral temperature was 99.4° F, rectal temperature was 100.1° F, sitting blood pressure was 118/78, and the pilot's pulse was 92 beats/min and regular. The skin of the pilot was warm and dry, and he showed little other evidence of dehydration. The pilot's weight loss was 4.5 ± 0.5 pounds, in spite of the fact that he ate and drank very little during the mission. The areas of sensor placement on his chest were examined carefully. There were slightly reddened areas due to pressure, but there was no evidence of irritation from either the tape or the electrolyte paste. Two small abrasions were noted over the proximal knuckle of the fifth finger of his right hand. The injury was received when the plunger of the explosive actuator for the egress hatch recoiled against his gloved hand. The injury was almost identical to the one received by the pilot of the MA-6 mission during egress from the spacecraft when he also was struck by this plunger. There was a reddened area over each acromial process due to pressure from the couch. Apparently, the reddened areas resulted from muscle-tensing exercises in which the pilot braced his feet on the foot board and his shoulders against the upper portion of the couch and tensed his back and leg muscles.

The modified caloric test of labyrinthine function was performed about 2 hours after landing and showed no significant change from the examination September 27, 1962. The EEG, which was taken about 3 hours after landing, was normal and showed no significant changes from the EEG done May 17, 1962.

A complete physical examination revealed only one finding which was considered significant; the pilot demonstrated orthostatic hypotension and increased lability of blood pressure and pulse with changes in body position. These values are shown in table XV. When supine, his heart rate averaged about 70 beats/min, but the rate immediately increased to 100 beats/min or more when the pilot stood up. His blood pressure showed a less dramatic, but still significant, drop in systolic pressure when he changed from the supine to the upright position. The reverse was true when the pilot changed his position from standing to supine. Pulse and blood-pressure values recorded when the pilot was seated consistently fell between the standing and supine values. In addition, it was noted that all his dependent veins were engorged. His feet and legs rapidly took on a dusky, reddish-purple color following standing. The pilot commented that the color changes were more noticeable than any he had observed previously.

All of these findings persisted for the 6 hours following recovery and prior to the retirement of the pilot for the night. The next morning, about 21 hours after landing, examination revealed that the orthostatic changes in pulse and blood pressure were much less marked. Also, the engorgement of the depended veins was much less apparent. At no time did the pilot complain of dizziness, lightheadedness, or other symptoms of orthostatic hypotension. He did, however, offer the information that he had felt lightheaded upon egress from the procedures trainer after he had been supine on the couch for 4 hours in a Mercury suit at normal gravity.

These findings were the result of several factors. Prolonged periods in the supine position can be followed by changes in hemodynamics. The pilot was slightly fatigued and dehydrated, and there was a possibility of individual variation that further complicated the picture. Similar hemodynamic reactions were observed in experimental work with individuals submerged in water or kept in bed for prolonged periods in attempts to simulate weightlessness. The pilot smoked several cigarettes during the postflight examination phase. Cigarette smoking is known to cause peripheral vasoconstriction and thereby affect blood pressure. In view of these factors, it was impossible to isolate the true contribution of 9 hours of weightlessness to the problem.

During the mission, the pilot drank about 473 cc of water. He urinated three times before lift-off and three times during flight, the last time just before retrofire. Unfortunately, the urine collection device failed at its attachment to the body and allowed the loss of most of the urine. Approximately 300 cc of urine was recovered and showed a specific gravity of 1.010. The specific gravity of the pilot's urine rose to 1.018 within a few hours after recovery, and the highest value of 1.021 occurred approximately 12 hours after recovery. The 24-hour period following the mission showed a fluid intake of 2580 cc and a measurable fluid loss of 775 cc. The pilot's hematocrit rose from a value of 44 percent before the mission to 47 percent immediately after the mission; 28 hours later, the hematocrit was 46 percent and dropped to 43 percent in another 24 hours. These values, coupled with the findings on physical examinations, indicated that dehydration of the pilot was minimal during the mission.

Following the initial medical examination after recovery, the pilot was taken to his cabin where he ate a hearty meal. He was still eager to talk and maintained his usual cheerful sense of humor. He retired for the night after a busy period of 21 hours 40 minutes. After 10 hours of sound sleep, he awoke, urinated, talked, read, and smoked for about an hour. He then returned to bed and slept for 3 more hours. He appeared well rested and had no apparent residual fatigue from the mission.

The aeromedical debriefing team, composed of the same individuals who conducted the preflight comprehensive medical evaluation, examined the pilot 30 hours after landing. The physical and mental evaluation of the pilot included, in addition to the physical examination by physicians, an ECG, an EEG 3.5 hours after landing, chest X-rays, and clinical laboratory studies. The preflight and postflight medical examination results are presented in tables XVI, XVII, and XVIII. Aside from the abrasion noted on the pilot's right hand, all findings were normal.

The following conclusions were made from the aeromedical results of the MA-8 mission:

1. There was no evidence of disorientation or related untoward symptoms of the pilot during the 9.5-hour period of weightlessness. The orientation test conducted during the mission demonstrated no impairment of his motor performance during the weightless period.

2. Orthostatic hypotension of the pilot was noted during the 24-hour period following landing. A decrease in his blood pressure and an associated increase in his heart rate upon standing may have more serious implications for longer duration missions.

3. Lability of instantaneous heart rate was noted, but it did not appear associated with respiration or activity of the pilot.

4. The radiation exposure was far less than the predicted level and posed no biological hazard to the pilot.

5. There appeared to be no medical contraindications to embarking on longer duration missions.

PILOT FLIGHT ACTIVITIES

The primary responsibility of the pilot during the MA-8 mission, as in the previous orbital missions, was to monitor and manage systems operations and, if necessary, to take corrective action in order to achieve the prescribed mission objectives. The secondary responsibility of the pilot during the mission was to accomplish various inflight activities that would further evaluate the spacecraft systems and provide a basis for evaluating the performance of man in space. Experimental scientific activities were reduced for the mission in view of the greater emphasis placed on operational objectives. The effectiveness of the pilot in achieving the primary mission objectives are described in the following paragraphs. The performance of the pilot in conducting certain scientific experiments, secondary objectives for the mission, are not described since they were discussed previously in the section on "Spacecraft Performance."

Flight-Plan Description

A flight plan was designed for the MA-8 mission to guide the pilot in carrying out the mission objectives with particular emphasis upon management of the systems and conservation of the control fuel. A few scientific activities were scheduled late in the mission on a flexible basis to avoid interfering with operational mission requirements. Control systems were evaluated prior to extending the mission duration beyond three orbital passes.

Pilot adherence to the flight plan was excellent, and all major activities were accomplished within the time periods scheduled. The spacecraft control systems were checked out completely during the first three orbital passes; and the drifting flight phase, as well as the automatic-control-system evaluation scheduled during the final three passes, was completed as planned. Observations of the ground flares at Woomera, Australia, and of the high-intensity lights at Durban, South Africa, were attempted at the proper times, but poor weather conditions prevented the observation by the pilot of both light sources.

Operational Equipment

As in previous manned Mercury missions, the MA-8 pilot had equipment available which was designed to provide quantitative operational data. The equipment was located in a special equipment-storage kit at the right-hand side of the pilot, in a compartment on the instrument panel, and in the chart case. The scientific equipment (described in the section on "Scientific Experiments") was also stowed in two of these places.

The following equipment was located in the special equipment-storage kit (pilot reference, ditty bag):

1. Hand-held camera

2. Terrestrial film magazine

3. Weather bureau film magazine
4. Camera shoulder strap
5. Three radiation dosimeters
6. Extinction photometer
7. Two food tubes and food cube holder
8. Food tube nozzle
9. Motion sickness container

The following equipment was contained in a compartment on the instrument panel (pilot reference, glove compartment):

1. Weather bureau filter mosaic slide
2. Yaw-attitude instrument cover
3. Standard light source
4. Automatic exposure meter
5. Magnetic compass
6. Flight-plan and checklist card holders

The following equipment was contained in the chart case:

1. Chart booklet
2. Star navigation charts
3. Time-conversion computer

The pilot experienced difficulty in reaching items located in the special equipment-storage kit and also items located in the compartment on the instrument panel. It was also difficult for the pilot to remove some of the items stowed in these two locations because they were excessively covered with Velcro (plastic fibrous dry-adhesive material).

The orbital chart booklet of operational aids contained map giving the orbital ground trace and indicating the ground elapsed time with position; the primary and contingency recovery-area locations; locations of the primary and emergency communication and tracking stations; the oxygen-rate rule curves; automatic- and manual-control fuel-usage curves; the emergency continuous-wave code; a nominal retrosequence chart; and an additional orbital map with forecasted weather information.

The star navigation charts (fig. 39) gave five separate plots of star positions near the orbital plane. Each chart was valid for a launch occurring within a half-hour period; therefore, the charts provided approximate star locations for a lift-off time within the period between 6:46 a.m. and 9:16 a.m. e.s.t. The charts were designed so that a slide could be positioned to display the star field equivalent to the window field of view of 30° at any point in the orbit. The star field presented by the chart was approximately 40° on either side of the flight path.

A time-conversion device (fig. 40) was used to refer elapsed times in the first orbital pass to the elapsed times of subsequent passes to determine the position on the star chart which corresponded to any spacecraft elapsed time. The two items presented a handling problem, since two hands were required for the conversion operation.

For the MA-8 mission, the flight-plan cards, one of which is shown in figure 41, were placed on pullout panels that were located just beneath the instrument-panel equipment container. The reverse side of the flight-plan cards contained checklists for critical orbital operations. An example of the checklists is shown in figure 42. Equipment stowage within the spacecraft was distributed between the three locations previously mentioned.

Control Tasks

Several inflight maneuvers and control tasks were programed for the MA-8 mission to obtain additional information about possible orientation problems in space and about the ability of the pilot to perform various attitude-control tasks using accuracy and fuel expenditure as the primary criteria of performance. The tasks are discussed in the following paragraphs.

Turnaround maneuver. - The primary purpose in accomplishing a manual turnaround manuever (using the FBW control mode, low thrusters only) was to conserve control-system fuel. Therefore, it was planned that, if the mission was proceeding normally, the turnaround would be executed at a leisurely pace using a 4-deg/sec rate about the yaw axis.

The pilot performed the maneuver identically as it was practiced on the procedures trainer prior to the mission. Figure 43 shows the spacecraft attitudes as indicated by the gyros and a background envelope of five turnaround maneuvers accomplished on the procedures trainer for comparison. The pilot performed the manuever smoothly and with precision. Only 0.3 pound, or less than 1 percent, of the automatic-control-system fuel supply was used. The quantity amount to approximately 10 percent of the total control fuel required by the automatic control system to accomplish the same maneuver.

The pilot reported that the turnaround maneuver proceeded just as it had on the procedures trainer. In accordance with practice in the trainer, the pilot used only the rate and attitude indicators for reference, and he resisted the temptation to look out the window when the horizon first came into view.

Yaw maneuvers. - Yaw maneuvers were planned for the mission to obtain quantitative information on the use of the window and periscope as independent references for determining and acquiring the proper spacecraft attitude about the yaw axis. The yaw indicator was to be covered and the spacecraft displaced in yaw. However, the maneuver was planned so that the yaw attitude would be retained within gyro- and repeater-stop limits. The maneuvers were performed during both daytime and nighttime phases of the orbit in which the views through the window and the periscope were used independently as external references.

The pilot stated early in the mission that he could accurately estimate yaw attitude during periods when either the ASCS mode was operating, or was in a drifting flight mode.

The first yaw maneuver on the dayside of the Earth, in which the view through the window was used as a reference, was performed over Bermuda at 01:41 g. e. t. during the second orbital pass. The maneuver was followed at 01:50 g. e. t. by a similar exercise using the view through the periscope as a reference. In addition, yaw maneuvers on the nightside of the Earth, in which the view through the window was again used as a reference, were performed in sequence over Muchea, Australia, during the second orbital pass at 02:26 and 02:28 g. e. t. The results of the yaw maneuvers are presented in figure 44, which gives the variation in spacecraft roll, pitch, and and yaw attitudes. Table XIX lists the fuel usage, time required, control mode, and visual reference used for the yaw maneuvers, which are discussed in the order tabulated.

The first yaw maneuver on the dayside of the Earth consisted of three separate yaw displacement and realinement maneuvers accomplished in rapid sequence. The pilot did not, however, record an attitude mark on the voice tape until the end of the final maneuver of the sequence. The pilot yawed the spacecraft approximately 8° to 10° from 0° in each case, holding pitch and roll attitudes reasonably close to retroattitude as intended. At the termination of the maneuver, yaw misalinement was +4°, with roll and pitch attitudes at a nominal 0° and -34°, respectively. As a result of the maneuver, the pilot reported that yaw errors were readily recognized and corrected by using the terrain features or any available type of cloud formation through the window. The pilot reported, and the results of the maneuver verified, that yaw realinement could be accomplished while holding the nominal retroattitude of -34° in pitch. The attitude in pitch made the horizon available for maintaining proper attitudes in pitch and roll while the spacecraft was being oriented in yaw.

In the second yaw maneuver on the dayside of the Earth, the pilot yawed 23° to the right while holding pitch and roll within ±5° of the desired attitudes. At the termination of the maneuver, the spacecraft was in error by +2° in yaw, with pitch and roll at -33° and 0°, respectively.

The pilot reported that yaw misalinements were readily apparent and that realinement to 0° was effected rapidly by using only the periscope reference. However, as a result of the two daytime yaw maneuvers, the pilot reported that the window provided an adequate yaw reference and that the periscope constituted a redundant external reference system.

In the third and fourth yaw maneuvers accomplished on the nightside of the orbit, the pilot used the window as a reference because he found the periscope to be ineffective at night. In performing each of the maneuvers, the pilot yawed approximately 20° left, and then he was able to realine in yaw very close to 9°. At the termination of the third maneuver, the yaw error was +3°; and at the end of the fourth maneuver, the yaw error was -1°. In the course of completing both of these maneuvers, pitch attitude was decreased from the nominal -34° to approximately -22°; however, pitch attitude was returned to about -34° by the end of each maneuver. Excursions in roll were somewhat larger for the maneuvers than they were during the daylight yaw maneuvers; however, the errors were reduced to nearly zero at the completion of the maneuver. The pilot used the Moon and Venus as visual references to perform both of the maneuvers.

The pilot reported that yaw determination on the nightside was more difficult than during the daylight phase because of the small field of view available for the acquisition of star patterns. He reported that through concentrated effort, he was able to acquire attitude alinement about all axes by using the airglow layer as his reference in pitch and roll and a known celestial body as his reference in yaw.

The results of the four maneuvers indicated that for yaw misalinements of the order obtained during the mission, the spacecraft could be realined in yaw during the day or during moonlit night conditions by using the window view as the only visual reference. The maneuvers were accomplished in a 2- to 3-minute time period with an average expenditure of between 0.2 and 0.3 pound of control fuel, and realinement of spacecraft attitudes was readily achieved to within ±5° of the nominal retroattitude. Yaw alinement on the dayside, in which the periscope was used, required approximately the same amount of both control fuel and time as was required when the window reference was used, with little or no improvement in accuracy.

Drifting Flight. - The spacecraft was permitted to drift completely free in attitude on two different occasions to conserve control fuel. This flight mode is referred to as limited drifting flight. During this time, power to the ASCS was switched off (powered down) to conserve electrical power. On three additional occasions, the pilot maintained the spacecraft attitudes within the limits of the horizon scanners with a minimum amount of control inputs. A total of 2 hours 29 minutes was spent in both types of drifting flight during the mission, with the longest continuous period extending for 1 hour 42 minutes. Most of the drifting period was devoted to flight in the attitude-free state. The total control fuel usage, directly associated with the drifting-flight phases, was approximately 1 pound, and the fuel was almost entirely consumed in reestablishing attitudes at the termination of each period of drifting flight. Drifting flight was not disturbing to the pilot, and the flight results verified that this operational technique provided the means of conserving fuel and electrical power.

Gyro realinement maneuvers. - The gyros were realined to an Earth reference through the window by using FBW on two different occasions. At the completion of both maneuvers, the gyros and horizon scanners were alined quite closely, and torquing of the gyros to the horizon scanners quickly corrected any remaining disparities. The first gyro realinement required 1.71 pounds, but the second maneuver required only 0.66 pound of automatic control fuel.

The first maneuver was accomplished during the night period of the orbit and required two separate gyro caging and uncaging operations to obtain the correct alinement. The procedure used was to determine attitude by observing available star patterns and to acquire and track the horizon by using 2-deg/sec rates or less until the proper position was indicated in the window. The gyros were then caged and uncaged. At this point, roll and pitch were quite well alined; however, an error of approximately 35° in yaw attitude existed at this time. Using the constellation Cassiopeia as a visual reference, the pilot quickly recognized the yaw error and maneuvered to the proper heading.

The procedure used by the pilot in performing the second gyro realinement was (1) to cage and uncage the gyros at -34° in pitch and 0° in roll and yaw and (2) to pitch up to an indicated attitude of +34°, while simultaneously holding roll and yaw attitudes at 0°, and again cage and uncage the gyros. The maneuver was performed during the daylight phase of the orbit, and again the Earth horizon reference through the window was used. The errors in slaving the gyros to the horizon scanners were within ±7° for all axes at the completion of the maneuver, and the scanners required less than a minute to correct the remaining gyro errors.

Pitch maneuvers. - On four occasions during the mission, the pilot maneuvered from retroattitude to reentry attitude in pitch, prior to selecting the automatic reentry-select control mode. Typical fuel usage for the pitch-attitude change was 0.20 pound of the automatic fuel supply. During the final pitch maneuver to reentry attitude, the pilot simultaneously checked the FBW high thrusters, and this action resulted in a much higher fuel usage than the previous pitch maneuvers. The pilot performed these maneuvers with precision, and at the completion of each maneuver, he engaged the automatic control system without actuating the high reaction control thrusters.

Retrofire. - The pilot completed stowage of the items on the preretrofire checklist, and he was thus prepared well in advance of the retrosequence event. Just before the last sunrise and prior to the retrosequence event, the pilot used Jupiter, Fomalhaut, and the constellation Grus to verify that the gyro indicators functioned properly. As planned, the automatic control system was used to control the spacecraft attitude during retrofire, with the MP control mode selected as a backup. During retrofire, the pilot cross-checked his window reference and reported that the spacecraft attitude was constant within less than 1° about all axes. Just prior to retrosequence, the pilot reported that the glare of the sun through the periscope was blinding, and he therefore placed the dark filter over the lens.

Reentry. - As planned, the pilot used the RSCS mode for controlling the reentry phase of the mission. Although the system consumed large quantities of control-system fuel at a rate which was expected (for example, 50 percent of the manual supply was expended from 0.05g to drogue-parachute deployment), this fact almost led the pilot to select the auxiliary damping control mode of the ASCS.

Systems Management and Operational Procedures

Throughout the mission, the pilot exhibited an excellent monitoring technique and operational procedure in managing the spacecraft systems. During the mission, the pilot reported clearly and accurately on the status of systems and maintained a commentary on in-flight activities, such as yaw maneuvers, control-mode usage, spacecraft elapsed time, and visual observations. The pilot exercised sound judgment and procedure in resolving the suit-circuit-temperature control problem. The procedure for switching off (powering down) and switching on (powering up) the ASCS inverter was performed exactly as planned. The pilot maintained an effective surveillance for possible discrepancies between true vehicle and gyro attitudes, as well as the overall operation of spacecraft electrical systems. The proper fuse-control switch positions were selected throughout the mission, and the drogue parachute and snorkle-inlet valves were manually activated at the proper time.

Control-mode switching. - The use of control systems and control-mode switching operations by the pilot was excellent. He was able to accomplish the switching operations with a minimum amount of fuel usage. Table XX is a tabulation of the operation of the control systems by the pilot and includes a correlation with major flight activities.

Table XXI lists the control modes and combinations of control-mode configurations and the total time and frequency that each control system was used during the mission. The pilot used a total of 14 single- or dual-control combinations, and he switched control modes 54 times during the mission. The automatic control system controlled the spacecraft 60 percent of the total orbital mission time; the pilot manually controlled the spacecraft 16 percent of the total mission time; and the spacecraft was permitted to drift in an attitude-free mode the remaining 24 percent of the mission time.

The pilot selected the automatic control system on 23 different occasions. In one case, he inadvertently activated the automatic-control-system high thrusters because he had engaged the automatic control system while the spacecraft was in proper retroattitude, but with the attitude-select switch in the reentry-attitude position. The only other time that automatic-control-system high-thruster operation occurred, other than during the retrofire period, was just prior to 0.05g. This activation resulted when the ASCS in orbit mode failed to keep the spacecraft attitude within the attitude limits.

The pilot selected double-authority control on four occasions during the mission. The first case was inadvertent and occurred when the pilot changed from the MP control mode to the FBW, low thrusters only (FBW low) control mode. The pilot noticed the greater than normal response for the FBW-low control mode, and immediately returned to a single-authority control configuration.

The second case of double-authority control occurred just before the single instance in which the pilot inadvertently actuated the automatic-control-system high thrusters. The pilot analyzed the situation as a stuck thruster in the automatic control system, and he selected rate command in conjunction with the FBW-low control mode to counteract the effect of the automatic-mode high thrusters.

In the third case, the MP system was utilized to override the automatic system in order to correct for an error of approximately 10° in roll at the end of the horizon-scanner test.

The final case of double-authority control occurred during the ignition period for the retrorockets. The pilot selected MP control, as planned, to back up the automatic control system in case it failed to control the spacecraft attitude properly during the event.

Fuel usage. - The amount of fuel used during the maneuvering flight phase and control-mode switching exercises was much less than the amount predicted from calculations based on the prescribed flight plan. A fuel-usage history is presented in figure 45. The fuel reserve at retrofire was approximately 80 percent of initial levels for both the manual and automatic fuel supplies, which represented a total fuel consumption of only 12 pounds for almost 9 hours of flight. The automatic control system controlled the spacecraft attitudes during 60 percent of the mission, and all the scheduled maneuvers and control system operations were accomplished. The fuel economy exhibited on the mission can be attributed to the following:

1. The pilot performed the turnaround maneuver using only the FBW-low control mode. Fuel usage for the maneuver was approximately 10 percent of that required by the automatic control system to accomplish the same task.

2. The high thrusters of the automatic control system were activated on two brief occasions prior to retrofire, one of which resulted from an oversight on the part of the pilot and for which he quickly corrected.

3. The FBW-low control mode was used for most of the manual maneuvers.

4. The pilot executed each maneuver smoothly and with minimal control inputs.

5. The pilot used a systematic procedure for fuel conservation, particularly during control-system checks.

Conclusions

Throughout the mission the pilot exhibited good monitoring and operational procedures in managing the spacecraft systems. During the entire mission, the pilot reported clearly and accurately on the status of systems, and he maintained a good verbal commentary on his in-flight activities, such as the yaw maneuvers, control-mode usage, spacecraft elapsed time, and visual observations. The pilot exercised good judgment and procedure in resolving the suit-circuit-temperature control problem. The procedure for powering down and powering up the ASCS inverter was performed exactly as planned. The pilot maintained a good surveillance for possible discrepancies between true vehicle and gyro attitudes, as well as the overall operation of the electrical systems. The proper fuse-control switch positions were selected throughout the mission, and the drogue and snorkle were manually activated as planned. Results of the mission indicate that the pilot was able to think ahead of the mission at all times.

PILOT'S FLIGHT REPORT

[Editor's note: A personal narrative is presented of the MA-8 pilot's flight experiences during the mission. This candid evaluation of the performance of the spacecraft throughout the mission was derived from the pilot's self-debriefing conducted on board the recovery aircraft carrier immediately following the flight. The transcript of that recorded debriefing was lightly edited to appear in the format which follows. The pilot's system-oriented opinions are a reflection of the greater emphasis placed on the engineering aspects of the Mercury program and were extremely valuable in making the postlaunch investigation of the flight results a comprehensive one.]

One of the main objectives of this flight was an engineering evaluation of the spacecraft systems to determine their capabilities for an extended mission. In line with this objective, we wanted to demonstrate that the consumable supplies could be conserved sufficiently to permit longer duration flights in the future using the Mercury spacecraft. Of course, most of the consumables, such as water, electrical power, and contaminant filters, will have to be increased, but it is still important to determine the long-term consumption rates.

Since this was to be an engineering evaluation, the name chosen for my spacecraft was that of the mathematical symbol for summation, sigma, with the number 7 added to it for the seven-member Mercury astronaut team. Thus was derived the name and symbol that was painted on the spacecraft, Sigma 7.

The camaraderie of everyone concerned with the flight preparations and equipment meant a great deal to me. For example, it was certainly a thrill while entering the spacecraft on launch day to see a dummy "ignition key" on the control stick safety pin. This and other small gestures really helped to make me realize that there are many other people who were interested in what I was doing. We know this inherently, but these visible examples of it mean quite a bit. Here again, sigma symbolizes the summation of the great efforts exerted by each and every man in the vast Mercury team.

The following comments are my observations and impressions of the flight from the countdown to recovery. In a previous section the flight plan was described and my performance in completing the assigned tasks was discussed. In this section, I will amplify that discussion, as well as describe my own flight sensations. In many instances, I will submit comparisons of my observations with those of astronauts who preceded me into space. It was their pioneering efforts which helped so much to make my flight a success.

Countdown and Powered Flight

The countdown was conducted very successfully; there were absolutely no problems. The only delay was that resulting from a temporary loss of signal from the Canary Islands' radar system, but waiting for what proved to be a rapid repair was worthwhile since they had good radar acquisition during the first orbital pass. The tracking task is critical at this time, because it provides early definition of the spacecraft trajectory.

The boosted flight itself was disappointingly short. Considerable training was conducted to prepare me for emergencies which might occur during powered flight. We so often practiced system failures and aborts, either in the procedures trainer or by coordinating the trainer with the Mercury Control Center and Bermuda stations, that this practice made a very pronounced impression upon me.

This launch, in contrast, was a successful, normal flight where I encountered many new experiences. I still believe that the amount of practice we had for the period prior to insertion is important, in that here the pilot must be prepared for reaction to an emergency, rather than thinking one out.

There is no doubt about when lift-off occurred. If anything, I was somewhat surprised because it occurred earlier than I had anticipated. I heard the vernier engines start, felt them thrusting, and then heard the main engines start. During ascent, the communications with the Cape Capsule Communicator were perfect except for the few seconds when the noise of maximum dynamic pressure triggered the voice-operated relay and prevented the ground transmissions from reaching me. I never felt rushed, and all the events during launch were in order.

I had more than the anticipated time available to me to make my system checks. My scan pattern of the instrumentation panel was developed to where it was instinctive. I thought from my training that I might have missed on making a good electrical check prior to 3 minutes but subsequent to tower jettison; however, I found that I had completed that in time. There was absolutely no question as to when booster engine cutoff (BECO) occurred. The change in acceleration was quite obvious; whereas in the trainer, I could only wait for the accelerometer indication to decrease. There is no doubt, whatsoever, when these forces decrease in actual flight. Since beginning this mission, I had become familiar with checkoff points for various emergencies; for example, a no-BECO abort, a no-staging abort, and an abort at 3 minutes and 50 seconds after lift-off. It was a very pleasant feeling to check each of these off and put them behind me.

I knew that the launch vehicle staged without having to wait for confirmation from the Cape Cap Com, which, by the way, did come in rapid order. You can see the flashback of smoke from the booster engines as they part from the sustainer stage, and you can see the escape rocket when it is jettisoned. Unfortunately, the escape rocket blast left a light film on the window.

It did seem that the buildup of acceleration during the sustainer period was rather slow. As I look back, the forces I experienced while being accelerated in boosted flight seemed to be much less than the later forces of reentry. This comparison, I am sure, is best explained by the fact that you have a breathing point at BECO, in between the accelerations, while at reentry there is a long continuous buildup of accelerations which are equally as exciting as those during boosted flight.

Orbital Flight

At sustainer engine cutoff (SECO), the sequence panel light did not seem to help very much. All the lights were somewhat dim, and I was made aware of these events better by the feel and sound than by the sequence light itself drawing my eye to it. After SECO, I immediately selected the auxiliary damping mode knowing from my previous training that there was no rush, selected fly-by-wire, low, on the thrust select switch, and commenced turnaround. I resisted every impulse to look out of the window at this point, as I wanted to make this a fuel-minimum turnaround by strictly monitoring the gyro instruments. I was pleased to note that I got exactly the turnaround I wanted in the fly-by-wire low control mode, including approximately 4 degrees per second left yaw. I had no trouble with any of the low thrusters at this time or at subsequent times during the flight. I attained retroattitude at about 6 minutes and 50 seconds after lift-off and then selected ASCS, dropping into this automatic-pilot mode without any high thruster action.

After turnaround, I observed the sustainer stage right where it had been predicted to be, and I was very intrigued. I was somewhat surprised to see the sustainer engine pointing toward me. By this, I mean that it was basically in an attitude where it must have turned lengthwise 180°. It was moving very, very slowly in relation to its insertion attitude, although it had managed to make a 180° turnaround during the time I had made mine. I was also impressed with the fact that it was almost black in appearance, rather than the shiny silvery vehicle that Astronauts Glenn and Carpenter had seen at this time and that I had observed on the launching pad. The white bellyband of condensed moisture, the frost itself, was apparent to me. The sustainer followed the path that was predicted, and this knowledge helped to satisfy me that the attitude gryos and horizon scanners were operating properly. I did not see any crystalline material exhausting from the sustainer engine which Scott Carpenter had described. The sustainer, in retrospect, appeared slightly to the right of the predicted position which indicated a slight error to the left in my indicated attitude about the yaw axis.

It was a very real satisfaction to receive the statement from the Cape Cap Com that I had at least a seven-orbit capability. As I proceeded on to the Canary Islands, the flight was textbook already. I never did feel rushed; in fact I could send a blood pressure, for example, and have little else to do. I got a good 10-minute check when the tower jettison and cap sep lights indicating spacecraft separation went out. I had loss of voice transmission with the Cape Cap Com just prior to 10 minutes. Although I had everything under control, I did store away all events and switch positions to transmit to the Canary Islands Station, since their relaying of these data would, in turn, update the flight director and the flight controllers back at the Cape.

At about 10 minutes 30 seconds, I went back to fly-by-wire, low, and tracked the sustainer as it traversed down through the window, and it was a thrill to realize the delicate touch that it is possible to have with fly-by-wire, low. This touch is an art that a pilot hopes to acquire in air-to-air gunnery for getting hits. In this case the control system was so effective that it just amounted to a light touch and maybe a few pulses in either axis to get the response I wanted. I could point the spacecraft at anything I wanted to. I could see the sustainer and track it, but I do not believe the relative motion problem would be so easy to solve that I would be able to steam along and join up with it. Although the relative velocity was on the order of 20 to 30 feet per second, it was enough to cause a problem, particularly at a time when one is becoming acclimated to a new environment. These problems would be difficult to solve by one's own inherent trajectory analysis, since there were no systems aboard to aid the pilot in solving the problem. I think that when we build up to the rendezvous technique, one will need more time than that just at the point of insertion to effect this rendezvous, even with proper training. The use of time while orbiting in space is only earth relative, therefore if a rendezvous is not hurried, the task should be relatively simple.

At the Canaries, the flight itself had settled into a very normal pattern, I was content with the autopilot function, although I was convinced by this time that I had a small discrepancy between indicated and actual yaw attitude. During the sustainer tracking exercise, I had disabled the yaw reference system, and I knew that I had to wait for it to precess out the errors before I misjudged it. Having pitched up with manual proportional control, I was content that the system was exactly as I felt it would be. The greatest effect I did notice in manual proportional control was the tail-off in thrust, rather than the response to control input. As a result, you have a tendency to overshoot, and you cannot park the spacecraft in the attitude you want without having to counteract and then recounteract a tail-off. As a result of this effect, almost every time I went from manual proportional back to automatic mode, I switched to fly-by-wire, low, to reduce these small rates to a level at which I could effect this transition without using high thrusters.

I did not have much chance to assess Africa as a viewing sight; I was much more engrossed in what was happening within the spacecraft. I did, of course, notice the color of Africa's desert terrain; it was difficult not to notice it. The country itself was exactly as I had anticipated from the orbital charts. At this time, I was well aware of the fact that we were working up to a slight suit-system cooling problem. I decided then to devote my primary attention to solving to solving this situation before it became necessary to end the flight prematurely. I was well aware of the fact that people on the ground were probably quite concerned and were thinking in terms of previous missions when cooling problems had persisted. Therefore, I decided I had better solve this one.

I did not want to increase the valve setting for the suit circuit too rapidly. I had said before the flight that I wanted to increase the flow settings about half a mark every 10 minutes, and this technique had been agreed upon by the system specialists. I had to go from a setting of 4 to 8, which represents about eight half marks. This procedure would therefore take about 80 minutes. At a setting of about 7, I had arrested the increase in the suit and dome temperatures, and I needed about another 10 or 15 minutes to get the cooling I wanted. I did not want to increase the setting too rapidly and freeze the system. I had everything monitored closely, and while I saw the temperature was still going up as I increased flow, the rate of change of the temperature was decreasing.

Even though it seemed to me that the Mercury Control Center did not have as much information as I did on this temperature problem, their request that I decrease the suit setting back to 3 was valid. I later decided that they might have made an analysis that I had not and subsequently backed down to the number 3 position as requested. I gave the system about 10 minutes to respond and saw that both the dome temperature and the suit inlet temperature were increasing again, so I immediately went from there up to about 7.5, which again arrested the temperature increases.

Once the suit circuit temperature was under control, no other problems demanded such careful attention. Continually, I metered the attitude control fuel and attempted to conserve its use. Electrical power, which is stored in six batteries, is another consumable that I wanted to conserve. There were scheduled periods during the flight where I powered down electrical systems. In addition, I conserved electrical power by recording my observations with a voice-operated relay "record-only" mode, rather than transmitting out of range of the Mercury tracking stations. Although we don't have a system for measuring the actual power remaining, battery voltage readings are a good indication, and I was very impressed that the voltage readings did not drop during the flight.

I do not believe I need to discuss the weather, the sun, or the stars. It seems more appropriate to discuss the events within the spacecraft. Each network station got as much information as I had available to give them. Once we had solved the suit circuit problem and I had begun to feel cool, I knew we were in a "go" status and I had achieved my goal of using minimum fuel up to this point. I had stated long ago that I wanted to do some control manuevers other than in fully automatic mode. I also had stated that I wanted to use the automatic mode when I did not need to employ manual modes or when I was too busy to fly the spacecraft, since this is why we have an autopilot. Admittedly, we have taken a system that was designed to be completely automatic and then tried to build some versatility into it and give the pilot the capability of controlling the vehicle as he desires. I had become satisfied with my capability of controlling the spacecraft before I got to the Canaries, a fact which I reported to the ground. From that time on, I merely wanted to make observations that seemed to have merit and to use the control system only during those periods when I had to reestablish the attitude within the limits required to drop back into the automatic mode.

I was discouraged by the tremendous quantity of cloud coverage around the earth and realized that it may always be a problem for certain space flight requirements. Africa, on the first and second passes, was ceiling and visibility unlimited (CAVU). The southwestern United States was also CAVU after I crossed over the ridge along the Baja California peninsula. I had a very good view, and I could easily determine yaw attitude by reference to the ground.

When I reestablish orbital attitude as I came over Muchea on the third pass, I was very pleased when I talked to the Muchea Cap Com, and he and I agreed on yaw attitude exactly except for a possible 4° error in left yaw, which was also indicated by my instruments. The telemetered scanner readings were coincident with the spacecraft attitudes, and I had just acquired these attitudes shortly prior to Muchea by using the moon and the planet Venus adjacent to it for visual references. They actually showed up over the Indian Ocean Ship and were very easy to work with. They both lined up to give me a roll, pitch, and yaw reference.

A smog-appearing layer was evident during the fourth pass while I was in drifting flight on the night side, almost at 32° South latitude. I would say that this layer represented about a quarter of the field of view out of the window, and this surprised me. I thought I was looking at clouds all the time until I saw stars down at the bottom or underneath the glowing layer.

Seeing the stars below the glowing layer was probably the biggest surprise I had during the flight. I expect that future flights may help to clarify the nature of this band of light, which appeared to be thicker than that reported by Scott Carpenter.

It was a real treat to pass over each station and realize that they were as excited as I was and as envious as anyone could ever be. I saw the particles that John Glenn reported, and I also saw what Scott Carpenter reported as having seen. I believe that both phenomena are varied in appearance because of lighting conditions at sunrise and during bright daylight.

Retrosequence

I checked the high thrusters in fly-by-wire prior to retrosequence, and on the first demand for each high thruster in all three axes, they worked and reacted beautifully. It was a tremendous feeling to know that I had no problem with the high thrusters becoming cool. At the nominal retrosequence, the Pacific Ocean Ship Cap Com gave a perfect count. Sequence and attitude lights actuated on time. I was sitting there ready to punch the retrosequence button. I did have the safety cover off the button and put it back on again. At the time of retrofire, the delay by a fraction of a second in firing the first rocket seemed agonizingly long. This time is probably the most critical of the flight, at least subsequent to insertion; and you know that these rockets have to work. Again, I was poised to punch off the retrofire button to back up the automatic system. I had its safety cover off, and I guess I put it back on again sometime later. The rocket ignition was crisp, clean, and each one actuated with a definite sound. There was no doubt as to when each rocket was firing. The spacecraft did not seem to vary as much as half a degree in attitude during the period of retrofire. I was also cross-checking out the window and had plenty of visual cues in case things did go wrong with the automatic mode. I could see stars that did not even quiver. Because of these cross-checks, I was aware that the ASCS was working well throughout this period and did not require any manual control inputs.

Subsequent to the retrofire maneuver, I controlled the spacecraft with fly-by-wire. I had the retrojettison switch armed in time, and the retropackage subsequently jettisoned. Control seemed somewhat loose. I guess I was probably excited about the fact that the retrorockets did ignite and did not have the cool head that I should have had. Therefore, I allowed the attitudes to drift off by perhaps 10° or 15° in roll and probably the same amount yaw and pitch. The flying was not really of poor quality, but it was not up to my usual standards. I then brought Sigma 7 up to reentry attitude on fly-by-wire and intentionally actuated some of the high thrusters to see what it felt like. They reacted very well. At this time, I did not want to stay in the rate command mode and use a large quantity of fuel needlessly. I have always believed, with regard to full consumption, that the rate stabilization control system (RSCS) was the most expensive mode of the spacecraft. I came into retrosequence with 80 percent of fuel in each tank, which was higher than my mark, and I was quite pleased that I had that much. After retrofire, the automatic fuel was somewhere around 52 or 53 percent. I easily got into reentry attitude and felt very comfortable with it. The periscope retracted on time. I noticed that my control of the spacecraft was still loose, so I tightened it up and then went into ACSC orbit mode. I wanted to see if the logic had picked up for reentry, and it dropped right in and held beautifully. Then, I set up rate command to give it a small check. It responded very well, and I was satisfied that the system was working.

Reentry

The beginning of the actual entry into the sensible atmosphere, with the attendant cues, was a very thrilling experience. Because my vision was somewhat obscured by perspiration on the inside surface of the visor, the cue for occurrence of the important event, 0.05g, was my visual sensing of the roll rate that was automatically induced by the control system rather than by the 0.05g event light on the panel. The spacecraft with a roll rate is something you just cannot effectively visualize in your mind. It is a very nice series of slow rolls, and you really feel as if you are back in the old fighter seat, just playing games. Looking out at the sky and at the surface of the earth which was starting to brighten up, I observed that the roll pattern was very slow and deliberate. You could integrate your attitude out of this very easily, and I knew that the spacecraft was as stable as an airplane.

The accelerations during reentry were not severe in the sense of bothering me, but it seemed to take much longer than I had anticipated. This was predictable, but it is just one of those things that you cannot seem to approximate in real time, even on the centrifuge which I had trained in just before the flight. It is difficult to store all these cues and inputs into your mind and just pull them out quickly. Physiologically, I never felt any strain as far as the reentry went. Each event came into place as closely as I could have wished.

As the acceleration buildup began, I could see external cues which were of great interest. I missed the hissing that John Glenn and Scott Carpenter described, possibly because I was concentrating so much on how the RSCS system was performing. I was prepared at any time to throw it into the auxiliary damping mode. As expected, an enormous amount of fuel was consumed during reentry before the drogue parachute was deployed. After drogue parachute deployment, of course, the fuel was jettisoned normally. But before the drogue parachute was deployed, that system must have been down to approximately the 20-percent level. This level corresponds to a total fuel consumption from the manual tank during reentry of some 60 percent, or approximately 14 pounds.

There were two occasions when I nearly switched from RSCS to the auxiliary damping mode. One was while I was monitoring the fuel gage; it looked just like a flowmeter. The indicator for the manual tank was visibly dropping. Yet, I continued with RSCS because I wanted to give it every chance to complete the reentry control task in order to evaluate it sufficiently. The second time that I thought about going to the auxiliary damping mode was when the yaw rate left the nominal 2.5 to 3 degrees per second and went off-scale (6 deg/sec) to the left. Soon after this occurrence, it held to about 5 degrees per second and then did the typical needle fanning that we have seen in the reentry training at Langley. Since it had started to hold again, I did not switch to auxiliary damping because I still wanted to allow the RSCS a full demonstration. However, I was perfectly content that the ASCS was working properly and it was good to know I had this powerful system ready to be switched on if needed.

I did see the green glow from the cylindrical section. It was a very pretty color, probably best described as a shade similar to limeade (a little green and chartreuse mixed together). This shade included a slightly stronger yellow cast than I had anticipated from earlier descriptions. One opinion which was ventured that might explain the green-yellow color is the copper treatment on the beryllium shingles. In fact, burning copper in a Bunsen burner flame is a good approximation to the effect that I saw. I did not see any distinctive color differences resulting from the different ablation panels that had been bonded to the beryllium shingles. There were no variances in color, such as a chromatic or a rainbow effect.

The altimeter came off the peg very nicely. I manually deployed the drogue parachute at 40 000 feet. There was a definite, strong thrumming accompanied by the drogue deployment, somewhat like being on a bumpy road. Although it is of no consequence, I was probably about 10 or 15 seconds slow in turning the hydrogen peroxide jettison fuse switch on, and this I can only blame on the intrigue and interest in looking at the drogue parachute up there straining and pulsating. The window definitely was further occluded during reentry.

I armed the recovery arm switch at about 15 000 feet. The main parachute opened at about 10 500 feet, and it was just as pretty as astronauts of previous flights had described it. It sort of puts the cap on the whole thing. I prepared for landing but did not hook up the survival raft to the suit.

Landing and Recovery

On landing, Sigma 7 seemed to sink way down in the water. It also seemed as if I were horizontal for a while. I allowed the main parachute to be jettisoned by punching in the main-parachute disconnect fuse. Then, I actuated the recovery aids switch to the manual position. The spacecraft seemed to take a long time to right itself, but again time is merely relative, and in actuality, the spacecraft righted itself in less than 1 minute. When Sigma 7 had finally started to right itself, it was a very, very pleasant feeling, and at this point I knew I could stay in there forever, if necessary. The suit temperature was 75° F or 76° F, and the highest point reached prior to egress was 78° F.

I had very good communications with the Cap Com at Hawaii. The recovery carrier, which was probably the nearest thing other than the recovery helicopter, was really "down in the mud" as far as communications are concerned. Communications from the carrier were very weak, but legible, as evidenced by the fact that my request for permission to come aboard was immediately granted.

Sigma 7 deserves some nonengineering closing remarks. Aviators are known to acquire an affection for their aircraft when it performs well, and now, in the space age, an astronaut should convey his personal thoughts about his spacecraft. I definitely fell in love with Sigma 7, and it is the first vehicle in my history of flight, that finally replaced the F8F, a Navy propeller-type fighter, as the one on the top of the list. This spacecraft, the crew that prepared her, and the flight itself, truly combine to make the MA-8 experience the high point in my life.

LAUNCH-VEHICLE PERFORMANCE

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

Airframe

The structural integrity of the airframe was maintained throughout powered flight, and maximum activity in airframe measurements occurred in the vicinity of a Mach number of 1 at maximum dynamic pressure as was expected and noted in previous Mercury-Atlas missions. Discrepancies previously attributed to a detected faulty fuel-tank seam weld, which was accepted prior to flight, were noted in the flight data.

Pneumatics

The unfiltered bulkhead differential pressure reached a value of 4.8 psi 1.5 seconds after lift-off, while the filtered bulkhead differential pressure was 8.9 psi. The oscillations were 5 cps with an amplitude of 7.4 psi for the unfiltered pressure and 3.0 psi for the filtered pressure. The oscillations in both measurements were damped out 25 seconds after lift-off. The MA-8 mission was the first Mercury mission without a launch hold-down, and there was a question concerning the possibility of lift-off transients under this condition. However, the bulkhead differential pressure did not reach the abort threshold, which had a lower limit of 2.5 psi.

Abort Sensing and Implementation System

Operation of the ASIS proved to be satisfactory throughout powered flight. The ASIS went to the ready state at T - 0.8 second when fuel pressures of the engines came up to flight level. Telemetry records indicated that pressure-switch operation was normal. No system parameters reached the abort level, and no abort command was generated. After SECO, when engine fuel pressure decayed, the system indicated an abort condition as a normal part of the orbital-insertion procedure.

Propellant Tanking and Utilization

Propellant utilization (PU) matched set 393 was installed in the MA-8 launch vehicle. Data indicated that the PU valve responded to and followed the error-demodulation output command signal. Approximately 215 seconds after lift-off, the PU valve reached the closed limit and remained there until SECO. The lox port uncovered at 7.8 seconds prior to SECO, and the fuel port uncovered at 10.4 seconds prior to SECO. The calculated residuals at SECO were 520 pounds of lox and 115 pounds of fuel.

Fuel tanking to the 100-percent probe was accomplished on X - 1 day. During the countdown, 112 gallons were off-loaded according to the operation plan. The tanking of lox was accomplished without incident. Prior to lox tanking, overall vehicle weight according to the Gilmore weighing system was 151 900 pounds. Predicted versus actual weights were the following:

	Predicted fuel, lb	Actual fuel, lb
95 percent	317 400	317 050
Low level	324 700	324 600
High level	325 250	325 300
Overfill	327 200	327 100

The securing weight of 324 600 pounds was derived by subtracting 2500 pounds from 327 100 pounds. The weight read-out at T - 2 minutes 10 seconds (lox tank securing) was 324 650 pounds.

Flight-Control and Guidance Systems

A clockwise roll transient occurred immediately after lift-off. The data indicated a maximum displacement of 2.52° and a peak rate of 7.83 deg/sec. The effective rate of the roll-control rate gyro, as monitored by the ASIS, was 4.53 deg/sec, which was below the abort level of 6.4 deg/sec for the roll-control rate gyro. Assuming an identical roll-control rate gyro indication, since the signal was not monitored by telemetry, the effective rate of the gyro as seen by the ASIS was approximately 7.72 deg/sec, which was below the abort threshold of 9.4 deg/sec. The difference resulted from the dissimilar attenuation characteristics of the channel filters involved at the 1.32-cps frequency of the roll transient. The high roll transient was probably caused by booster-engine misalinement and gas-generator exhaust thrust, which were in a direction to cause clockwise roll. The booster-engine differential in yaw, as measured 9 days prior to launch, was 0.23° in the direction which caused clockwise roll. Telemetered engine-position data indicated this differential to be 0.14° in the same sense.

The launch-vehicle radio-guidance system performed well and guided the Atlas sustainer stage to cutoff conditions which were within acceptable limits; however, the radar data were quite noisy near SECO. The errors at insertion were 15 ft/sec high in velocity, 49 feet high in altitude, and 0.0084° low in flight-path angle.

The guidance configuration was the same as that for the MA-7 mission except that the duration of the second-stage pitch program was reduced by 2.5 seconds (5° less pitch-down maneuver). The purpose of the change was to reduce the steering transients after guidance initiation. Also, for a near nominal trajectory without launch guidance steering, the change would permit acceptable orbital-insertion conditions.

A somewhat lofted trajectory was flown prior to staging, and this maneuver resulted in a 2-second-early discrete signal at BECO; consequently SECO was about 10 seconds later than nominal. The radar elevation angle at SECO was 7.2°, compared with a nominal angle of 7.4°, as a result of an increase of 17 nautical miles in the down-range distance at SECO.

The guidance system acquired the tracking beacon of the launch vehicle in the first radar cube, and lock was continuous from 00:01:04.3 to 00:05:35.7 g.e.t. (20 seconds after SECO). The rate lock was continuous in all functions from 00:00:56.5 to 00:05:31.8 g.e.t. (16.9 seconds after SECO). Cyclic lateral-rate noise became apparent at 00:04:54 g.e.t. (22 seconds prior to SECO) and continued to 16.9 seconds after SECO, when it reached maximum amplitude.

Guidance steering started at 00:02:30.8 g.e.t. with a 40-percent positive pitch rate and a 15-percent positive yaw rate. The commanded steering rates were smooth and almost zero until 22 seconds before SECO. The commanded pitch rates appeared to respond to the radar lateral rate noise with a rate fluctuation of about ±35 percent at 16 seconds prior to SECO. The noise level was about twice that experienced during the MA-4 and MA-5 launches and about five times that experienced during the MA-6 and MA-7 missions. Despite the large noise level, acceptable insertion conditions were achieved. Yaw steering performed with a low noise level and guided the launch vehicle to the proper heading, and the actual orbital inclination was 0.03° higher than nominal. The roll transient at lift-off had little effect on the launch trajectory.

Figures 46 to 48 show the velocity and flight-path angle in the region of SECO. The launch-vehicle guidance data are shown in figure 46, and the range-safety impact-predictor (IP) 7090 computer data are shown in figure 47 to illustrate the noise level during the time of the go-no-go computations. Although both sources of data were considered noisy, the average agreed with actual flight conditions. Maximum peak-to-peak deviations in the launch-vehicle guidance data after SECO were of the magnitude experienced on the MA-4 mission and about twice that of the MA-5, MA-6, and MA-7 missions. The IP 7090 computer noise level was about 1.25 times the magnitude experienced on MA-4 and about two to three times greater than the noise level on the MA-5, MA-6, and MA-7 missions.

Figure 48 shows the variation of flight-path angle with velocity ratio and is the type of display used by the flight-dynamics officer in the Mercury Control Center for the orbital go-no-go decision. Both the launch-vehicle guidance and the IP 7090 data indicated a go condition.

TRAJECTORY AND MISSION EVENTS

Sequence of Flight Events

The times at which the major events of the MA-8 mission occurred are given in table XXII. In the table, the parameters shown for the planned launch trajectory were computed using the 1959 Air Research and Development Command (ARDC) model atmosphere to maintain consistency with other published preflight trajectory documents. The density of the atmosphere at Cape Canaveral was approximately 10 percent higher than that of the ARDC model atmosphere in the region of maximum dynamic pressure, which occurred at an altitude of approximately 37 000 feet. As a result, the maximum dynamic pressure expected was 10 percent higher than that shown as planned.

Flight Trajectory

The trajectory for the MA-8 mission is discussed in the performance phases of launch, orbit, and reentry. The altitude-longitude profile is presented in figure 49. Table XXIII is a comparison of the planned and actual trajectory parameters. The differences between the planned and actual flight trajectory parameters resulted from a higher actual cutoff velocity and a slightly lower actual flight-path angle at orbital insertion.

Launch trajectory data. - The launch trajectory data (fig. 50) are based on the real-time output of the range safety IP 7090 computer, which used Azusa MK II and Cape Canaveral FPS-16 radar, and the General Electric-Burroughs launch-vehicle guidance computer. The data from these tracking facilities were used during the following time periods:

Facility	Time, min:sec
Cape Canaveral FPS-16	0 to 00:42
Azusa MK II	00:42 to 01:04
General Electric-Burroughs	01:04 to 05:16

Orbital phase. - The orbital phase of the trajectory (fig. 51) was derived by starting with the spacecraft position and velocity vector obtained during the first orbital pass over Muchea, as determined by the Goddard computer using Mercury Worldwide Network tracking data. The calculated orbital trajectory was the result of integrating backward along the flight trajectory to orbital insertion and forward to the start of retrorocket ignition in the sixth orbital pass. The integrated values were in good agreement with the values measured by the launch-vehicle guidance system at orbital insertion. The values were also in good agreement with the position and velocity vectors determined by the Goddard computer for passes near Eglin Air Force Base, Florida (end of the first pass), and Point Arguello, California (end of the third pass). Thus, the validity of the integrated orbital portion of the flight trajectory was established.

Reentry phase. - The reentry phase of the trajectory (fig. 52) was derived by starting with the spacecraft position and velocity vector obtained at the end of the third orbital pass near Point Arguello, California, as determined by the Goddard computer. Integrating forward along the flight path to retrorocket ignition and, after introducing nominal retrofire conditions, continuing the integration through spacecraft landing yielded the reentry trajectory. Nominal retrofire conditions included a retrorocket total impulse of 38 975 lb/sec at spacecraft attitudes of -34° in pitch and 0° in roll and yaw. The actual spacecraft weight at retrofire was estimated to be 2994 pounds by using data obtained from the Mercury Worldwide Network command stations. The times of drogue- and main-parachute deployment from the integrated reentry trajectory and from the spacecraft onboard measurements were in good agreement.

In addition, the landing point from the integrated reentry trajectory agreed within 1 mile of the retrieval point reported by the recovery ship. The agreement confirmed the validity of the integrated reentry phase of the trajectory.

The aerodynamic parameters for the planned and integrated reentry trajectories were computed using the MSC model atmosphere. This atmosphere was based on the Discoverer satellite data for altitudes above 50 nautical miles and the Patrick Air Force Base, Florida, atmosphere at altitudes below 25 nautical miles. In the trajectory figures, the values integrated by this method are labeled actual.

MERCURY WORLDWIDE NETWORK PERFORMANCE

General

The Mercury Worldwide Network for MA-8 consisted of the Mercury Control Center at Cape Canaveral; stations at the AMR, Bermuda, and 14 other locations along the orbital ground track; and a computing and communications center at the NASA Goddard Space Flight Center. Two S-band radar-equipped ships, the Huntsville and the Watertown, and the C-band radar-equipped ship American Mariner were positioned up range from the prime landing areas for the fifth and sixth orbital passes. Relay aircraft with uhf to hf/single-sideband capability were available in the prime recovery areas off Puerto Rico and Midway Island. Additional aircraft were positioned in the prime recovery areas for telemetry coverage during reentry. Note that ground-to-ground voice communications were provided to each station, including the ships Huntsville and Watertown. Also, special data circuits were required for routing information from the ships.

The overall performance of the Mercury Worldwide Network was good. Some network anomalies were experienced, but these did not affect the monitoring or control of the mission. For the MA-8 mission, there were some intermittent communications problems, both in voice and teletype, throughout the mission. In particular, voice and teletype communications to the ships, Australia, and the African stations were not as good as those for the MA-6 and MA-7 missions. The quality of A/G voice communications received on the Goddard Conference Loop during the mission varied between poor and good. However, communications were adequate to maintain proper ground surveillance of the mission. The Canary Islands VERLORT radar was temporarily inoperative prior to lift-off, and the countdown was delayed 15 minutes for repairs. Communications to both the Indian Ocean and Pacific Ocean ships were marginal at times; however, adequate communications with these stations were available when required. The Pacific Command ship was located east of the Philippine Islands for reentry command coverage, and two S-band and one C-band radar-equipped ships were positioned west of Midway Island for coverage during reentry.

Overall, telemetry coverage was excellent. Radar coverage was excellent from the land stations with the spacecraft beacons on and unusable with the beacons off; radar data from the ships were unusable by the Goddard computers; command coverage was available, but not required for spacecraft control; communications between the stations and Mercury Control Center were good in most instances; spacecraft-to-ground communications were good. The response of the network to the needs of the MA-8 mission was comparable to the support given the MA-6 and the MA-7 missions.

Trajectory

The computer program used at the NASA Goddard Space Flight Center for the MA-8 mission was checked out and verified more than a month prior to launch. The program included a paper-tape input feature to compute retrosequence information for landing at any desired longitude along any orbital ground track.

Confidence checks during the countdown indicated that the launch monitor system was in a go condition. The trajectory check at T - 145 minutes revealed a communication problem on the Bermuda low-speed data, but the problem was quickly resolved. Earlier checks were successful; therefore, the malfunction (a sticky relay) apparently occurred after those checks. The high-speed portion of the test was completed in time for the flight director to approve resumption of the launch countdown at T -135 minutes.

Tracking. - A failure in the Canary Islands radar caused a hold at T - 45 minutes. The hold lasted 15 minutes and was sufficient to make the radar system operational. After the countdown was resumed, a short burst of data was transmitted to NASA Goddard Space Flight Center to verify continuity of the system. At lift-off, the selected tracking source was the Cape Canaveral FPS-16 radar as planned. The source selection history is shown in the table on the following page.

For the first 42 seconds of flight, the IP 7090 computer selected the Azusa system several times, but the quality of Azusa data was not satisfactory until 42.2 seconds. General Electric-Burroughs radar acquisition, reported by the guidance test conductor, occurred as planned in the first cube. The General Electric-Burroughs source was used for the remainder of powered flight and was excellent until the last 10 seconds. At that time, the data became noisy at a level which was comparable to the level experienced on the MA-4 mission. However, the data gave a clear go indication, and the condition was confirmed by Bermuda. The cutoff conditions are shown in table XXIV.

Facility	Time from lift-off, sec
Cape Canaveral FPS-16	0 to 12.6
Azusa MK II	12.6 to 15
Cape Canaveral FPS-16	15 to 16.2
Azusa MK II	16.2 to 21
Cape Canaveral FPS-16	21 to 42.2
Azusa MK II	42.2 to 69.4
General Electric-Burroughs	69.4 to end of powered flight

The programed autopilot phase of powered flight showed minor deviations in pitch and flight direction. At BECO, the flight-path angle was 1.5° high, which resulted in an early BECO command at 00:02:07.6 g.e.t. A deviation was also noticed in the flight azimuth, since the position and landing-point track were slightly north of the nominal path. When ground steering was initiated after tower jettison, both of the deviations were corrected.

Low-speed tracking data from all the ground-based remote stations were excellent, and the orbit was well established after the correction was made which used the Canary Islands data. During the periods when the beacons were turned off, attempts at skin tracking by various stations were unsuccessful, as was expected. Table XXV is a summary of MA-8 tracking-system operation.

Three ships were used in the Pacific area to provide reentry tracking for the fifth and sixth orbital passes. None of the data were usable. The data were garbled to such an extent that it was not possible to determine reliably where the errors were introduced. Further analysis of the shipboard tape recording was required to determine accurately the performance of the ship tracking system. Backup teletype communications were planned through Midway, but they were unsuccessful and no explanation was found for the failure.

Computation. - The nominal retrograde firing time for the six-pass mission (necessary to land the spacecraft in planned recovery area 6-1 at longitude 174°33' W) was 08:50:51 g.e.t., which corresponded to a retrosequence time of 08:50:21 g.e.t. After effects of the overspeed insertion conditions and weight losses were considered, the calculated retrosequence times for the primary sixth-pass recovery area (area 6-1) varied from 08:51:21 to 08:51:28 g.e.t. As instructed, the pilot increased the spacecraft-elapsed-time clock setting by 1 minute over Cape Canaveral on the third orbital pass.

On the fifth pass, Hawaii was instructed to relay a calculated retrosequence time for area 6-1 of 08:51:28 g.e.t., obtained from the latest orbital ephemeris and final estimated weight changes. However, the time did not include the extrapolated +5-second spacecraft-elapsed-time clock difference, compared to ground elapsed time. The California station reported that the latest retrosequence time calculation did not include this correction, and the California Cap Com instructed the pilot to increase his clock setting by 5 seconds if he concurred. The clock change was initiated over the California station and confirmed by the Guaymas station, at which time the final spacecraft clock setting of 08:51:33 g. e. t. was observed. During the mission, all clock changes were made with no apparent difficulty.

Following retrograde, two computations, using the observed retrofire times and spacecraft attitudes, indicated a nominal landing point within 4 miles of the center of the primary landing area. During reentry, the reported blackout time served to confirm the predicted landing point, as did all mission events after that. A report of a visual sighting of the spacecraft before landing from the recovery ship provided final confirmation of the computed predictions (table XXVI).

Command system. - The command system for the MA-8 mission operated in a satisfactory manner. There were no malfunctions during the mission, and only one recorded decoder event occurred that was unplanned. An operator error caused a delayed indication from Bermuda to Cape Canaveral on the first pass, but it had no effect on the mission. Table XXVII is a summary of command handover exercises. Table XXVIII is a summary of command transmissions.

Ground system: A preliminary evaluation of the data showed that all command stations appeared to have slightly less command coverage than was noted on previous missions. The 10-kilowatt command stations using the quadhelix antenna averaged 45 percent better coverage above the 7. 5-microvolt level than those of the 600-watt command stations. Coverage became reliable at slant ranges varying from 250 to 650 nautical miles. The large variance was believed to be caused by the change in spacecraft antenna-pattern aspect angle while the spacecraft was in attitude-free drifting flight.

Five messages were transmitted to the command stations during the mission to change the command handover exercise. The changes compensated for the insertion-overspeed trajectory, which altered the best function times slightly more than 1 minute by the time of the last pass over the Pacific Command ship.

A total of 11 functions were transmitted from the command stations. All of the functions were received successfully, although the telemetry R- and Z-calibrations from Guaymas on the fourth pass were received intermittently because of low signal strengths.

Spacecraft system: The MA-8 spacecraft 16 had a single command receiver on board, as planned. The threshold value was between 2. 5 and 3. 0 microvolts, and the saturation value was between 35 and 45 microvolts. The system appeared to operate normally with the exception of one unexplained command function recorded at 09:08:21 g. e. t. The command function, which appeared as a single indication of decoder operation and was unidentified, did not affect the mission. The time at which the function was recorded was the time of antenna-fairing release and main-parachute deployment, and was coincident with a recorded signal strength of approximately 3 microvolts.

Radar system. - Both C- and S-band radar beacons operated satisfactorily throughout the mission. Some beacon countdown (absence of beacon response to interrogation) was noted, but no stations lost track because of the effect. Some amplitude modulation of the beacon reply was also noted, which was rather severe in two instances and was probably caused by the wobbulator.

The tracking of all Cape Canaveral FPS-16 radars was good, although some radio-frequency (rf) interference was noted by the Hawaii and California stations. The tracking of the S-band radars was also good, although there was some interference as a result of phasing problems. Figures 53 and 54 show the C- and S-band radar coverages, respectively. No radar tracking data were obtained during the fourth orbital pass because the beacons were turned off. All stations attempted to skin-track the spacecraft, but the attempts were unsuccessful.

Telemetry and voice systems. - The telemetry coverage was excellent (fig. 55). Significant difficulties in telemetry reception included the operation below specification of the hf receivers at Woomera, Australia; a prime-receiver power failure at the California station during the fifth pass, with the low-frequency signal successfully remoted to the California station from St. Nicholas Island; and a serious decommutator problem at Guaymas.

The uhf A/G communications were good, although slightly inferior to similar communications for the MA-6 and MA-7 missions. The uhf A/G communications from launch until the spacecraft changed from VOX to push-to-talk were erratic; VOX was affected by launch-vehicle background noise. For a complete transcription of the MA-8 A/G voice communications, refer to reference 4.

The uhf-to-hf relay through the AMR and Pacific Missile Range (PMR) was marginally effective. Only one transmission was received from the spacecraft through the AMR aircraft. The PMR aircraft made a brief attempt during the fifth orbital pass to relay communications, but a two-way automatic relay was never established. The problem appeared to be one of aircraft reception of the spacecraft transmission. If the antenna gain of the aircraft (whose antenna gain was zero) was improved, the problem might have been eliminated. Also, on the AMR aircraft, equipment was shared for both aircraft and relay communications. The PMR relay worked satisfactorily during a segment of reentry.

The hf A/G communications coverage was not very extensive, although more hf was used on this mission than was used on the MA-7 mission. Some stations did not receive any hf on the hf test; other stations received signals far beyond their normal range. The problems experienced during hf transmission included atmospheric propagation; rf interference, which was more of a problem than had been anticipated; inadvertent shifting of the antenna-selector switch position; spacecraft attitude in relation to the ground station during transmissions; and the nonoptimum selection of transmission frequency.

Few equipment failures were noted. The greatest difficulty encountered in communication was related to adverse atmospheric propagation and rf interference. The most critical equipment failures were the losses of power on board the Watertown tracking ship and at the California station. Another malfunction which underwent a comprehensive investigation was the distortion of spacecraft transmission caused by the Cape Canaveral voice transfer circuit on Bermuda. Table XXIX presents the A/G signal strength measurements, and figure 56 shows the hf and uhf voice-communications coverage.

TABLE VI. - REQUIREMENTS FOR AUTOMATIC MODE SWITCHING

Requirements for automatic switching from -	Spacecraft attitude deviation, deg	
	Model A-9	Model A-11
Orientation mode to orbit mode	$<\pm 3.0$	$<\pm 5.5$
Orbit mode to pitch orientation mode[a, b]	$>\pm 12$	$>\pm 15$

[a] Also dictated retroattitude-permission limits.

[b] From -34°.

TABLE VII. - ORBIT-MODE OPERATION

Pulse	Attitude, deg		Pulse duration, sec	
	Model A-9	Model A-11	Model A-9	Model A-11
1	±3.0	±5.5	0.20	0.20
2	±4.25	±7.0	.15	.075
3	±5.5	±8.5	.25	.25
4	±7.75	±10.0	.44	.44
5	±8.5	±11.5	.75	.75

TABLE VIII. - REACTION-CONTROL-SYSTEM FUEL CONSUMPTION

Elapsed time, hr:min	Mission phase	Automatic supply		Manual supply	
		Fuel used, lb	Fuel remaining, lb	Fuel used, lb	Fuel remaining, lb
00:00	Launch	0	34.2	0	24.7
00:05	Turnaround and damping	.3	33.9	0	24.7
01:37	First pass	.8	33.1	.6	24.1
03:11	Second pass	1.8	31.3	.9	23.2
04:44	Third pass	2.5	28.8	0	23.2
06:20	Fourth pass	0	28.8	0	23.2
07:55	Fifth pass	3.6	25.2	0	23.2
08:51	Fifth pass to retrofire	1.1	24.1	3.8	19.4
09:02	Retrofire to 0.05g	4.2	19.9	.5	18.9
09:07	0.05g to drogue-parachute deployment	.1	19.8	9.3	9.6
09:08	Drogue-parachute deployment to main-parachute deployment[a]	0	19.8	9.6	0

[a]Depletion occurred during this period.

TABLE IX. - LOW-RESIDUE DIET

Meal	Sept. 30, 1962	Oct. 1, 1962	Oct. 2, 1962	Oct. 3, 1962
Breakfast	9:00 a. m. Grapefruit juice Cream of rice Scrambled eggs Canadian bacon Toast and butter Jelly Coffee	6:15 a. m. Orange juice Baked egg and bacon Toast and butter Jelly Coffee	6:30 a. m. Orange-grapefruit juice Cream of rice Soft-cooked egg Canadian bacon Toast and butter Jelly Coffee	2:10 a. m. Orange juice Scrambled eggs Steak and fish Toast and butter Jelly Coffee
Lunch		12:00 noon Tomato juice Noodles and veal Cottage cheese Melba toast Butter Pound cake and apricots Coffee and tea	11:30 a. m. Chicken-noodle soup Meat loaf on toast Peas Sherbet Coffee and tea	
Dinner	4:00 p. m. Shrimp cocktail Crackers Baked chicken Rice and peas Hard rolls and butter Sherbet and cookies Coffee and tea	5:00 p. m. Consomme and crackers Steak Potato and green peas Hard rolls and butter Jello Coffee and tea	5:30 p. m. Pineapple juice Roast beef Baked potato Wax beans Angel food cake Peaches Coffee and tea	

TABLE X. - AEROMEDICAL COUNTDOWN

Activity	Pad count, T - time, min	Aeromedical count, A - time, min	Actual time, a. m. e. s. t.	Duration, min	
				Planned	Actual
Awaken	T - 220	A - 180	1:40	30	30
Breakfast	T - 190	A - 150	2:10	20	30
Physical examination	T - 170	A - 130	2:46	16	9
Psychomotor studies	T - 154	A - 114	2:56	14	14
Partial dressing	T - 140	A - 100	3:10	5	
Sensor placement		A - 95	3:10	15	16
Suiting		A - 80	3:26	20	23
Suit and sensor checkout		A - 60	3:49	15	12
Suit accessories		A - 45	4:01	5	2
Hangar S to transfer van		A - 40	4:02	10	5
Transfer van to pad		A - 30	4:07	20	21
Ascend gantry		A - 10	4:37	10	4
Insertion	T - 140	A - 0	4:41	140	4
Launch	T - 0		7:15		

TABLE XI. - PHYSICAL EXAMINATIONS CONDUCTED FOR MA-8 OPERATIONS

Date, 1962	Preflight activities prior to which medical examinations were conducted
Sept. 10	Simulated flight, suited and with sensors
Sept. 13	Simulated flight (flight acceptance composite test), suited and with sensors
Sept. 15	Procedures trainer, Mercury Control Center, suited
Sept. 18	X - 15 medical evaluation
Sept. 20	Procedures trainer, Mercury Control Center, suited
Sept. 21	Controlled diet begun
Sept. 28	Launch simulation, suited with sensors
Sept. 29	Simulated flight, unsuited
Oct. 1	Comprehensive medical evaluation
Oct. 3	Aeromedical countdown, flight, and postrecovery examination
Oct. 4 and 5	Aeromedical debriefing
Oct. 6	Departure from debriefing site
Oct. 9	Return to Cape

TABLE XII. - SUMMARY OF HEART RATE AND RESPIRATION DATA FROM PHYSIOLOGICAL MONITORING

Date	Procedure	Duration of observation, hr:min	Heart rate, beats/min				Respiration rate, breaths/min			
			Number of determinations	Standard deviations, 2σ	Range	Mean	Number of determinations	Standard deviations, 2σ	Range	Mean
Preflight										
March 1959	Lovelace Clinic dynamic tests	Variable	39	(a)	68 to 160	96	--	--	--	--
Sept. 22, 1961	Mercury-Atlas centrifuge dynamic simulation	1:07.5	75	50 to 78	48 to 78	64	25	9 to 15	7 to 18	12
May 4, 1962	MA-7 launch-pad simulated flight	1:09	24	53 to 91	58 to 88	72	19	10 to 22	10 to 24	16
Apr. 17 and Aug. 14, 1962	Hangar simulated flights	9:47	87	52 to 78	51 to 76	65	19	14 to 26	14 to 24	20
Sept. 10, 1962	Launch-pad simulated flight 1A	3:09	69	45 to 65	43 to 72	55	68	14 to 26	10 to 28	20
Sept. 14, 1962	Launch-pad simulated flight 2A	2:35	68	54 to 82	52 to 86	68	68	14 to 30	12 to 28	22
Sept. 28, 1962	Launch-pad simulated launch	3:07	72	49 to 73	46 to 74	61	71	12 to 28	9 to 26	20
Oct. 3, 1962	Launch countdown	2:33	61	64 to 80	58 to 88	72	61	17 to 23	16 to 26	20
In-flight										
Oct. 3, 1962	In-flight	9:13	220	50 to 102	56 to 121	76	220	11 to 27	10 to 43	19
Postflight, clinical										
Oct. 3 and 4, 1962	Debriefing on board recovery ship	Variable	22	52 to 112	56 to 104	82	--	--	--	--

[a]These data are included for completeness, but the conditions were very different from the other procedures.

TABLE XIII. - SUMMARY OF BLOOD-PRESSURE DATA

Date	Procedure	Mean blood pressure, mm Hg	Systole				Diastole				Mean pulse pressure, mm Hg
			Number of determinations	Standard deviation, 2σ	Range, mm Hg	Mean, mm Hg	Number of determinations	Standard deviation, 2σ	Range, mm Hg	Mean, mm Hg	
Preflight, clinical											
Mar. 1959	Lovelace Clinic dynamic tests	119/67	39	(a)	90 to 164	119	39	(a)	52 to 84	67	52
July 25, 1962	Special BPMS test	104/75	27	92 to 116	94 to 116	104	27	62 to 88	64 to 94	75	29
1960 to Oct. 3, 1962	Random clinical determinations	115/76	13	103 to 127	100 to 122	115	13	62 to 90	64 to 84	76	39
Preflight, BMPS											
Sept. 22, 1961	Mercury-Atlas dynamic simulation on centrifuge	133/96	11	111 to 155	115 to 150	133	11	68 to 124	76 to 120	96	37
July 25, 1962	Special BPMS test	108/67	28	(a)	94 to 126	108	28	(a)	54 to 100	67	41
May to Oct. 1962	Hangar and launch-complex	107/70	31	92 to 122	94 to 123	107	29	58 to 82	58 to 80	70	37
Oct. 3, 1962	Prelaunch (hangar, transfer van, and blockhouse)	117/80	14	103 to 121	110 to 143	117	14	66 to 94	71 to 94	80	37
In-flight BPMS											
Oct. 3, 1962	In-flight	126/69	20	116 to 136	111 to 158	126	16	64 to 74	59 to 75	69	57
Postflight, clinical											
Oct. 3 and 4, 1962	Debriefing on board carrier	112/78	12	92 to 132	94 to 120	112	12	70 to 86	70 to 84	78	37

[a]These data are included for completeness but the conditions were very different from the other procedures.

TABLE XIV. - IN-FLIGHT BODY-TEMPERATURE VALUES

Ground elapsed time, hr:min	Value, °F
00:00 to 01:52	Off scale
01:52 to 02:16	98.5
02:16 to 04:05	98.3 to 98.5
04:05 to 05:24	97.7
05:24 to 09:12	98

TABLE XV. - POSTFLIGHT BLOOD-PRESSURE VALUES AND HEART RATES

Time, p.m. e.s.t.	Blood pressure, mm Hg	Preflight heart rate, beats/min	Comments (a)
	Standing, 122/28 Supine, 120/78	Sitting, 64	
		Oct. 3, 1962	
5:28	Sitting, 118/78	Sitting, 92	Temperature: oral, 99.4° F; rectal, 100.1° F
5:47		Supine, 72	Blood drawn: 40 cc
6:15		Standing, 92	
7:10	Supine, 108/70	Supine, 72 Supine, 64 Standing, 92 to 100	Orange juice: 180 cc
7:18	Standing, 104/78	Standing, 92 to 100	
7:20	Supine, 120/76	Supine, 64	
7:24	Standing, 94/74	Standing, 104	
7:26	Sitting, 94/74	Sitting, 88	
7:32		Sitting, 80	
7:42		Sitting, 80 Standing, 104 Supine, 68	Ate first meal and drank 690 cc of liquids
9:41	Sitting, 120/78 Standing, 104/78 Supine, 124/80	Sitting, 84 Standing, 104 Supine, 80	Temperature: oral, 99° F Blood drawn: 25 cc
10:00		Sitting, 96 Supine, 76	
10:10			Urine voided: 245 cc
		Oct. 4, 1962	
1:35	Sitting, 118/84 Standing, 114/84 Supine, 120/80	Sitting, 68 Standing, 72 Supine, 56	Superficial dependent veins not unduly distended

[a]The pilot smoked about 12 cigarettes between 5:30 p.m. and 10:00 p.m.

TABLE XVI. - CLINICAL EVALUATION[a]

Condition	Preflight, Cape Canaveral, 2:46 a.m. (b)	Postflight, U.S.S. Kearsarge (c)
Temperature (oral), °F	97.6	99.4
Heart rate, beats/min	64 (supine)	92 (sitting)
Blood pressure (left arm), mm Hg	120/78 (supine 122/85 (standing)	118/78 (sitting) See section on "Postflight Physical Examination"
Respiratory rate, breaths/min	14	--
Weight (nude, bladder empty), lb	176.75	172.25
Additional	Hematoma, right inguinal region; otherwise, no abnormalities including ECG, audiogram, and chest X-rays performed Oct. 1, 1962	Abrasion of right knuckles, pressure points over both acromial processes, orthostasis otherwise normal

[a]October 3, 1962; all times e.s.t.

[b]Unchanged from the several other preflight examinations.

[c]Repeated examination the next day did not reveal orthostasis; abrasions and pressure points were resolving. Complete examination October 1 was repeated October 4 and 5; no significant change was detected.

TABLE XVII. - PERIPHERAL BLOOD VALUES

Determination	Preflight	Postlanding			
	-15.5 hr	+1.5 hr	+5 hr	+14.5 hr	+51 hr
Hemoglobin, Cyanmethemoglobin method, grams/100 ml	15.0	--	14.5	15	14.7
Hematocrit, percent	44	47	45	46	43
Red blood cells, millions/mm^3	5.0	--	4.7	4.8	4.6
White blood cells/mm^3	9800	--	10 350	8 400	9 400
Differential blood count:					
Lymphocytes, percent	34	--	31	49	47
Neutrophiles, percent	62	--	63	46	51
Monocytes, percent	3	--	4	3	1
Eosinophiles, percent	1	--	2	2	1
Basophiles, percent	0	--	0	0	0
Platelets/mm^3	Adequate	--	Adequate	274 000	294 000
Sodium, mEq/l	152	150	147	145	145
Potassium, mEq/l	3.9	4.1	3.9	3.8	4.3
Chloride, mEq/l	102	108	107	103	104
Calcium, mEq/l	5.2	5.9	5.6	5.2	5.1
Protein (total), g/100 ml	8.0	8.0	7.0	8.1	7.0

TABLE XVIII. - URINE SUMMARY

Determination	Preflight	In-flight	Postlanding								
	-1 day		+6 hr	+17.5 hr	+23 hr	+50 hr	+53 hr	+56.5 hr	+61 hr	+63 hr	+69 hr
Volume, cc	--	(a)	233	323	150	440	460	410	8.50	125	375
Specific gravity	1.010	1.010	1.018	1.021	1.021	1.013	1.010	1.014	1.020		
Osmolarity, milliosmoles	593	595	848	995	951	442	266	609	262	301	568
pH	6.0	Acid	Acid	Acid	Acid	6.0	7.0	6.0			
Albumin, glucose, ketones, bile	0	0	0	0	0	0	0	0	0	0	0
Sodium, mEq/l	103	86	107	47	54	69	62	112	35	19	66
Potassium, mEq/l	47	49	58	46	69	34	18	38	14	19	59
Chloride, mEq/l	127	106	103	47	93	62	32	70	24	24	91
Calcium, mEq/l	8.5	6.1	4.8	8.4	8.4	7.0	2.9	4.0	2.2	1.6	3.1
Microscopic examination (high-power field)	Occasional white blood cells; few squamous cells	--	4 to 5 white blood cells; occasional red blood cells; mucous threads rare granular cast, some epithelial threads	Occasional white blood cells; occasional epithelial cell, no red blood cells	Occasional white blood cells; amorphous sediment	3 to 6 white blood cells; minimal mucus	Occasional white blood cells	Occasional white blood cells	--	--	--

[a]Most of the in-flight specimen was lost into the Mercury pressure suit. A total of 292 cc was recovered.

TABLE XIX. - YAW MANEUVERS

Maneuver	Visual reference	Control mode	Automatic fuel usage, lb	Gyro switch position
1	Window	FBW low	0.39	Normal
2	Periscope	FBW low	.32	Free
3	Window	FBW low	.23	Free
4	Window	FBW low	.30	Free

TABLE XX. - SUMMARY OF MAJOR FLIGHT ACTIVITIES

Control mode	Attitude-select switch position	Time from launch		Gyro switch position			Flight activities
		From -	To -	Position	From -	To -	
Auxiliary damping	Retro	00:05:17	00:05:21	Normal	Prelaunch	00:17:12	5-sec rate damping at spacecraft separation
FBW low		00:05:21	00:07:11				Turnaround maneuver
ASCS orbit		00:07:11	00:10:51				Sustainer observation, orbit checklist
FBW low		00:10:51	00:12:08				Sustainer tracking
MP		00:12:08	00:12:51				MP control-mode check
ASCS orbit		00:12:51	00:56:04				TS + 5 check Suit-circuit temperature control problem Yaw reticle used
				Free	00:17:12	00:18:48	
				Normal	00:18:48	00:56:31	
FBW low		00:56:04	01:02:41				Maneuver to observe flares Pitch held at -50° for 2 min
				Free	00:56:31	01:02:18	
				Normal	01:02:18	01:50:44	
ASCS orbit		01:02:41	01:05:05				
FBW low		01:05:05	01:06:21				
ASCS orbit	Reentry	01:06:21	01:09:07				Orientation low Pitch rate 1.6° when ASCS selected (one 1-space blip in pitch)
FBW low		01:09:07	01:10:58				Stars observed
ASCS orbit	Retro	01:10:58	01:33:26				Orientation low (one 1-space blip in all axes) Dosimeter check Particles observed
FBW low	Retro	01:33:26	01:34:27				Yaw check using yaw reticle

TABLE XX. - SUMMARY OF MAJOR FLIGHT ACTIVITIES - Continued

Control mode	Attitude-select switch position	Time from launch		Gyro switch position			Flight activities
		From -	To -	Position	From -	To -	
ASCS orbit		01:34:27	01:41:43				Orientation low (one 1-space blip in roll and pitch)
FBW low		01:41:43	01:44:41				Yaw check (window)
ASCS orbit		01:44:41	01:50:46				Orientation low (one 1-space blip in pitch and yaw) Dosimeter check
				Free	01:50:44	01:53:46	
FBW low		01:50:46	01:53:37				Yaw check (periscope)
ASCS orbit		01:53:37	02:03:15				Orientation low (one 1-space blip in yaw)
				Normal	01:53:46	02:03:14	Suit-temperature problem concentrated on
				Free	02:03:14	02:07:10	Suit temperature under control at approximately 2 hours elapsed
MP		02:03:15	02:06:09				
RSCS and FBW low		02:06:09	02:06:26				Pilot aware of double authority
FBW low		02:06:26	02:09:25				
				Normal	02:07:10	02:26:01	
ASCS orbit		02:09:25	02:26:05				Orientation low (one 1-space blip in roll)
				Free	02:26:01	02:30:02	Perth used as yaw reference check (02:23:30)
FBW low		02:26:05	02:31:00				Yaw check using Moon as reference
				Normal	02:30:02	03:09:38	
ASCS orbit		02:31:00	03:09:27				Orientation low (one 1-space blip in pitch) ASCS orbit-mode check Particles observed Terrestrial observations

TABLE XX. - SUMMARY OF MAJOR FLIGHT ACTIVITIES - Continued

Control mode	Attitude-select switch position	Time from launch		Gyro switch position			Flight activities
		From -	To -	Position	From -	To -	
FBW low	Reentry	03:09:27	03:51:47				Preparation for power-down
				Free	03:09:38	03:09:40	
				Caged	03:09:40	03:49:52	Powered down at 03:09:50 Drifting started at 03:10:00
				Free	03:49:52	03:55:15	Orientation test Dosimeter check Drifting flight stopped at 03:40:00 Power-up at 03:44:09
ASCS orbit		03:51:47	03:54:44				Orientation low (low thrust in pitch and yaw for 6 sec)
FBW low		03:54:44	04:00:07				
				Caged	03:55:15	03:59:10	Gyros realined
				Free	03:59:10	04:00:18	Yaw to observe Moon and stars
ASCS orbit		04:00:07	04:19:20				Orientation low (one 1-space blip in each axis)
				Normal	04:00:18	04:35:09	Magnetic compass used
FBW low	Retro	04:19:20	04:20:54				
ASCS orbit		04:20:54	04:35:05				Orientation low (one 1-space blip in roll and pitch) Six-orbit go
FBW low		04:35:05	04:36:00				Power-down at 04:35:18
				Caged	04:35:09	06:20:04	Drifting started at 04:36:00
ASCS	Reentry	04:36:00	06:05:30				Powering down rate gyros Photographs Dosimeter check Particles observed Orientation test at 05:19:00 Star observations Extinct Aldebaran 05:27:27 Observed sunrise inverted

TABLE XX. - SUMMARY OF MAJOR FLIGHT ACTIVITIES - Continued

Control mode	Attitude-select switch position	Time from launch		Gyro switch position			Flight activities
		From -	To -	Position	From -	To -	
FBW low		06:05:30	06:22:44				Power-up at 06:06:40 Dosimeter check Limited drifting flight started at 06:15:30 Drifting flight stopped at 06:20:00
				Free	06:20:04	06:21:26	Gyro realinement
				Caged	06:21:26	06:21:30	
				Free	06:21:30	06:21:39	
				Normal	06:21:39	07:20:09	
ASCS orbit		06:22:44	06:27:11				Orientation low (one 1-space blip in roll)
MP		06:27:11	06:28:13				MP control-mode check
ASCS orientation		06:28:13	06:28:16				Orientation high. Pilot gone to ASCS with proper retroattitude but attitude-select switch in reentry position
FBW low		06:28:16	06:28:22				
FBW low and RSCS		06:28:22	06:28:52				
FBW low	Retro	06:28:52	06:29:43				
ASCS orbit		06:29:43	07:45:14				Orientation low (one 1-space blip in roll and yaw) Weather photographs. Sunset, star, and Moon observations Port Elizabeth observed at 06:49:00 Venus extincted at 06:54:29 Moon photographed Lights observed over Philippines (07:10:00)
				Free	07:20:09	07:46:36	Scanner test
ASCS and MP in roll		07:45:14	07:46:07				Correcting a -10° roll

TABLE XX. - SUMMARY OF MAJOR FLIGHT ACTIVITIES - Continued

Control mode	Attitude-select switch position	Time from launch		Gyro switch position			Flight activities
		From -	To -	Position	From -	To -	
FBW low		07:46:07	07:47:37				
				Normal	07:46:36	08:22:23	
ASCS orbit		07:47:37	08:12:40				Orientation low (one 1-space blip in each axis) Terrestrial photographs of South America Equipment stowed at 08:10:00
FBW low		08:12:40	08:14:11				
ASCS orbit		08:14:11	08:22:33				Orientation low (one 1-space blip in each axis)
				Free	08:22:33	08:25:06	Orientation test Moon used as yaw reference
MP		08:22:33	08:24:56				MP control-mode check Pitch-down to observe lights of Durban
FBW low		08:24:56	08:26:36				
				Normal	08:25:06	08:51:34	
ASCS orbit		08:26:36	08:31:34				Orientation low (4 sec of 1-pound thrusting in each axis) Preretrosequence checklist at 08:27:00 Rate gyro-select switch to TR - 10 bypass at 08:28:00. FBW-select switch to NORM at 08:31:00
FBW normal		08:31:34	08:32:43				Checked FBW high thrusters
ASCS orbit		08:32:43	08:50:30				Orientation low (one 1-space blip in roll and yaw) Stars and planets used to cross-check yaw accuracy
ASCS orbit and MP		08:50:30	08:51:34				MP selected as backup to ASCS for retrofire Squibs armed at 08:51:29

TABLE XX. - SUMMARY OF MAJOR FLIGHT ACTIVITIES - Concluded

Control mode	Attitude-select switch position	Time from launch		Gyro switch position			Flight activities
		From -	To -	Position	From -	To -	
ASCS orientation and MP		08:51:34	08:52:43				Retrosequence
				Free	08:51:34	08:53:03	Retrofire at 08:52:05 Retrojettison switch armed at 08:52:35
FBW normal		08:52:43	08:54:00				Pitch to reentry attitude
				Normal	08:53:03	Landing	FBW high thrusters checked Retropackage jettisoned at 08:53:05
ASCS orbit	Reentry	08:54:00	08:59:31				ASCS reentry logic check Orientation low (6 sec of 1-pound thrusting)
ASCS orientation		08:59:31	08:59:41				Orbit mode did not hold pitch $<15^\circ$ from reentry pitch attitude
ASCS orbit		08:59:41	09:00:27				
RSCS	Reentry	09:00:27	Landing				Controlling reentry-rate damping Communications blackout at 09:01:00 0.05g at 09:01:45 RSCS inserted 6 deg/sec roll Drogue pilot-deployed at 09:06:55 (40° K) Manual fuel depletion at 09:07:30 Snorkle pulled at 20° K Recovery arm at 15° K Main parachute deploy and automatic fuel jettison on at 09:08:16 (10.5° K) Automatic fuel jettison off at 09:09:16

TABLE XXI. - CONTROL-MODE UTILIZATION

[Does not include gyro switch position]

Control-mode configuration	Total time used in rank order, hr: min: sec	Maximum time used at any time, hr:min:sec	Frequency used
ASCS retroattitude select	04:57:34	01:15:29	16
Free drift	02:11:56	01:41:56	2
FBW low	00:40:59	00:06:36	20
ASCS reentry select	00:35:09	00:19:11	6
Drift and FBW low	00:17:00 (approx)	00:09:22	3
MP	00:07:05	00:02:54	4
RSCS	00:06:28	00:06:28	1
FBW normal	00:02:17	00:01:21	2
ASCS orientation low	00:01:06	00:00:10	17
MP and ASCS	00:00:53	00:00:53	2
FBW low and RSCS	00:00:31	00:00:31	1
ASCS orientation high	00:00:36	00:00:23	3
MP and FBW low	00:00:07	00:00:07	1
ASCS auxiliary damping	00:00:04	00:00:04	1

TABLE XXII. - SEQUENCE OF EVENTS

Event	Planned time, hr:min:sec (a)	Actual time, hr:min:sec	Difference, sec (b)
Launch phase			
BECO	00:02:10.8	00:02:08.6	-2.2
Tower release	00:02:33.8	00:02:33	-0.8
Escape-rocket ignition	00:02:33.8	00:02:33	-0.8
SECO discrete	(c)	00:05:15.7	--
Tail-off complete	00:05:05.8	00:05:15.9	10.1
Spacecraft separation	00:05:06.8	00:05:17.9	11.1
Orbital phase			
Retrofire-sequence initiation	08:50:21.8	08:51:30	68.2
Retrorocket No. 1 (left)	08:50:51.8	08:52:00	68.2
Retrorocket No. 2 (bottom)	08:50:56.8	08:52:05	68.2
Retrorocket No. 3 (right)	08:51:01.8	08:52:10	68.2
Retrorocket assembly jettison	08:51:51.8	08:53:00	68.2
Reentry phase			
0.05 g relay	09:00:20.8	09:01:40	[d]79.2 (7)
Drogue-parachute deployment	09:05:36.8	09:06:50	[d]73.2
Main-parachute deployment	09:07:02.8	09:08:12	[d]69.2 (-1)
Main-parachute jettison (water landing)	09:11:33.8	09:13:11	[d]97.2 (7)

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

[b]The relatively large difference between the planned and actual times from retrofire to landing resulted from the slight overspeed condition which gave a longer orbital period.

[c]Planned trajectory times were based on tail-off-complete conditions, rather than on SECO conditions.

[d]The differences between the actual and the postflight-calculated reentry event times, shown in parentheses, were based on actual insertion parameters.

TABLE XXIII. - COMPARISON OF PLANNED AND ACTUAL TRAJECTORY PARAMETERS

Condition and quantity	Planned	Actual	Difference
Cut-off conditions (including tail-off)			
Range time, sec	305.8	315.9	10.1
Range time, min:sec	05:05.8	05:15.9	00:10.1
Geodetic latitude, deg N	30.4309	30.5447	.1138
Longitude, deg W	72.5071	72.2157	-.2914
Altitude, ft	528 418	528 467	49
Altitude, n. mi.	86.97	86.97	0
Range, n. mi.	437	453.7	16.7
Space-fixed velocity, ft/sec	25 715	25 730	15
Space-fixed flight-path angle, deg	.0022	-.0062	-.0084
Space-fixed heading angle, deg E of N	77.4874	77.7043	.2169
Postposigrade firing conditions			
Range time, sec	307.8	318.9	11.1
Range time, min:sec	05:07.8	05:18.9	00:11.1
Geodetic latitude, deg N	30.4607	30.5885	.1278
Longitude, deg W	72.3600	71.9946	-.3654
Altitude, ft	528 451	528 510	59
Altitude, n. mi.	86.97	86.98	.01
Range, n. mi.	445	465.5	20.5
Space-fixed velocity, ft/sec	25 736	25 751	15
Space-fixed flight-path angle, deg	-.0006	-.0085	-.0079
Space-fixed heading angle, deg E of N	77.5660	77.8228	.2568
Orbit parameters			
Perigee altitude, statute mi.	100.08	100.05	-0.03
Perigee altitude, n. mi.	86.97	86.94	-.03
Apogee altitude, statute mi.	166.3	175.84	9.54
Apogee altitude, n. mi.	144.2	152.8	8.6
Period, min:sec	88:45	88:55	00:10
Angle of inclination, deg	32.52	32.55	.03
Maximum conditions			
Altitude, statute mi.	166.3	175.84	9.54
Altitude, n. mi.	144.2	152.8	8.6
Space-fixed velocity, ft/sec	25 736	25 751	15
Earth-fixed velocity, ft/sec	24 420	24 435	15
Exit acceleration, g	7.7	8.1	.4
Exit dynamic pressure, lb/ft^2	[a]966	964	-2
Exit dynamic pressure, lb/ft^2	[b]877	964	
Reentry deceleration, g	7.6	7.6	0
Reentry dynamic pressure, lb/ft^2	456	458	2
Landing point			
Latitude, deg:min	32°06' N	[c]32°06' N	0
Longitude, deg:min	174°33' W	[c]174°28' W	-05' W

[a]Based on atmosphere at Cape Canaveral.

[b]Based on 1959 Air Research and Development Command model atmosphere.

[c]Actual landing coordinates shown were those which resulted from the trajectory integration. The retrieval point after landing was reported as 32°06' N and 174°29' W by the recovery ship (refer to section on "Recovery Operations").

TABLE XXIV. - ORBITAL-INSERTION CONDITIONS AVAILABLE AT THE MERCURY CONTROL CENTER

Insertion conditions	Nominal	General Electric Burroughs	Impact predictor	Bermuda	Back from Muchea
Inertial velocity with posigrades,[a,b] ft/sec	25 736	25 746	25 762	25 783	25 751
Inertial flight-path angle,[b] deg . . .	-.0006	-.0281	-.120	+.203	-.0078
Insertion altitude, n. mi.	87.0	87.0	--	--	86.98
Inclination angle, deg	32.52	32.5	--	--	32.55
Apogee, n. mi.	144.2	150	--	--	152.8

[a]For previous flights, the variation in the data from the different sources was not as great. However, the increased disagreement for the MA-8 mission was expected because of the high noise level observed in the data.

[b]Average of go-no-go.

TABLE XXV. - RADAR TRACKING

Station	Number of observations	Used differential correction	Accepted	Rejected
		First orbital pass		
Bermuda				
FPS-16	43	42	X	
VERLORT	73	0		
Grand Canary Island	57	45	X	
Muchea, Australia	81	50	X	
Woomera, Australia	38	38	X	
Guaymas, Mexico	39	34		Late report
White Sands Missile Range, New Mexico	20	20	X	
Texas	55	48		No improvement in solution
Eglin AFB, Florida				
FPS-16	39	39	X	
VERLORT	15			
Cape Canaveral, Florida	14	10	X	
		Second orbital pass		
Bermuda				
FPS-16	48	46	X	
VERLORT	6	0		
Grand Canary Island	48	38	X	
Muchea, Australia	75	50	X	
Woomera, Australia	27	27	X	
Hawaii				
FPS-16	13	13	X	
VERLORT	30	0	X	
California				
FPS-16	9	9		
VERLORT	43			
White Sands Missile Range, New Mexico	37	37	X	

TABLE XXV. - RADAR TRACKING - Concluded

Station	Number of observations	Used differential correction	Accepted	Rejected
Second orbital pass — concluded				
Texas	49	45	X	
Eglin AFB, Florida				
FPS-16	27	27		Late report
VERLORT	11			
Cape Canaveral, Florida	14	14	X	
Third orbital pass				
Muchea, Australia	62	50	X	
Hawaii				
FPS-16	37	37	X	
VERLORT	16	0		
California				
FPS-16	5	4		
VERLORT	12	11	X	

TABLE XXVI. - LANDING-POINT DATA

Data source	Latitude N	Incremental latitude, n. mi.	Longitude W	Incremental longitude, n. mi.
Based on assumed time of retrofire (assuming correct attitudes)	32°06'	1	174°32'	1
Based on actual time of retrofire and reported attitudes	32°09'	4	174°29'	
Planned nominal	32°05'		174°33'	
Based on signals from SOFAR bomb	32°04'	1	174°32'	1
Actual landing point reported by recovery ship	32°06'		174°28'	

TABLE XXVII. - COMMAND HANDOVER SUMMARY

Station	Command carrier (a)		+7.5-μV carrier coverage above line of sight, percent
	ON	OFF	
Cape Canaveral, Florida	Launch	00:06:00 00:06:00	98
Bermuda	00:05:58 (00:05:58)	00:12:00 (00:12:00)	44
Muchea, Australia	00:45:00 (00:45:00)	00:59:00 (00:59:00)	25
Guaymas, Mexico	01:20:00 (01:20:00)	01:33:00 (01:33:00)	26
Cape Canaveral, Florida	01:33:00 (01:33:30)	01:38:00 (01:38:29)	90
Bermuda	01:37:58 (01:38:00)	01:45:00 (01:45:00)	82
Muchea, Australia	02:15:00 (02:15:00)	02:32:00 (02:32:00)	46
Hawaii	02:45:00 (02:45:00)	02:56:35 (02:56:00)	91
California	02:56:35 (02:56:30)	03:04:35 (03:04:35)	85
Guaymas, Mexico	03:04:35 (03:04:35)	03:06:50 (03:06:50)	06
Cape Canaveral, Florida	03:06:50 (03:06:51)	03:12:50 (03:12:59)	94
Bermuda	03:12:50 (03:12:50)	03:18:20 (03:18:20)	93

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

TABLE XXVII. - COMMAND HANDOVER SUMMARY - Continued

Station	Command carrier (a)		+7.5-μV carrier coverage above line of sight, percent
	ON	OFF	
Muchea, Australia	03:54:00 (03:54:00)	04:05:00 (04:05:00)	32
Hawaii	04:15:00 (04:15:04)	04:31:00 (04:31:00)	15
California	04:31:00 (04:31:00)	04:38:00 (04:38:00)	87
Guaymas, Mexico	04:38:00 (04:38:00)	04:40:00 (04:40:00)	15
Cape Canaveral, Florida	04:40:00 (04:40:01)	04:45:45 (04:45:32)	74
Cape Canaveral, Florida (San Salvador)	04:46:30 (04:45:32)	04:47:45 (04:47:45)	56
Cape Canaveral, Florida (Grand Turk)	04:47:45 (04:47:45)	04:51:45 (04:51:45)	71
Hawaii	05:56:30 (05:56:00)	06:03:00 (06:03:31)	67
California	06:03:00 (06:03:00)	06:09:20 (06:09:45)	85
Guaymas, Mexico	06:09:20 (06:09:20)	06:15:00 (06:15:03)	12
Cape Canaveral, Florida	06:15:00 (06:15:01)	06:20:00 (06:20:00)	77
Pacific Command ship	07:15:30 (07:11:00)	07:23:00 (07:23:00)	23

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

TABLE XXVII. - COMMAND HANDOVER SUMMARY - Concluded

Station	Command carrier (a)		+7.5 -μV carrier coverage above line of sight, percent
	ON	OFF	
Hawaii	07:31:00 (07:31:00)	07:36:00 (07:36:05)	34
California	07:38:30 (07:35:22)	07:42:30 (07:45:22)	15
Guaymas, Mexico	07:42:30 (07:42:30)	07:47:00 (07:47:00)	0
Pacific Command ship	08:47:00 (08:46:00)	08:57:00 (08:58:00)	33

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

TABLE XXVIII. - COMMAND FUNCTION SUMMARY

Station	Function	Signal transmission: Time of initiation, hr:min:sec	Signal transmission: Duration of signal transmission, sec	Approximate slant range, n. mi.	Signal strength at spacecraft, μV
Cape Canaveral, Florida	ASCO[a]	00:05:16	5	430	30
	Z-Cal[b]	01:35:22	14	515	25
	R-Cal[c]	01:35:37	9	460	25
	Z-Cal	03:10:10	11	276	40
	R-Cal	03:10:22	11	250	35
Hawaii	Z-Cal	04:25:24	9	345	15
	R-Cal	04:25:41	19	290	20
Guaymas, Mexico	Z-Cal	06:10:01	10	395	1 to 3
	R-Cal	06:10:25	[d]1 3 1 [d]5	300	0 to 3
Pacific Command ship	Z-Cal	07:18:18	19	375	10
	R-Cal	07:18:42	17	330	10

[a]ASCO - Auxiliary sustainer cut-off.

[b]Z-Cal - Instrumentation zero calibration.

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

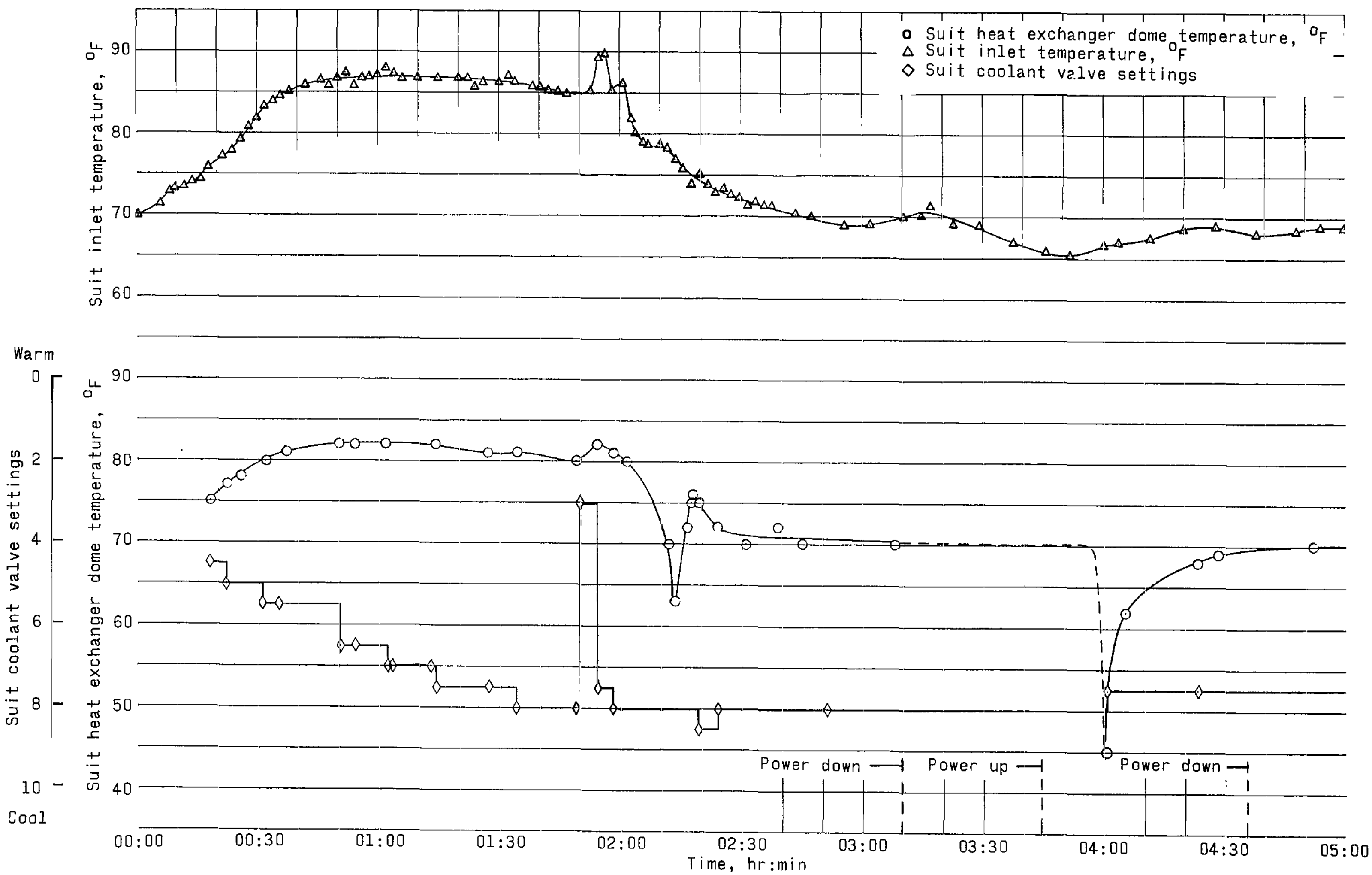
[d]Functions dropped out because signal strength went below receiver threshold.

TABLE XXIX. - AIR-TO-GROUND SIGNAL STRENGTH

Station	Orbital pass	Average signal strength, μV	
		uhf	hf
Grand Turk Island	Launch	20	2
	1	202	202
	2	127	602
	3	202	---
	4	202	---
Grand Bahama Island	Launch	1500	2500
	1	---	2500
	2	Weak	---
	3	Weak	---
	4	Weak	---
	5	Weak	---
Bermuda	1	9	---
	2	23.6	---
	3	17.9	---
	4	10	---
Grand Canary Island	1	25.6	---
	2	5.8	---
Kano, Nigeria, SW. Africa	1	9	
	2	5.6	12.4
Zanzibar, East Africa	1	350	200
	2	200	10
Indian Ocean ship	2	15.6	---
	3	49.6	---
	4	27	---
	5	15	---
Muchea, Australia	1	---	183
	2	27.7	---
	3	30.5	---
	4	---	16.6
Woomera, Australia	1	---	500
	2	30	---
	3	15.6	---

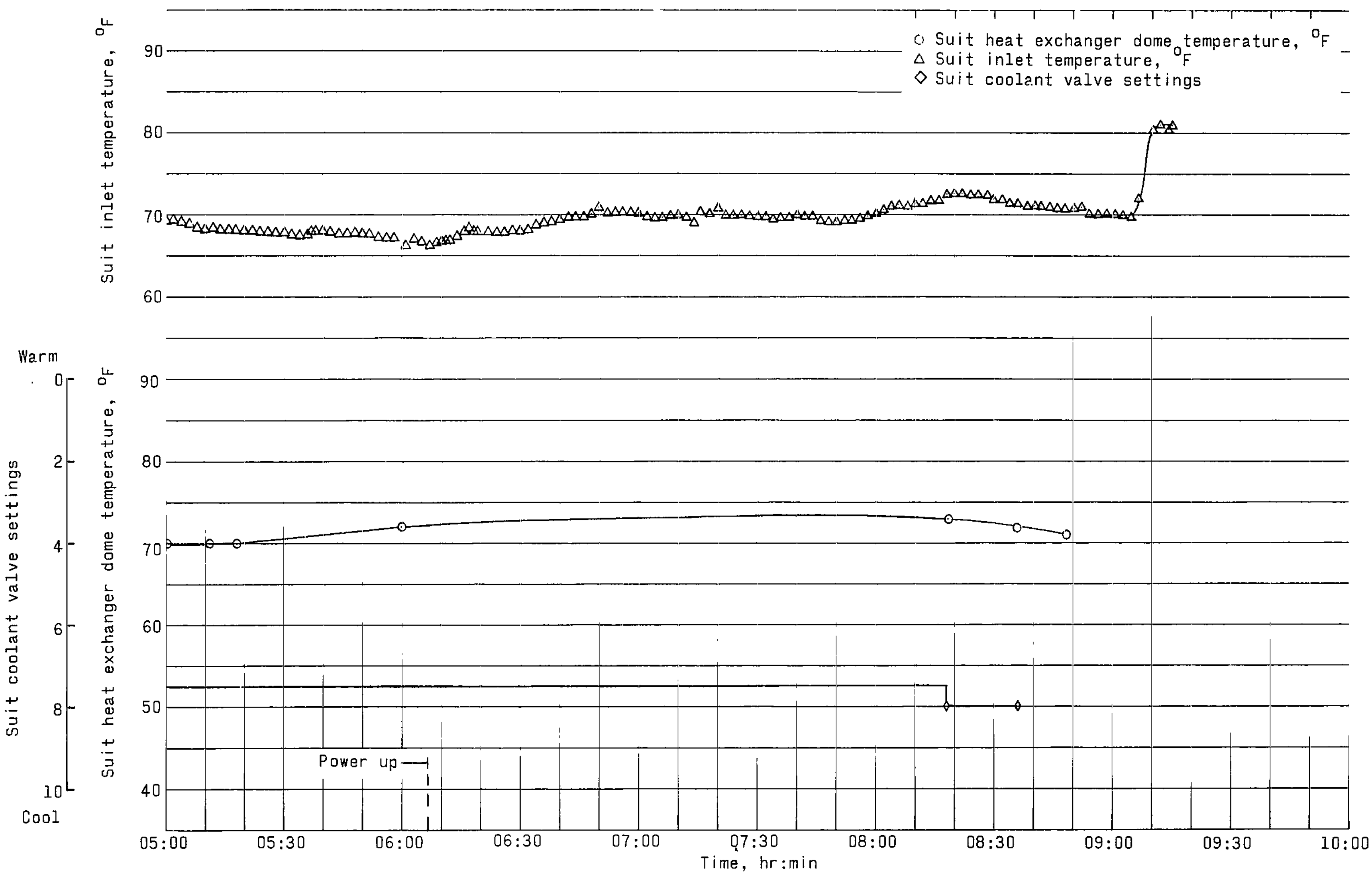
TABLE XXIX. - AIR-TO-GROUND SIGNAL STRENGTH - Concluded

Station	Orbital pass	Average signal strength, μV	
		uhf	hf
Canton Island	1	---	22.5
	2	---	16
Hawaii	2	---	40
	3	Recording trouble	---
	4	Recording trouble	---
	5	Recording trouble	---
Guaymas, Mexico	1	---	150
	2	---	Weak
	3	23	---
	4	60	---
	5	65	20
California	1	---	13
	2	20.6	30
	3	27	---
	4	23.7	10.7
Texas	1	---	107
	2	12	---
	3	38.7	---
	4	22	---
	5	15	21
Eglin AFB, Florida	1	5	20
	2	---	5
	3	---	7
	4	5	15



(a) Flight elapsed time, 00:00 to 05:00.

Figure 18. - Variation of space suit inlet temperature, suit heat-exchanger dome temperature, and associated suit coolant-valve settings with time.



(b) Flight elapsed time, 05:00 to 10:00.

Figure 18. - Concluded.

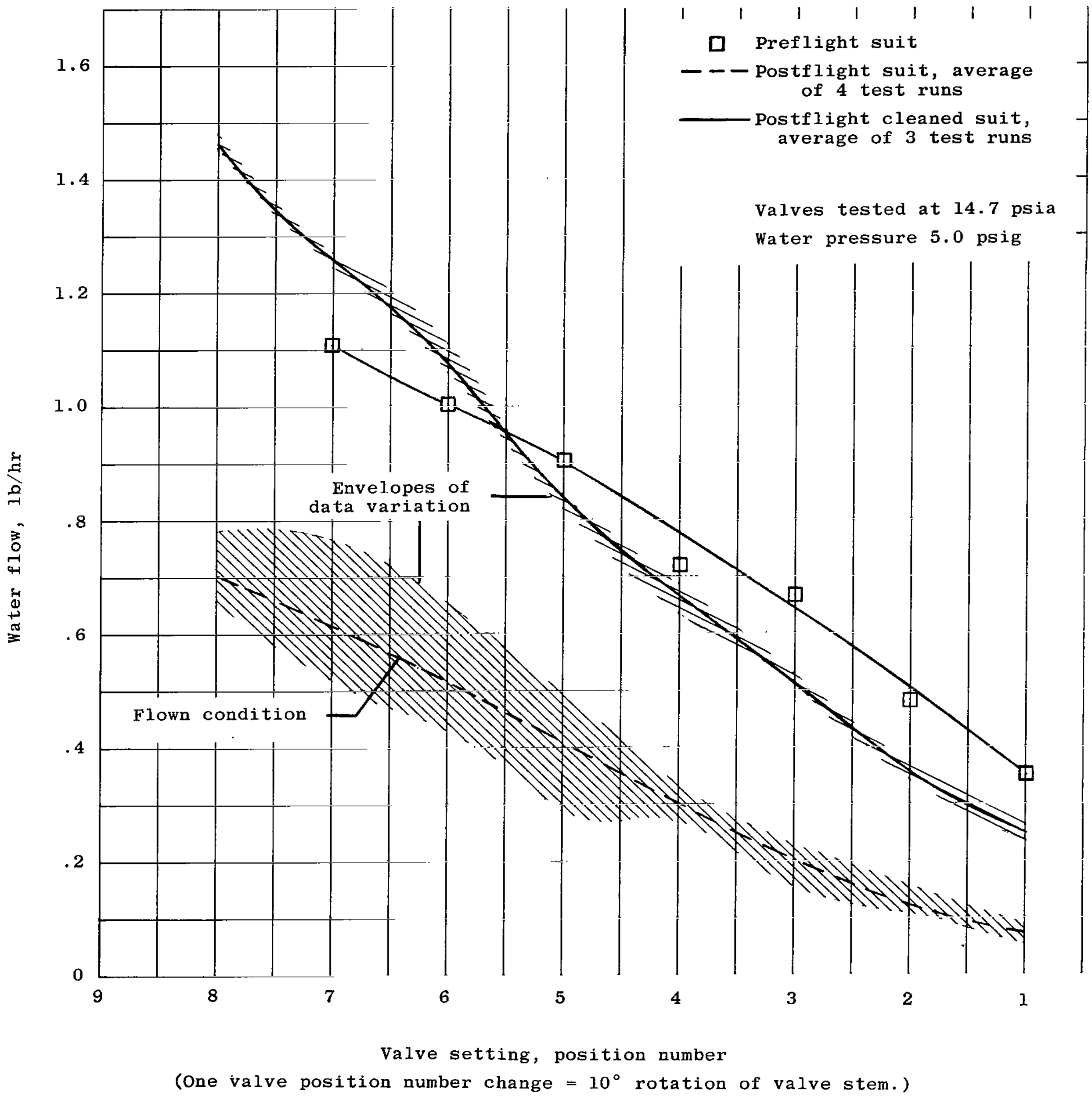
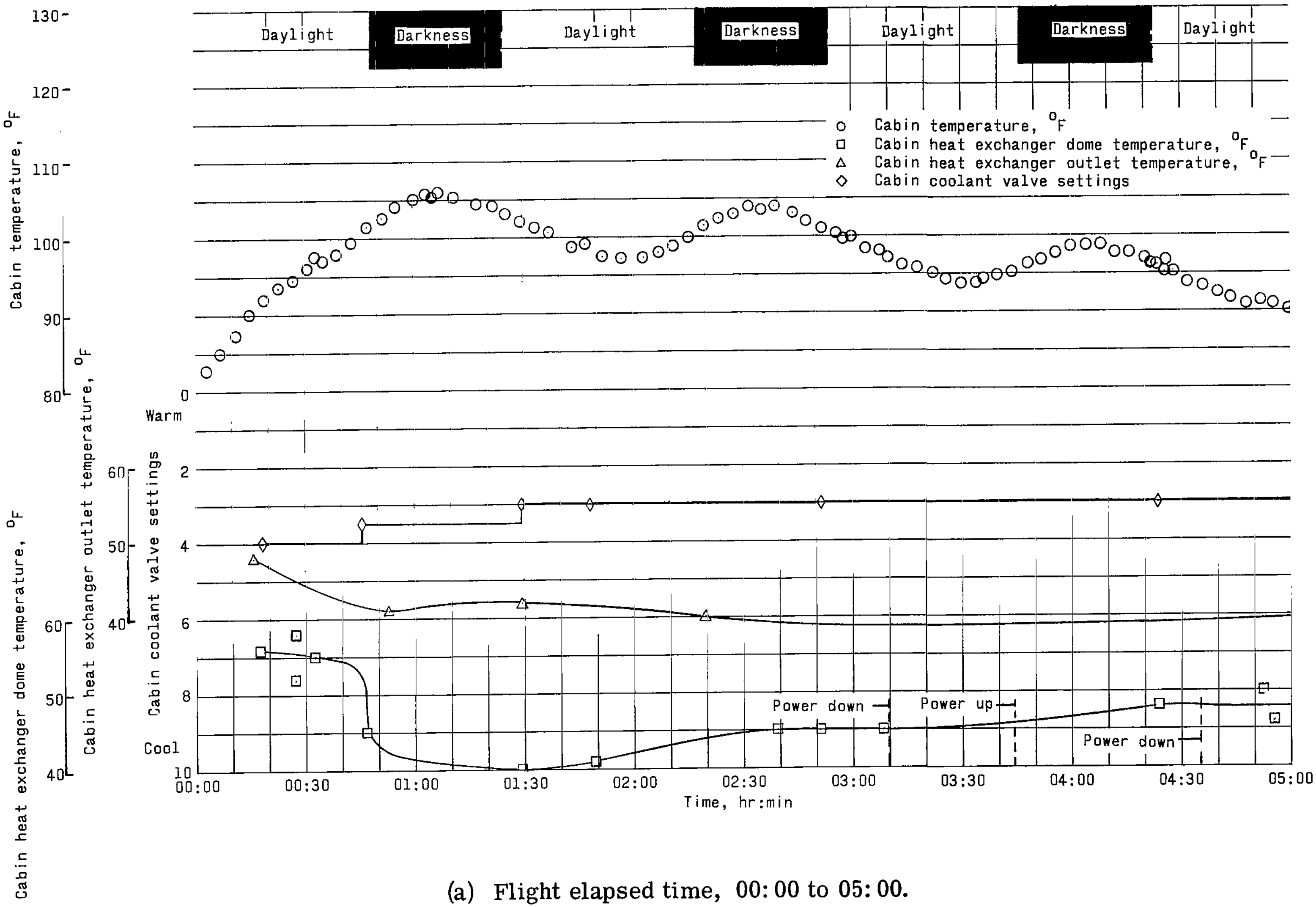
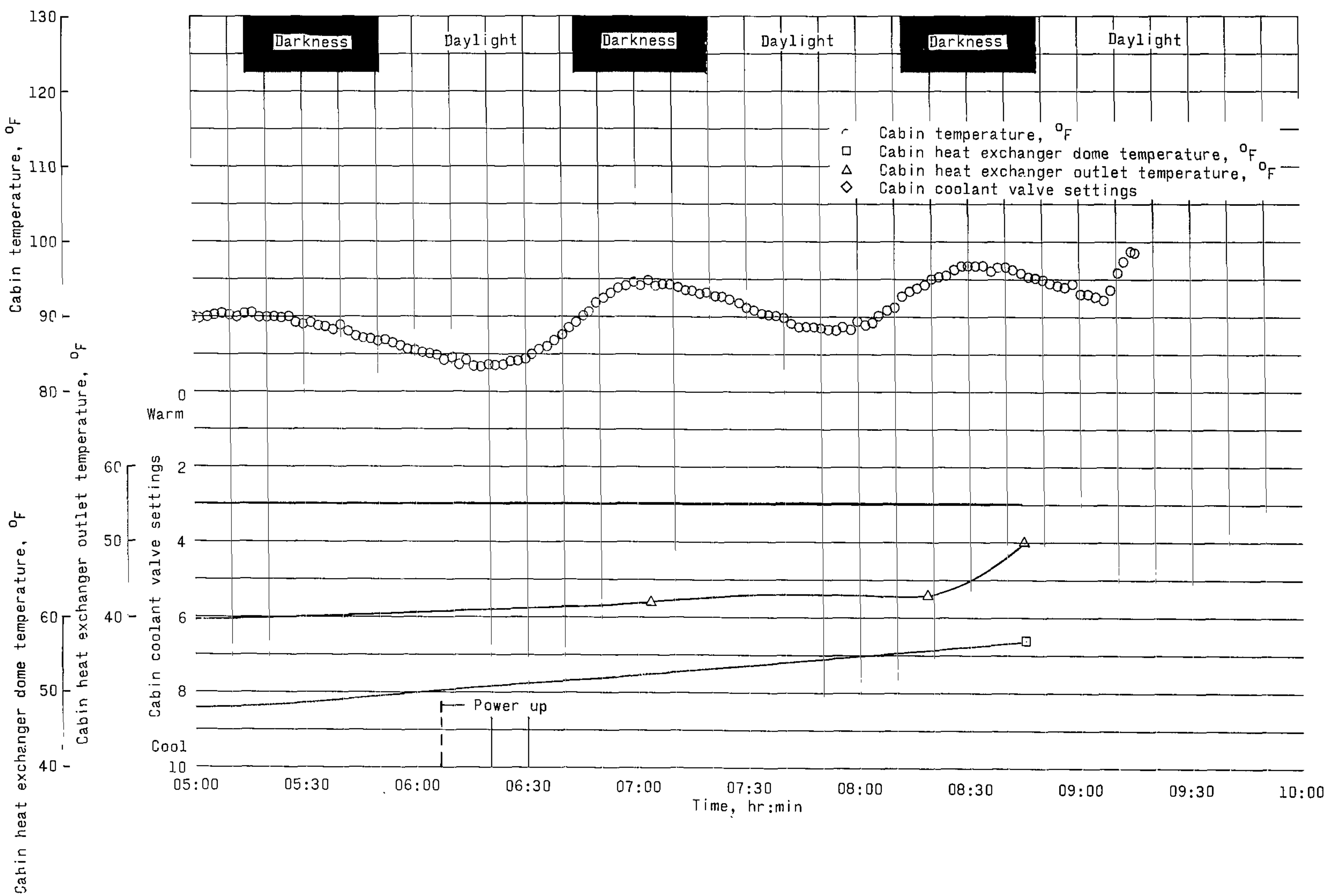


Figure 19. - Comfort-control-valve calibration curve.



(a) Flight elapsed time, 00:00 to 05:00.

Figure 20. - Variation of cabin air temperature, cabin heat-exchanger dome temperature, and associated comfort-control-valve settings with time.



(b) Flight elapsed time, 05: 00 to 10: 00.

Figure 20. - Concluded.

Figure 21. - High-frequency dipole antenna in the extended position.

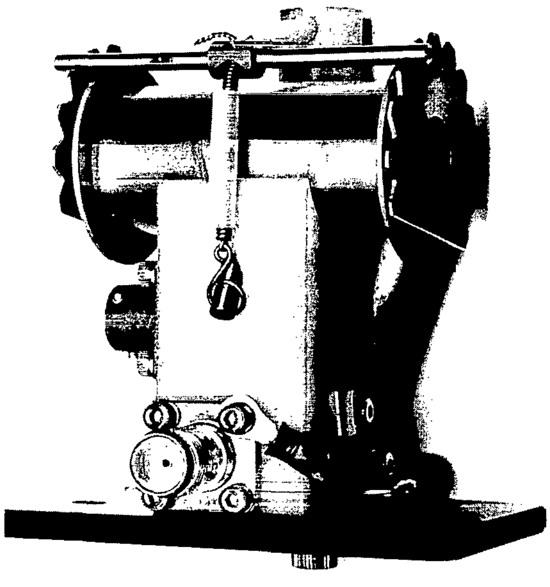


Figure 22. - One element of the hf dipole antenna in retracted position.

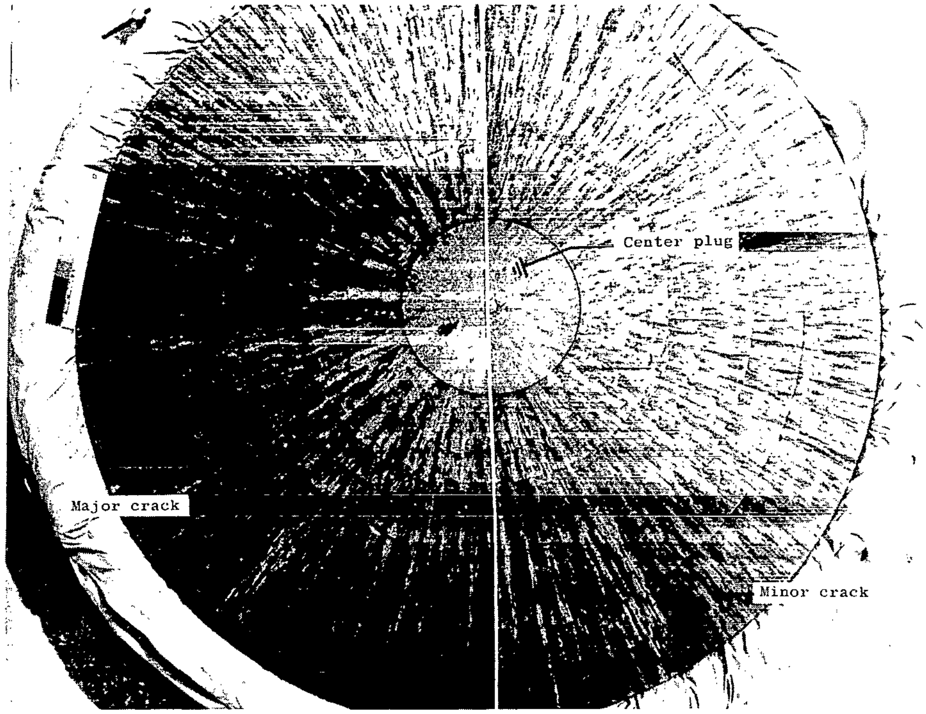


Figure 23. - Postflight appearance of heat-shield ablation surface.

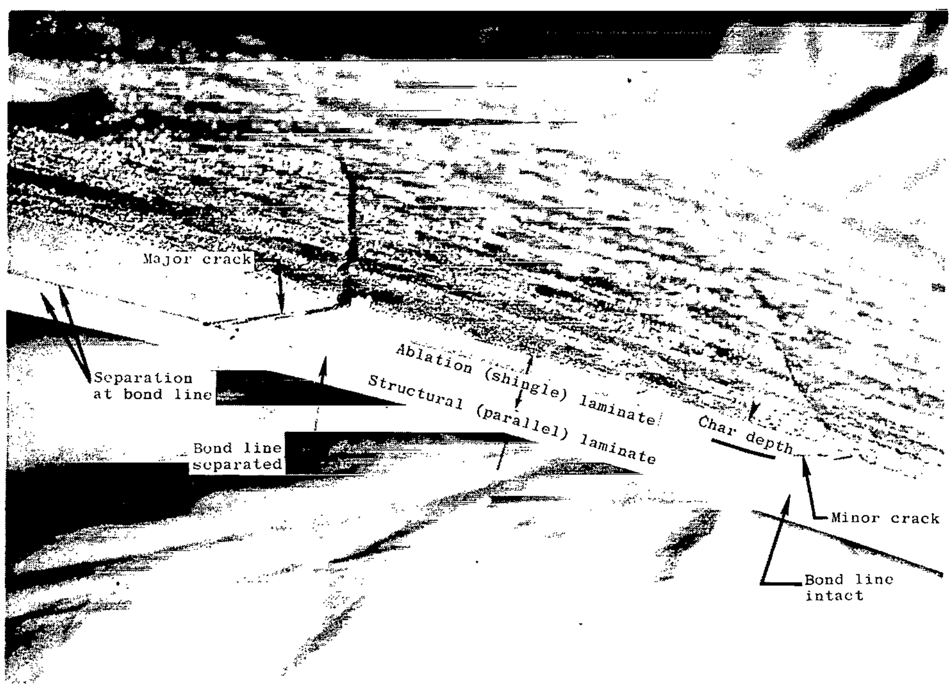


Figure 24. - Cross-section view of heat shield showing major cracking of ablation laminate and separation at bond line.

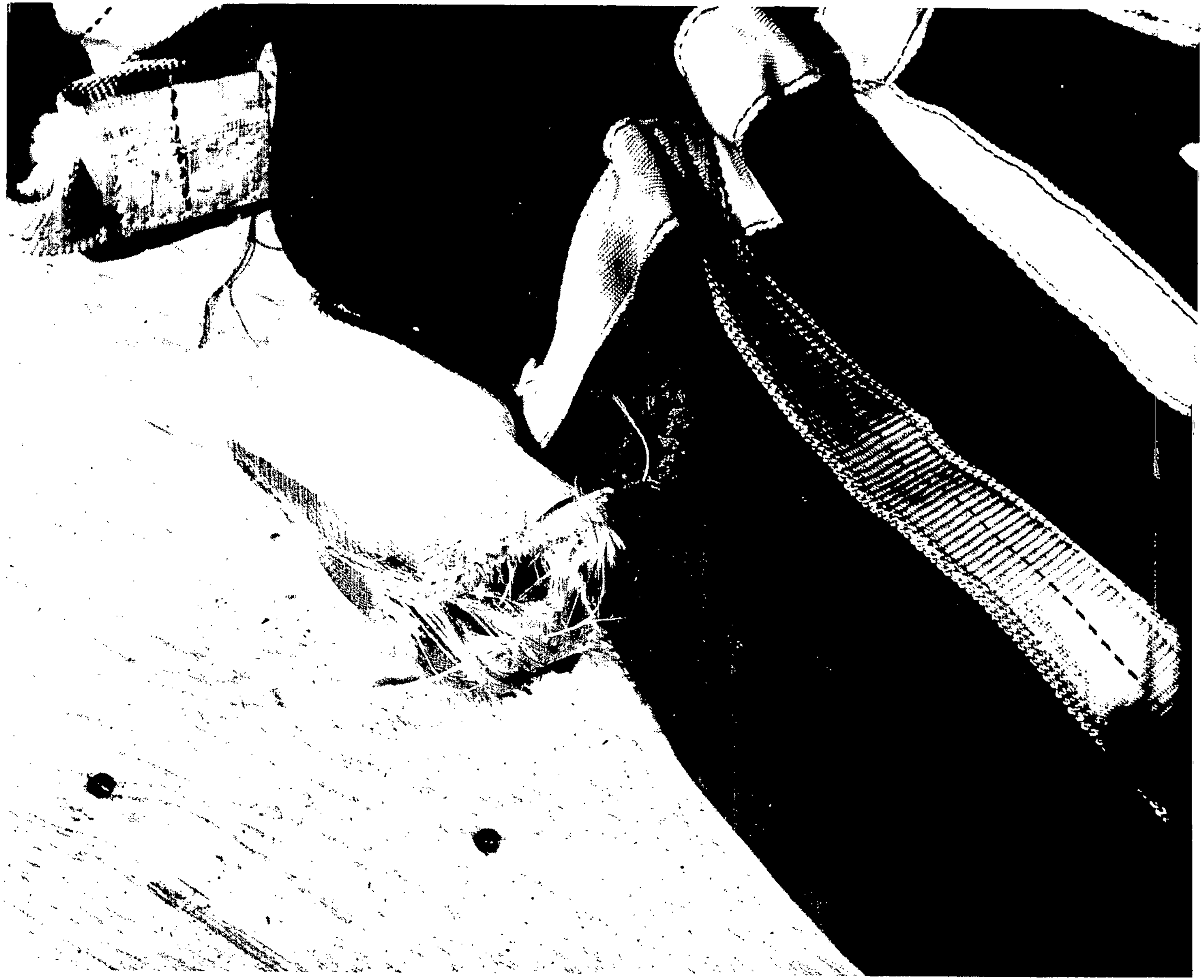


Figure 25. - Postflight photograph of main-parachute deployment bag showing tears.

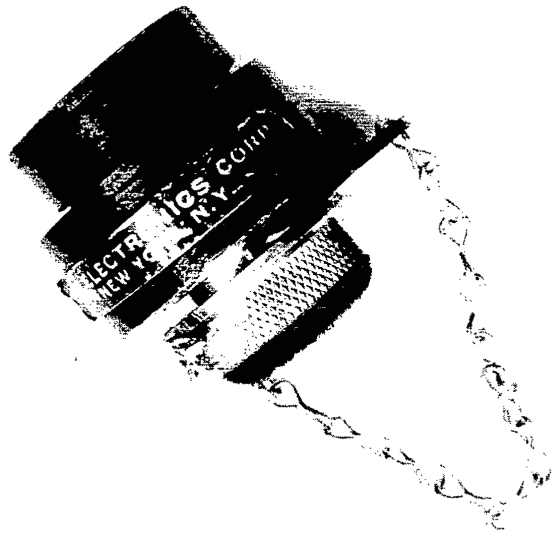


Figure 26. - Standard light source.

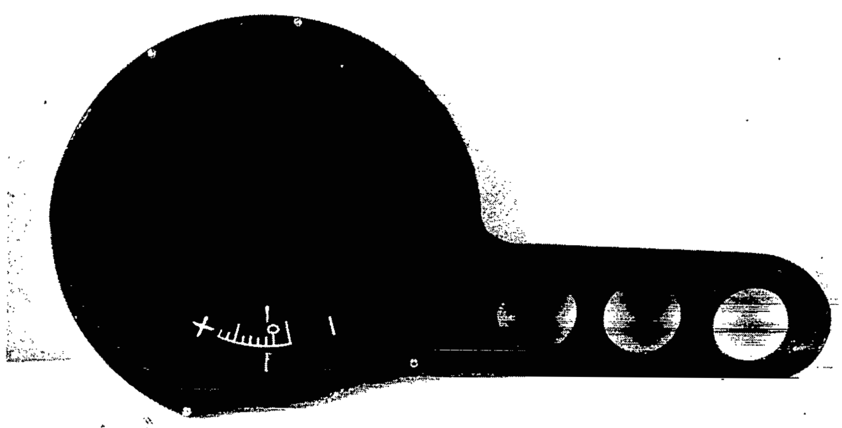


Figure 27. - Extinction photometer.

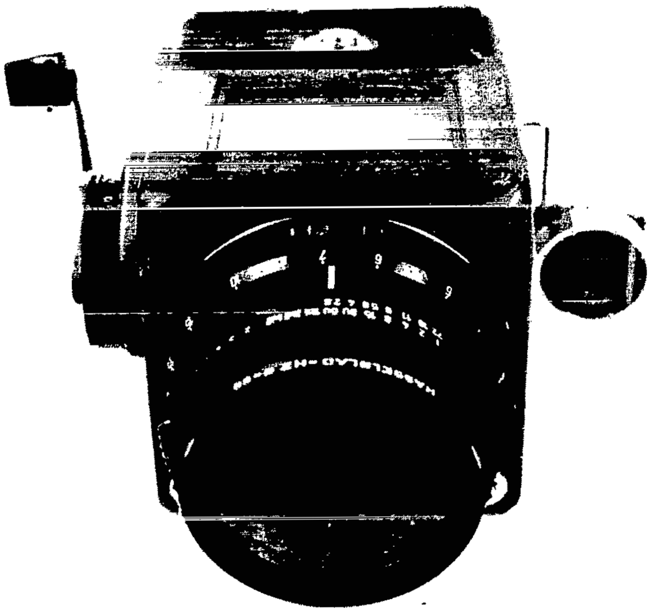


Figure 28. - Hand-held camera.

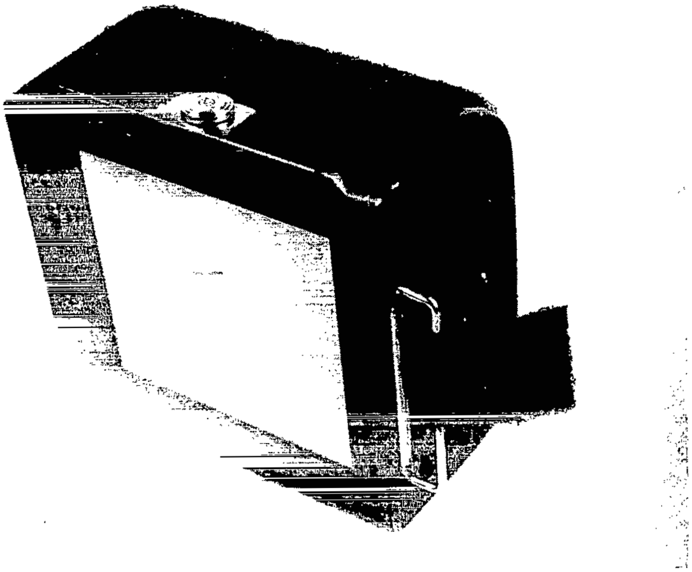


Figure 29. - Film magazine for camera.

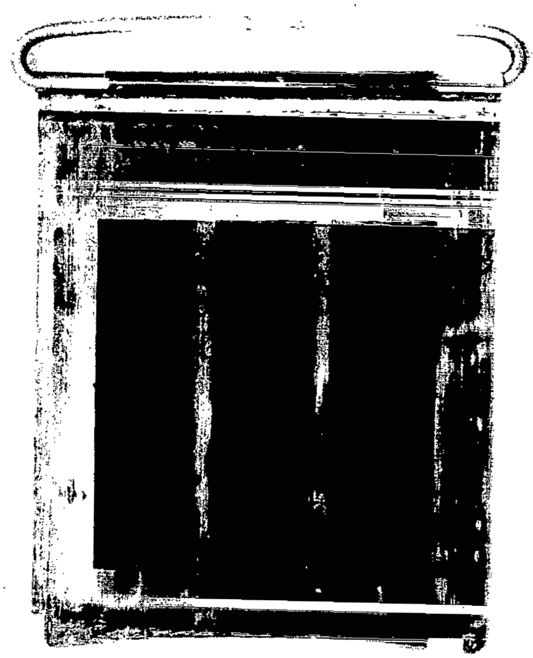


Figure 30. - Filter mosaic slide.

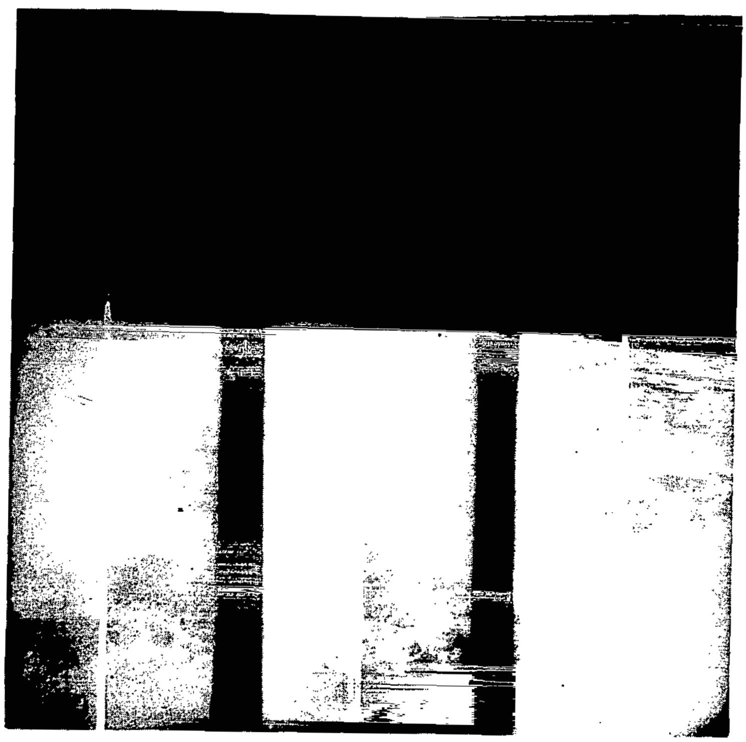


Figure 31. - Weather photograph showing filter comparison.

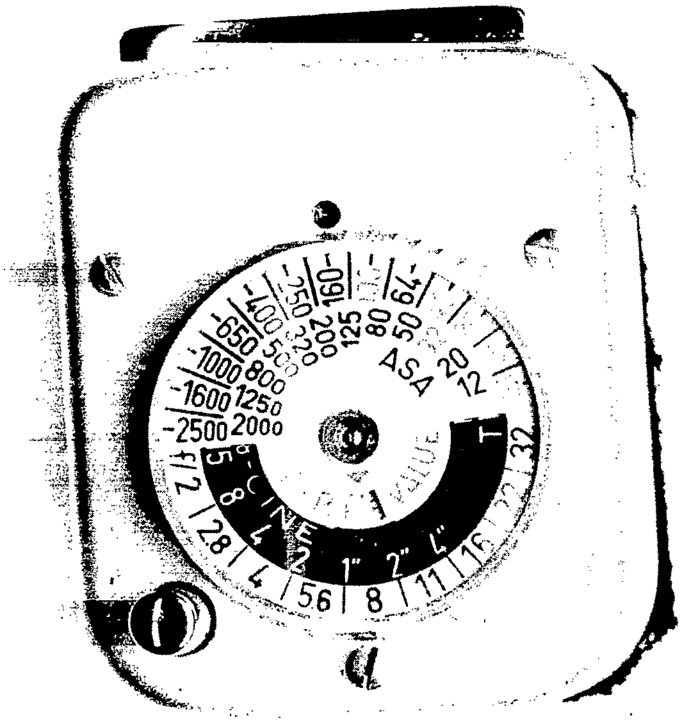


Figure 32. - Exposure meter.

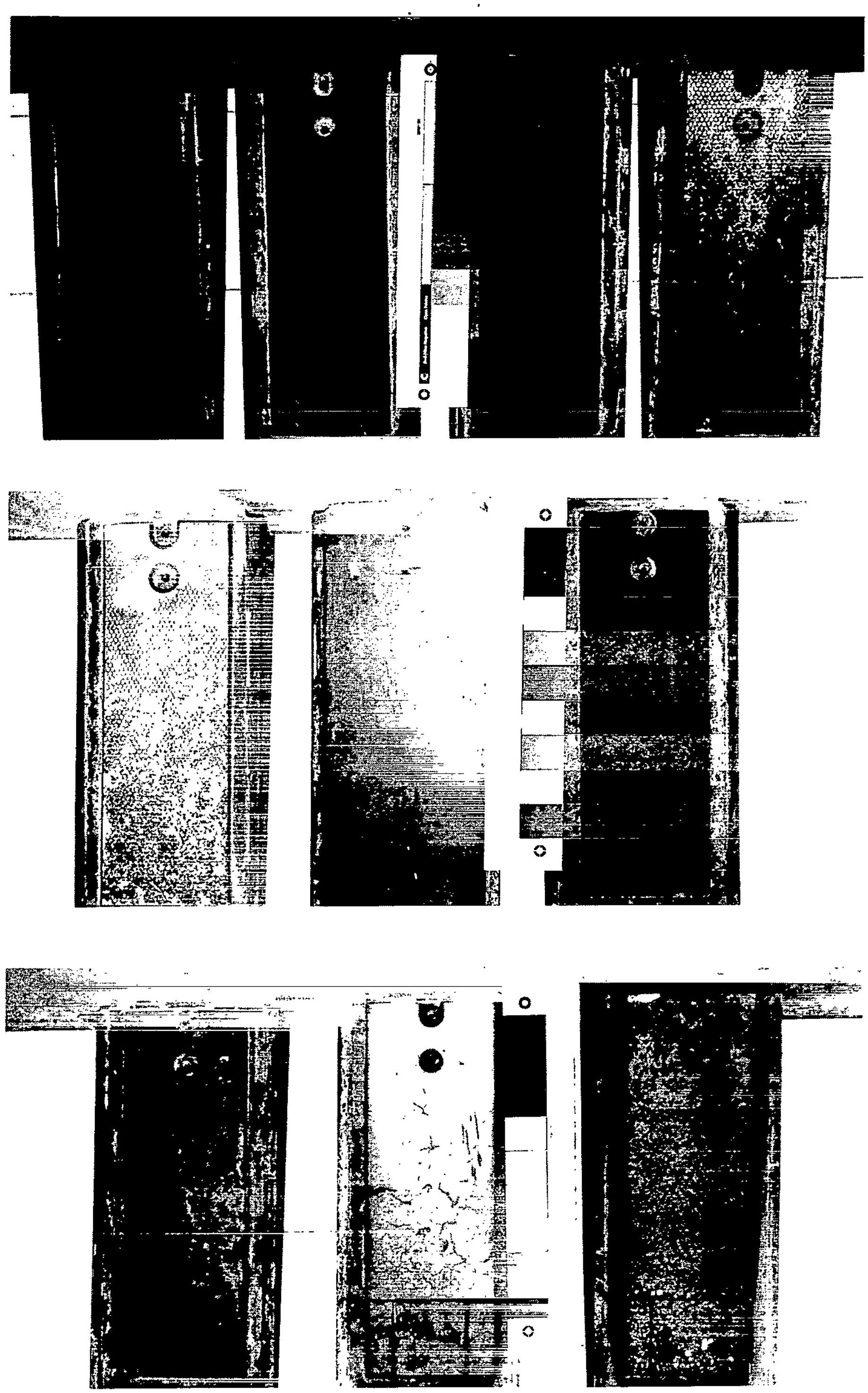


Figure 33. - Preflight photograph of ablation-material samples mounted on beryllium shingles.

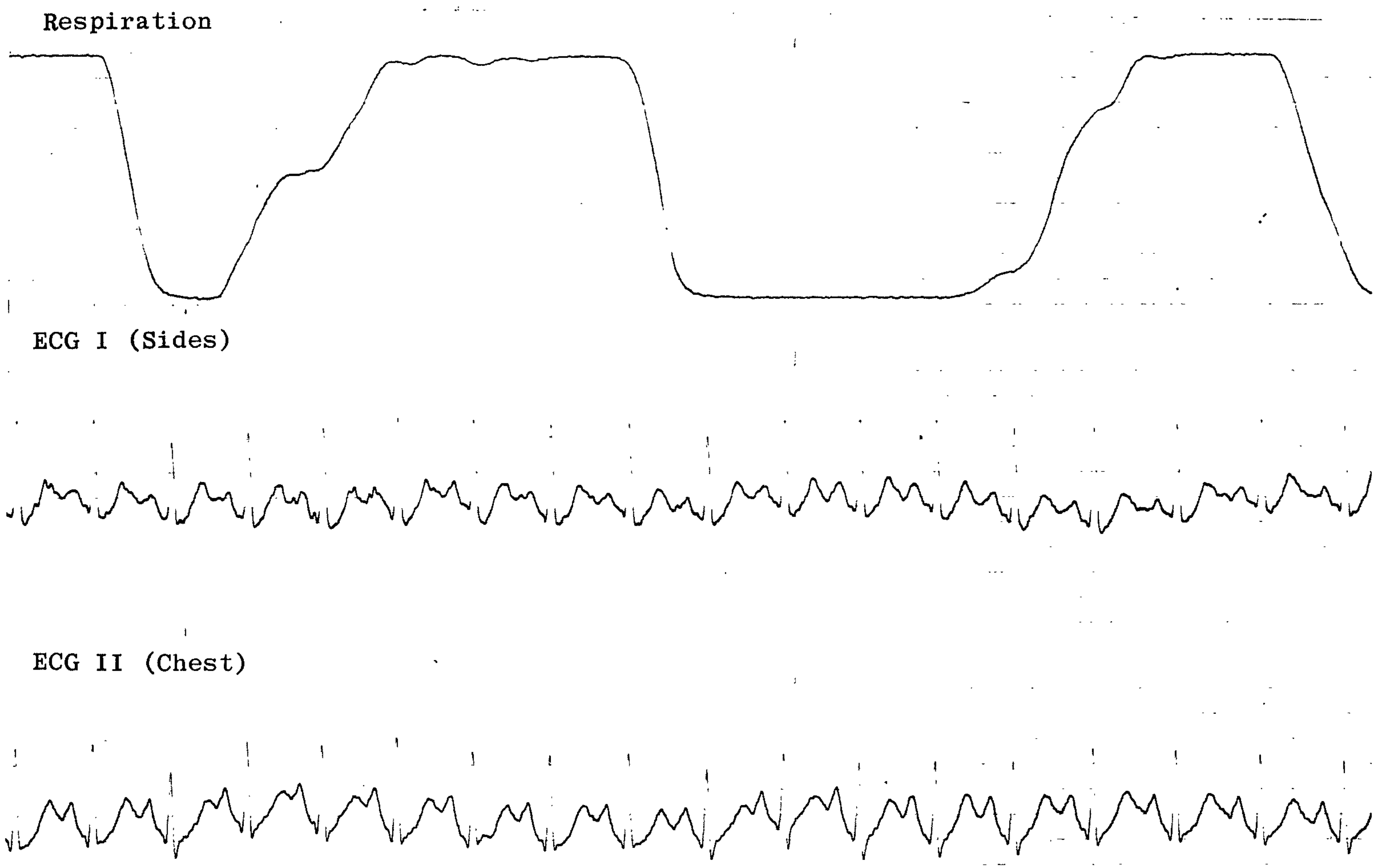
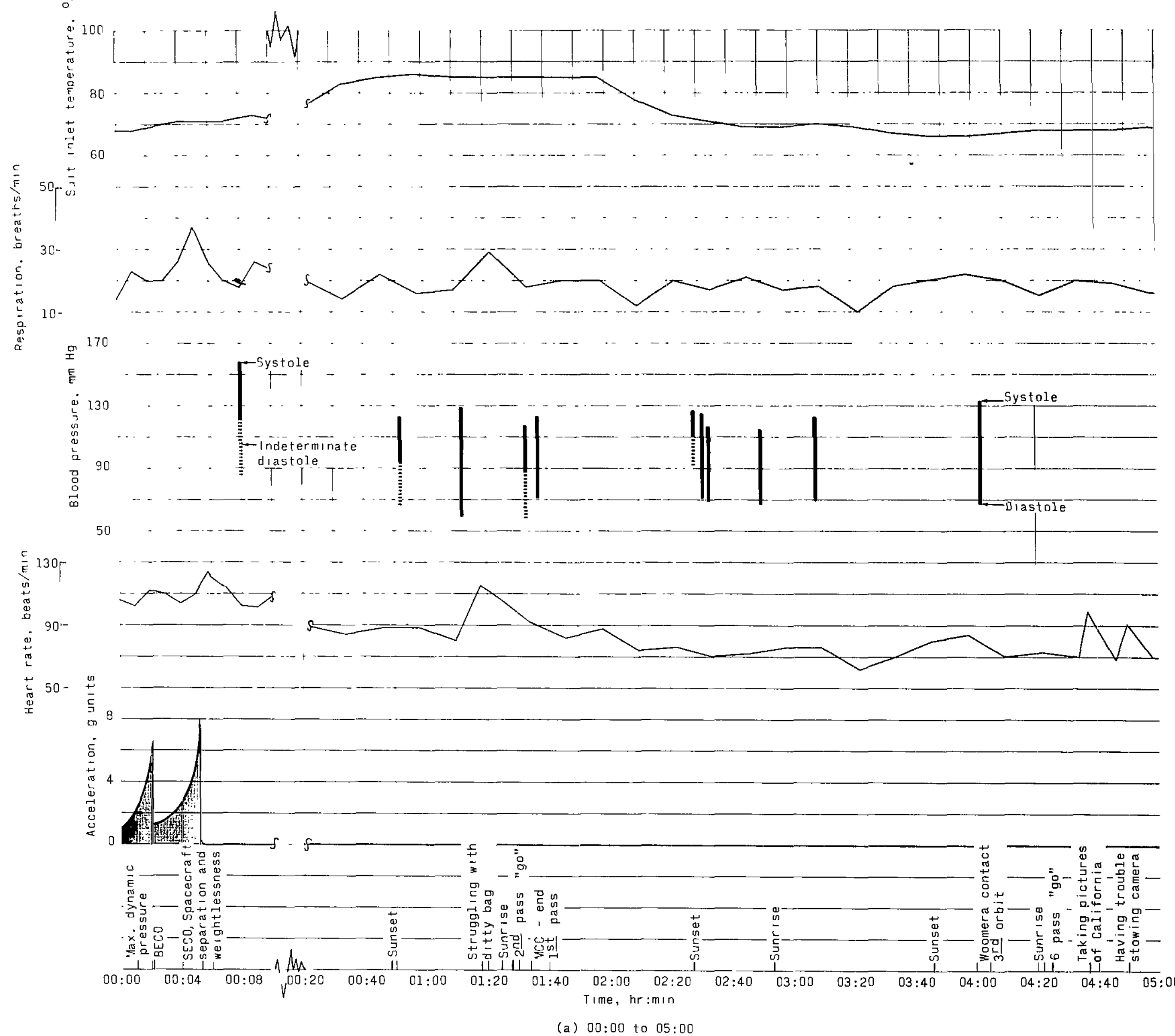
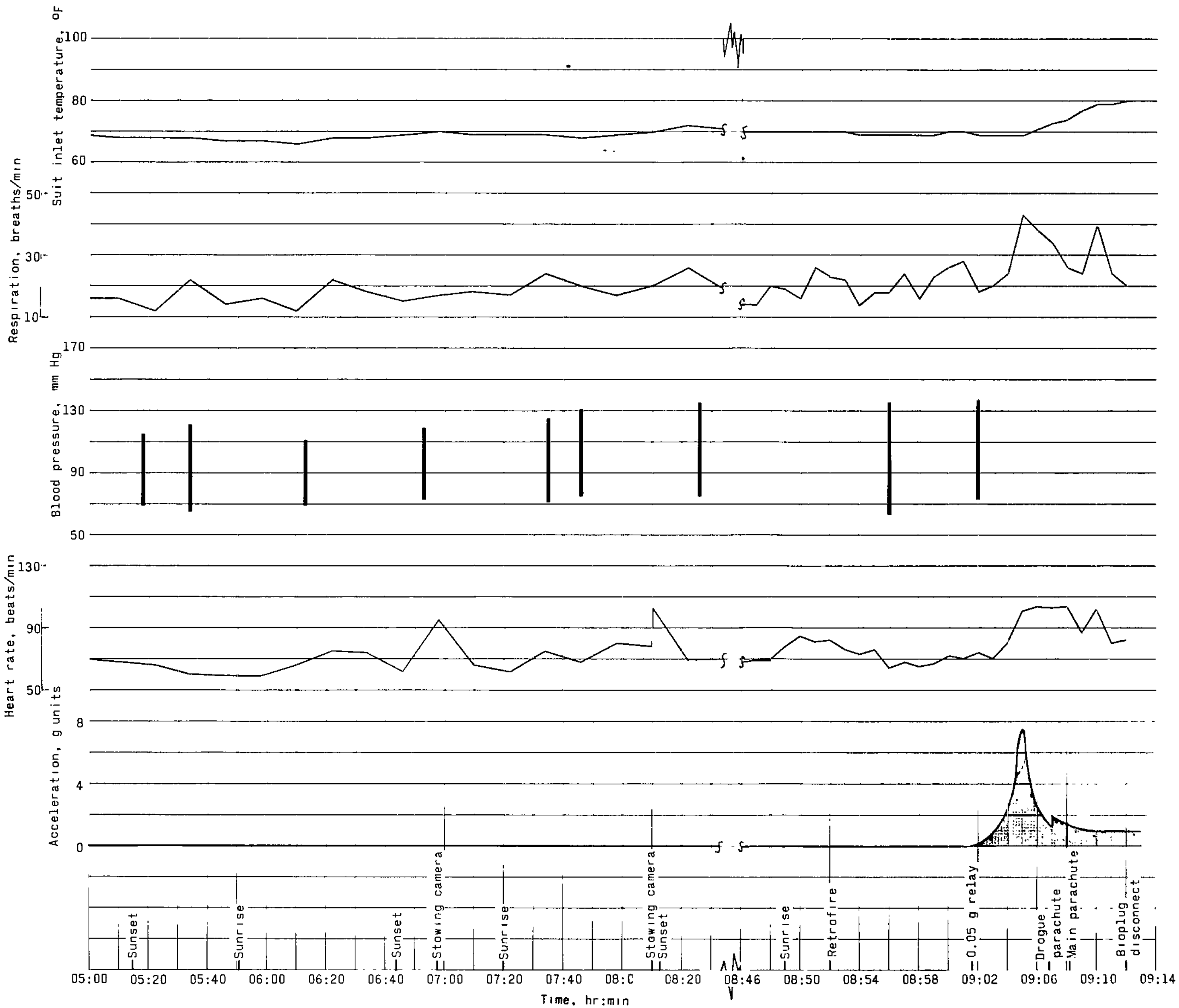


Figure 34. - Sample of the playback record from the onboard tape during launch (at 00:07:20 g. e. t.) illustrating the clarity of the trace at normal record and paper speed 25 mm/sec.



(a) 00: 00 to 05: 00.

Figure 35. - Flight physiological responses.



(b) 05:00 to 09:14

Figure 35. - Concluded.

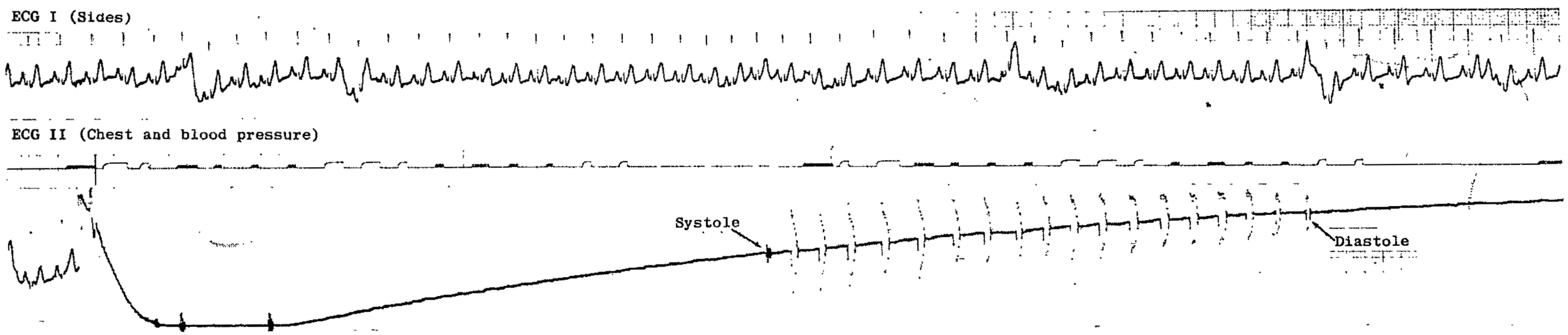


Figure 36. - Sample of playback of onboard record illustrating a typical blood-pressure cycle (at 2: 32 g. e. t.), paper speed 10 mm/sec.

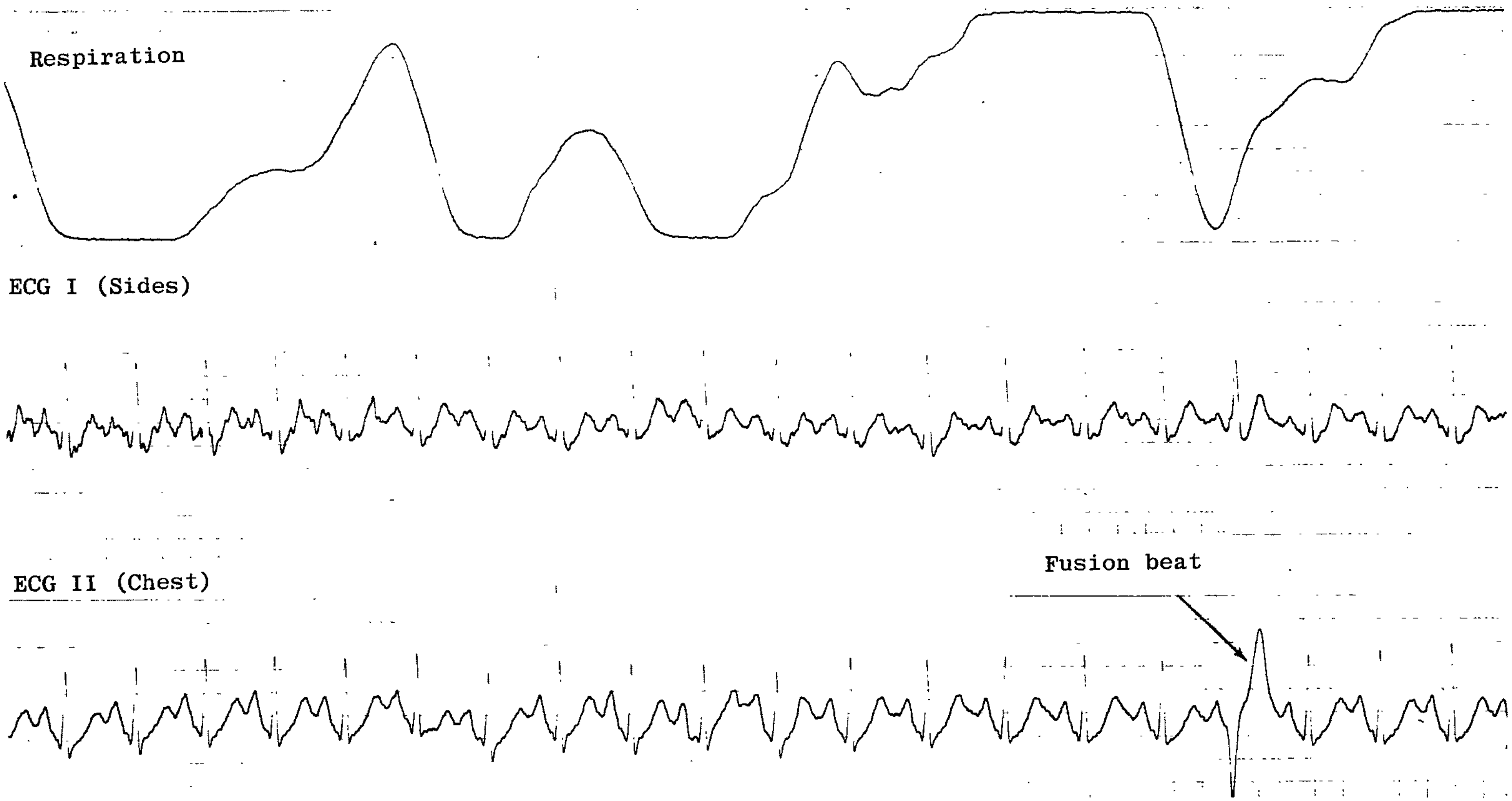


Figure 37. - Sample of the playback record from the onboard tape during launch (at 00: 07: 00 g. e. t.) illustrating a ventricular fusion beat, paper speed 25 mm/sec.

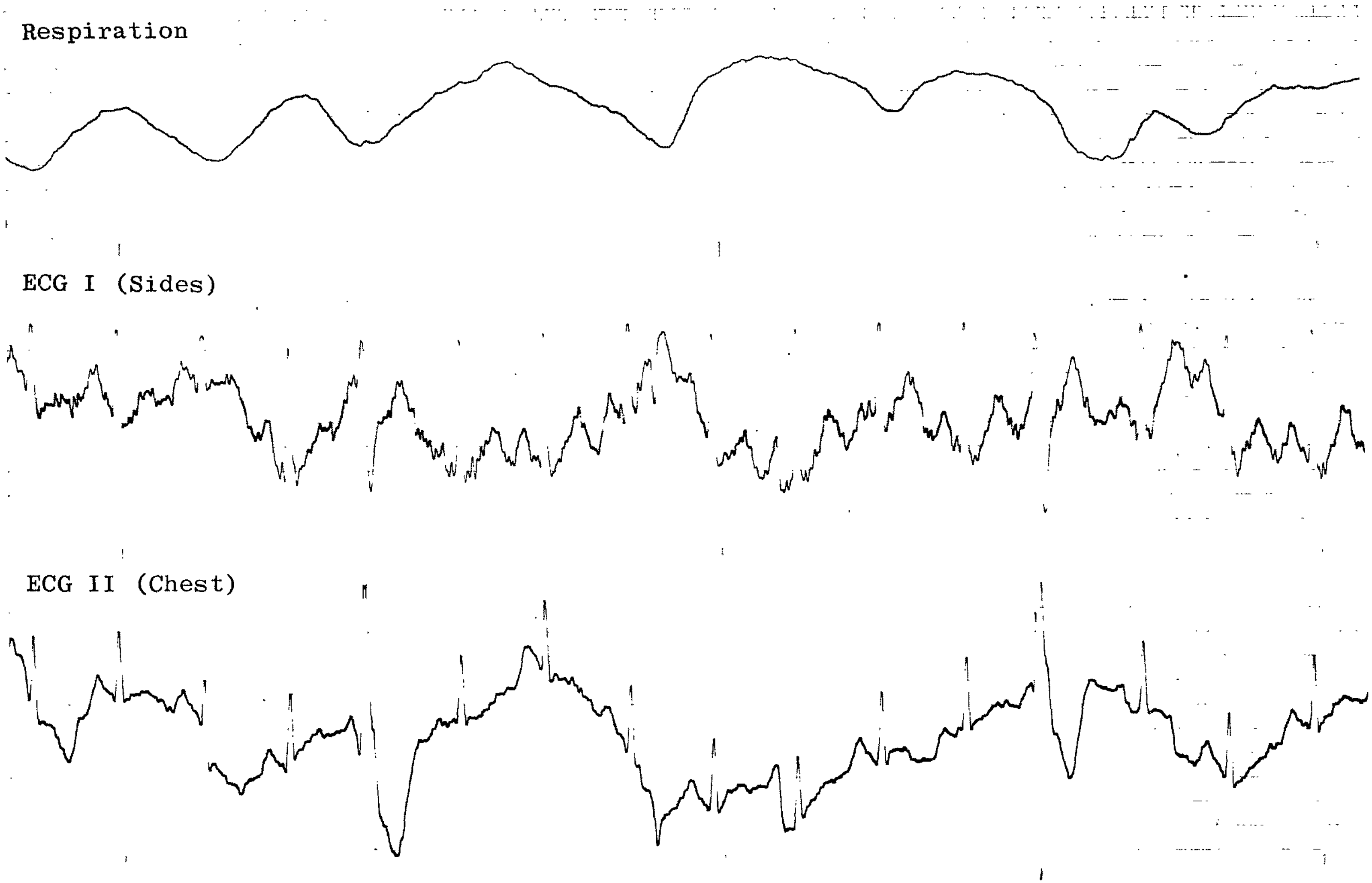


Figure 38. - Sample of the playback record from the onboard tape illustrating the appearance of artifacts on the bioinstrumentation record (at 09:05 g.e.t.), paper speed 25 mm/sec.

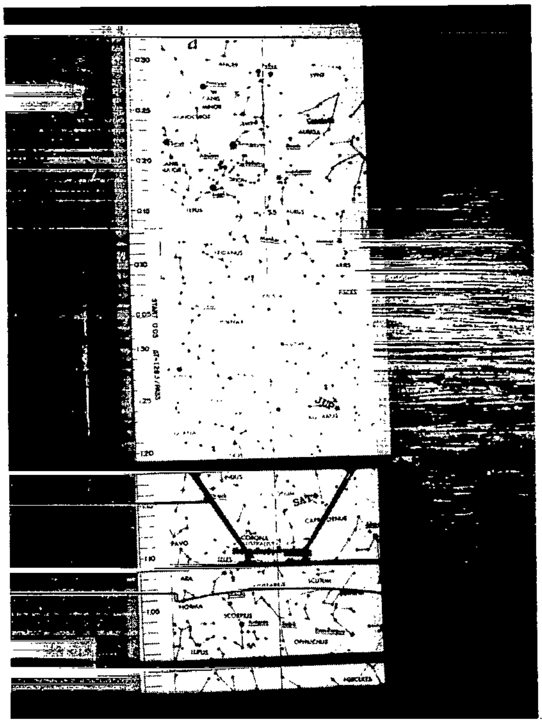


Figure 39. - Star navigation charts.

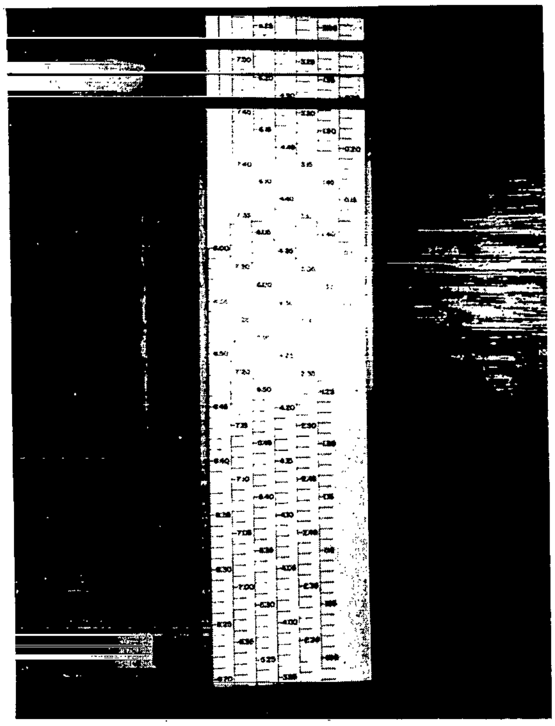


Figure 40. - Time-conversion computer.

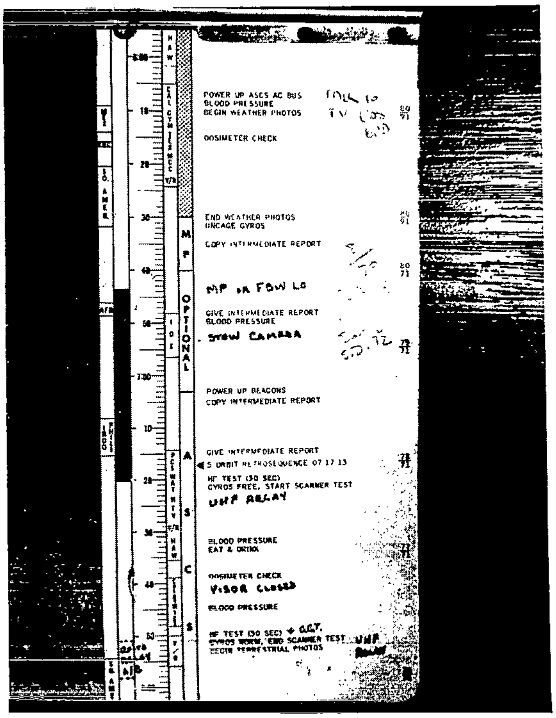


Figure 41. - Flight-plan card.

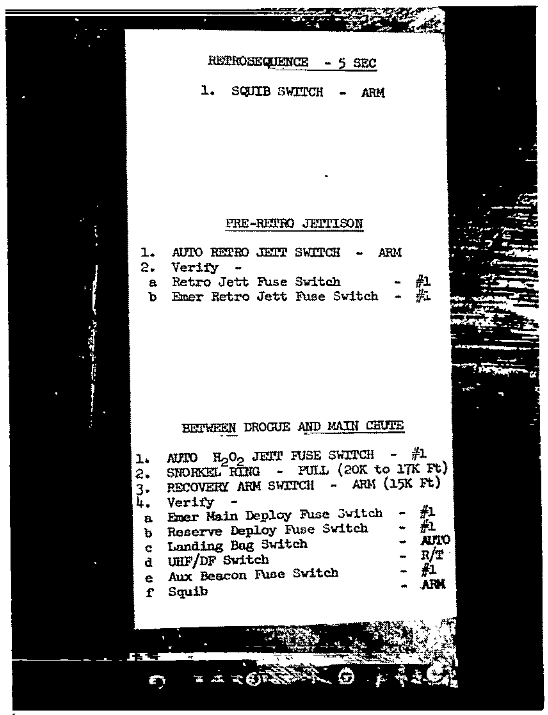


Figure 42. - Checklist for critical orbital operations.

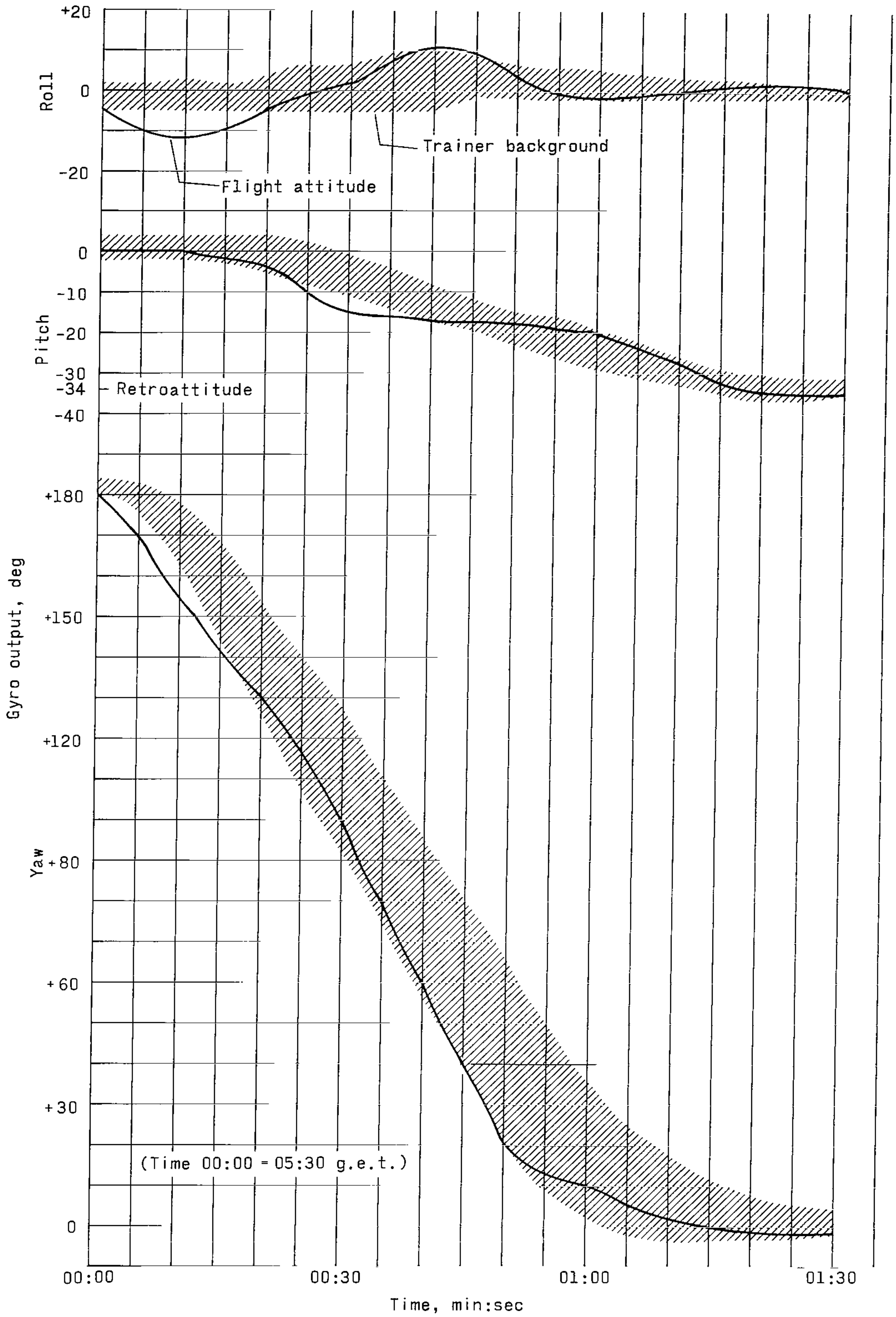
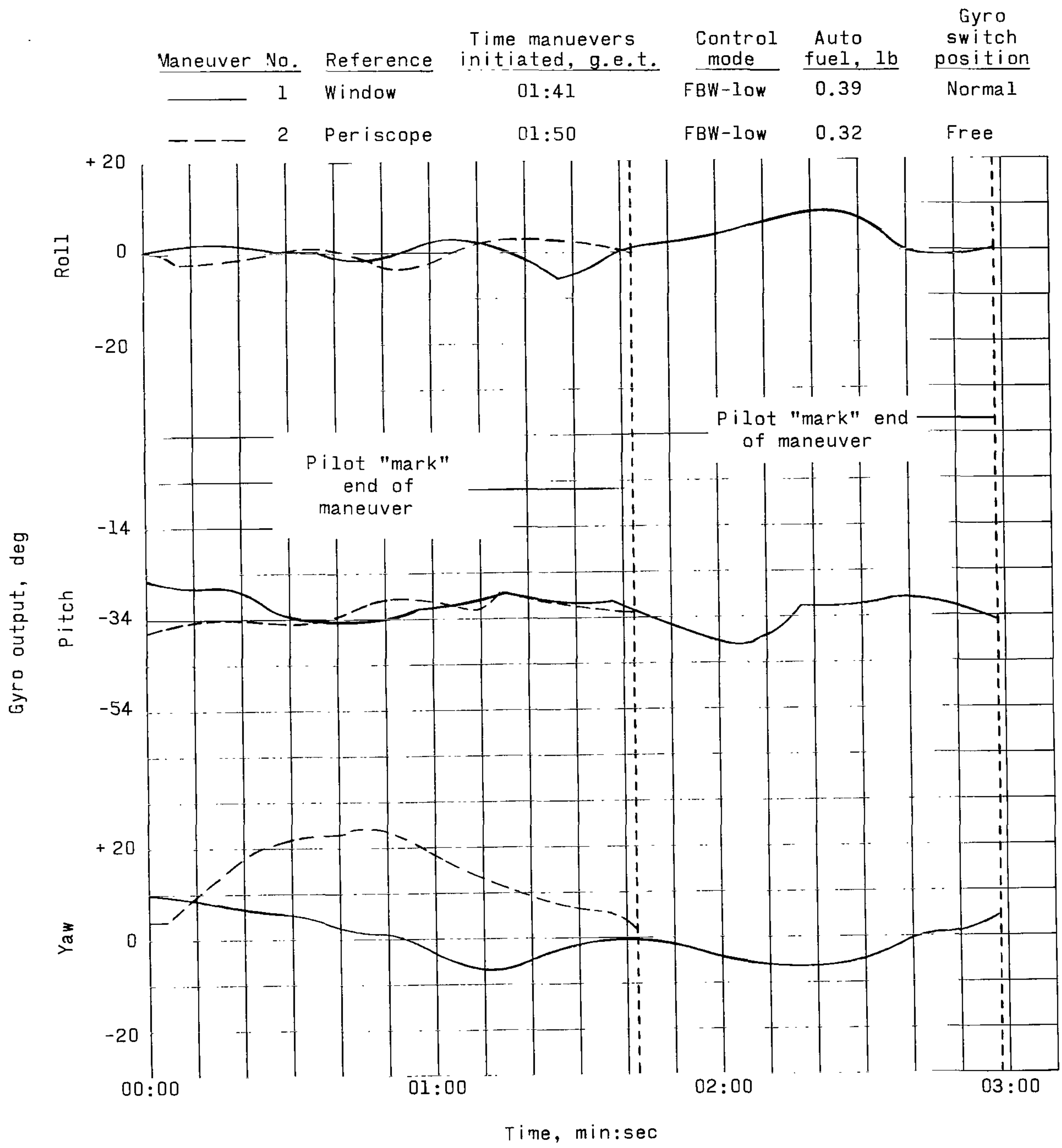
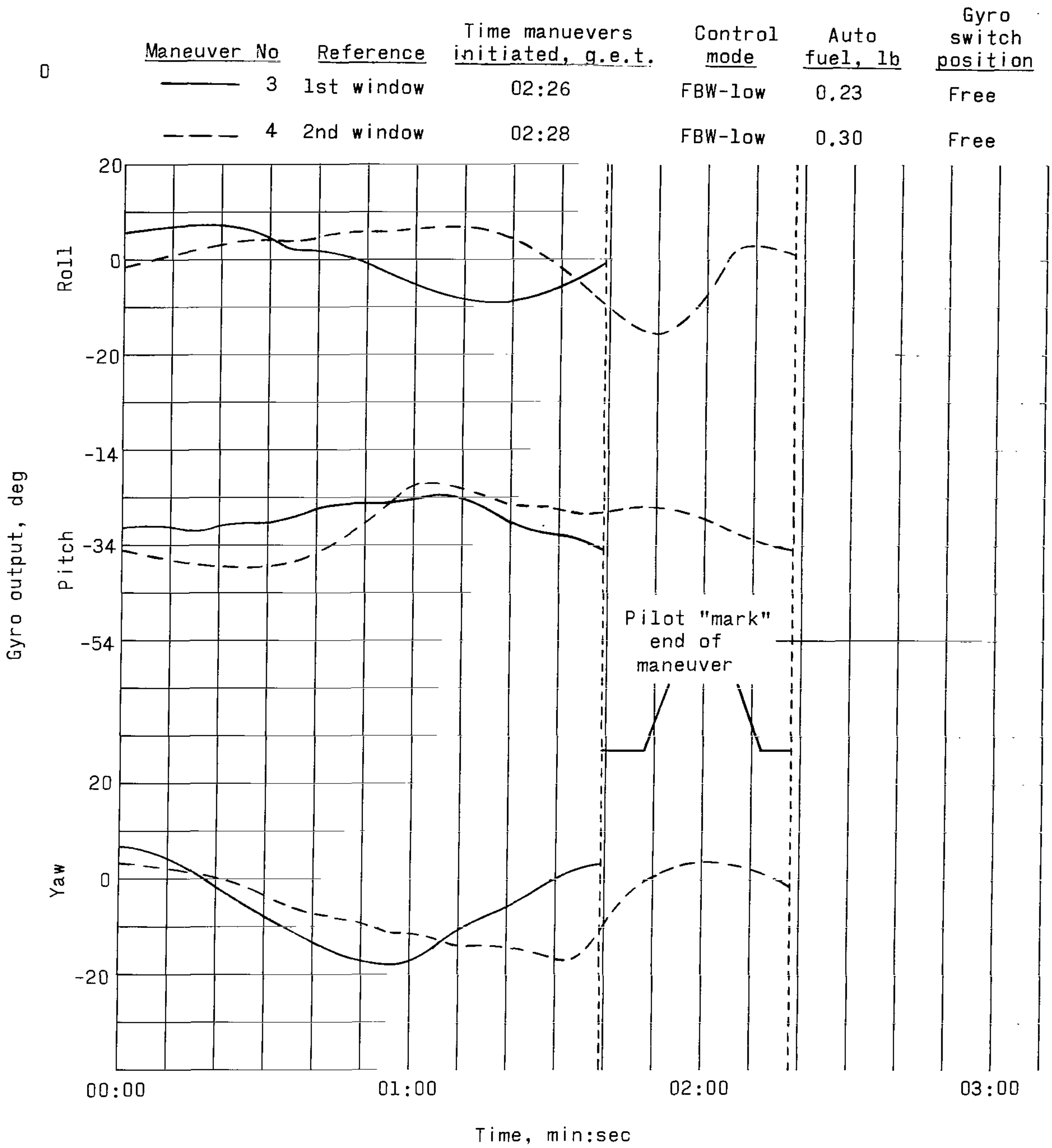


Figure 43. - Flight turnaround maneuver with background of five procedures-trainer-turnaround maneuvers (0.41 lb H_2O_2 usage).



(a) Day.

Figure 44. - Yaw maneuvers.



(b) Night.

Figure 44. - Concluded.

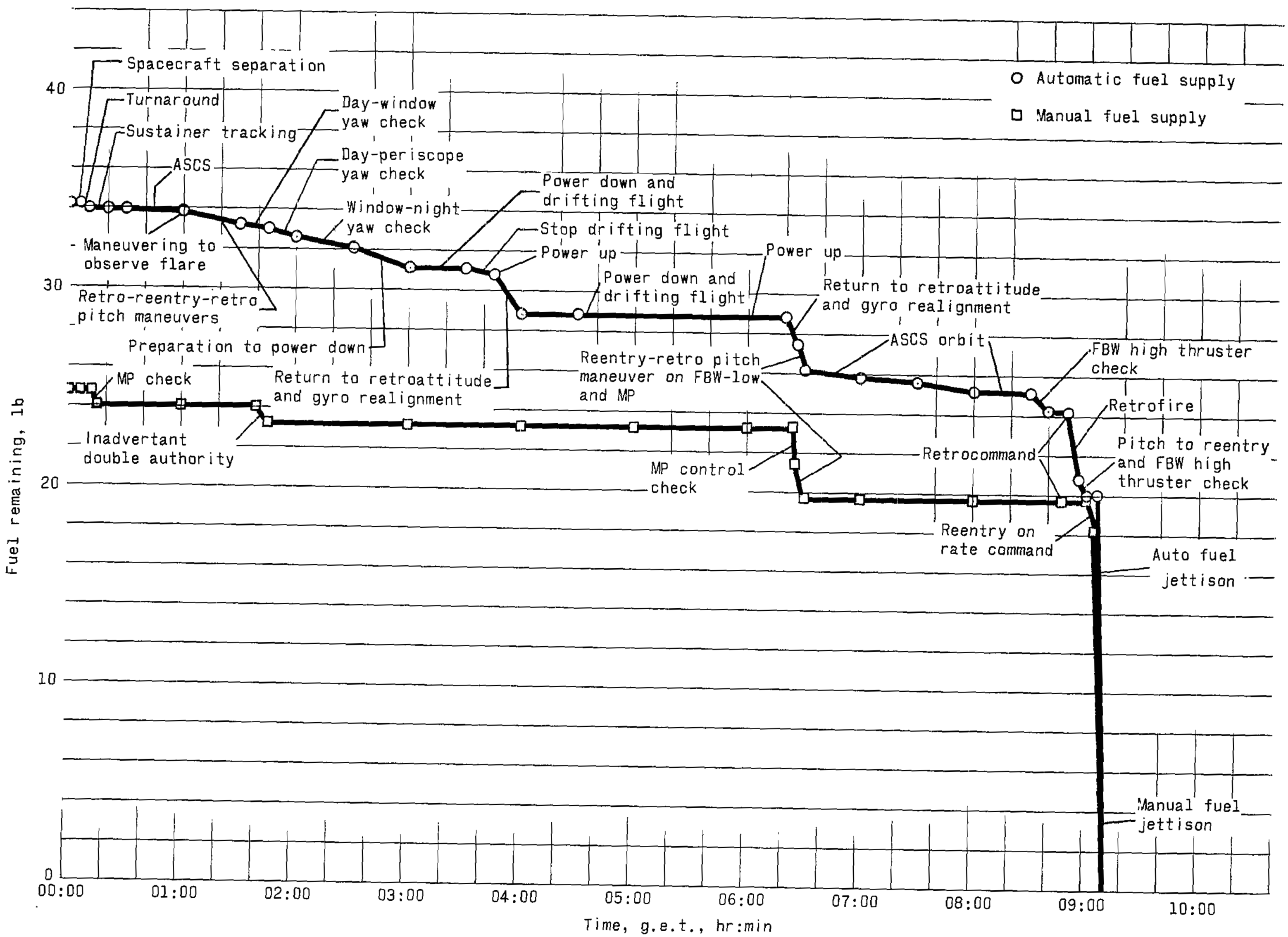
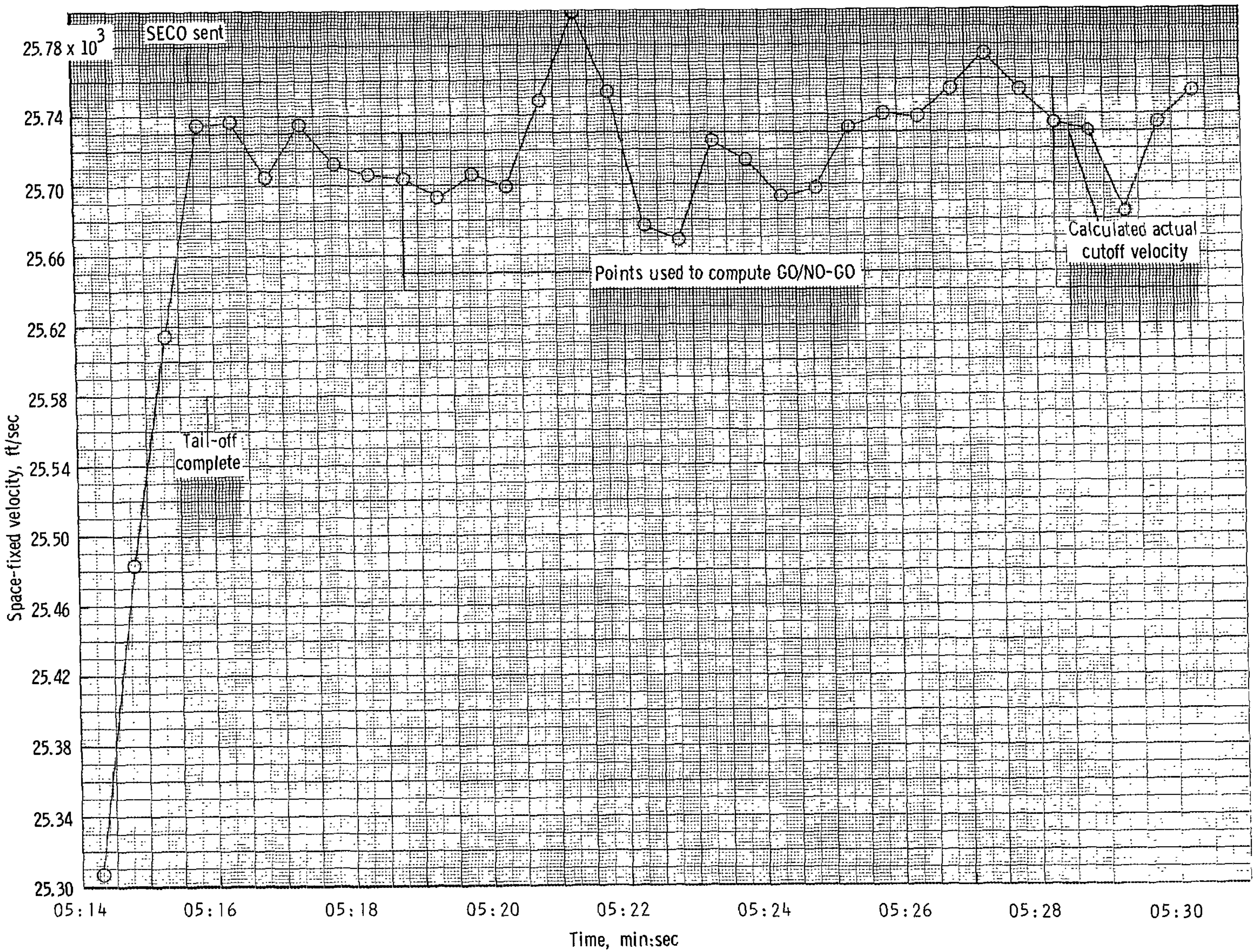
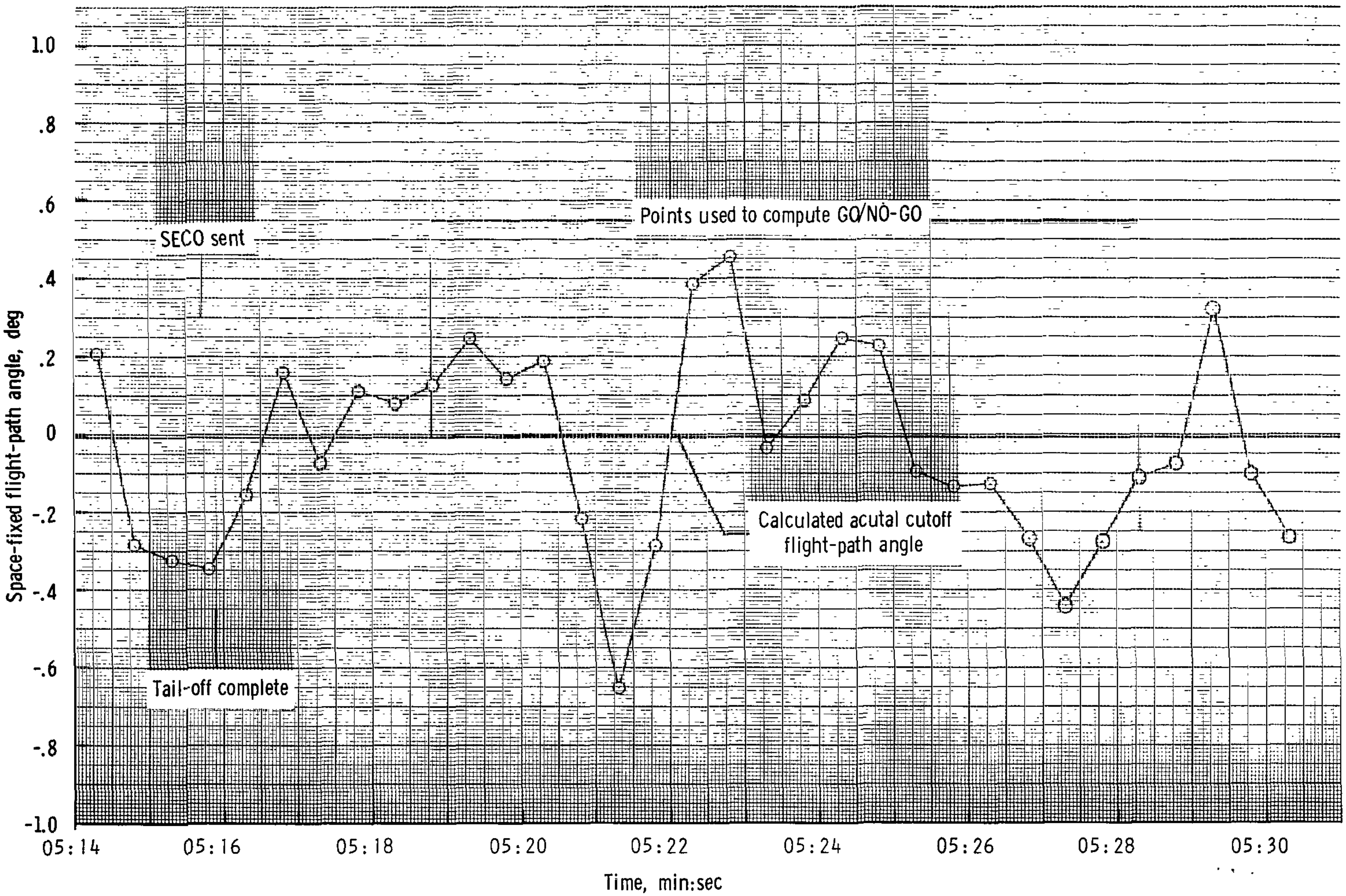


Figure 45. - Hydrogen peroxide fuel usage.



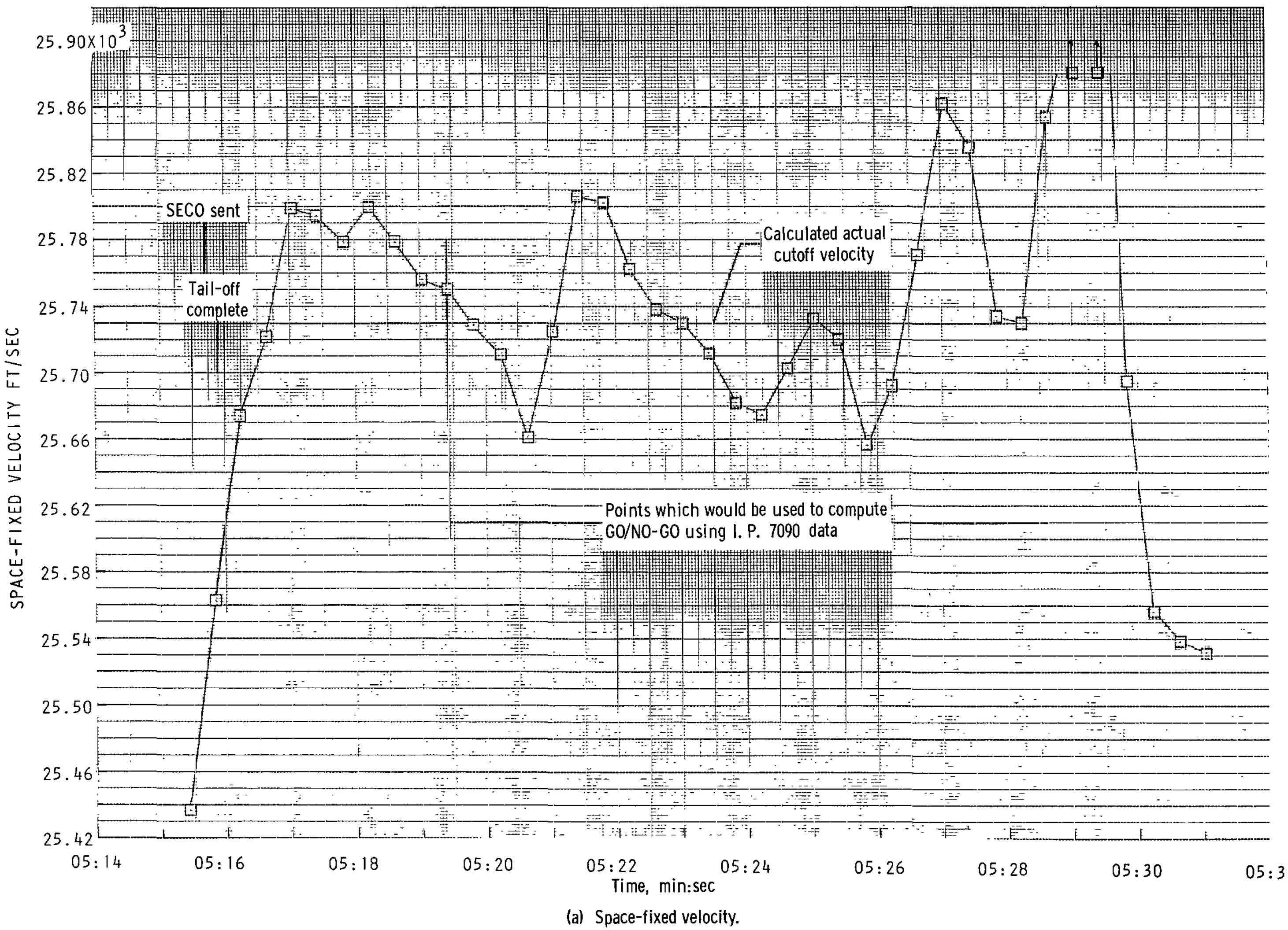
(a) Space-fixed velocity.

Figure 46. - Space-fixed velocity and flight-path angle in the region of cutoff using launch-vehicle guidance data.



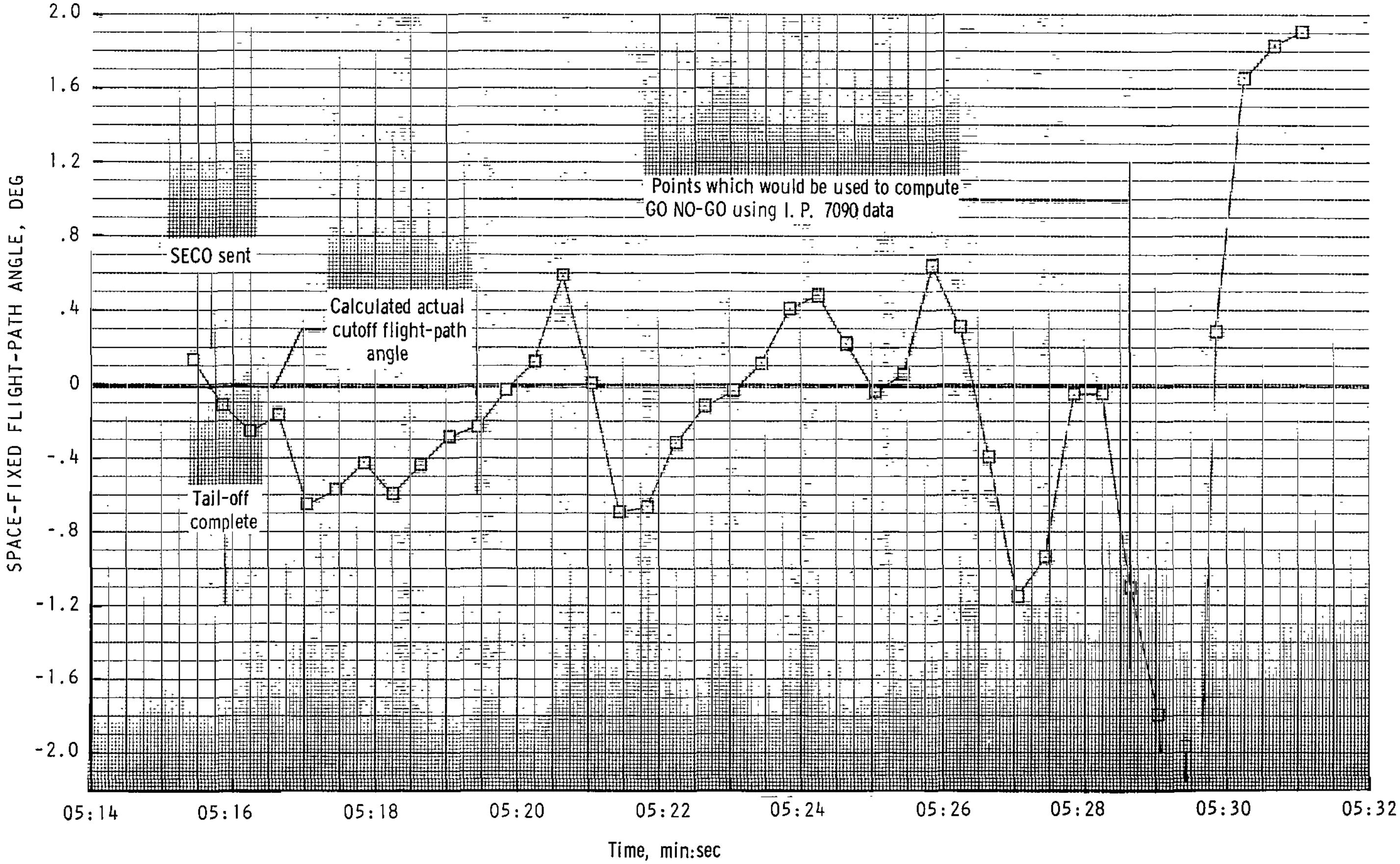
(b) Space-fixed flight-path angle.

Figure 46. - Concluded.



(a) Space-fixed velocity.

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



(b) Space-fixed flight-path angle.

Figure 47. - Concluded.

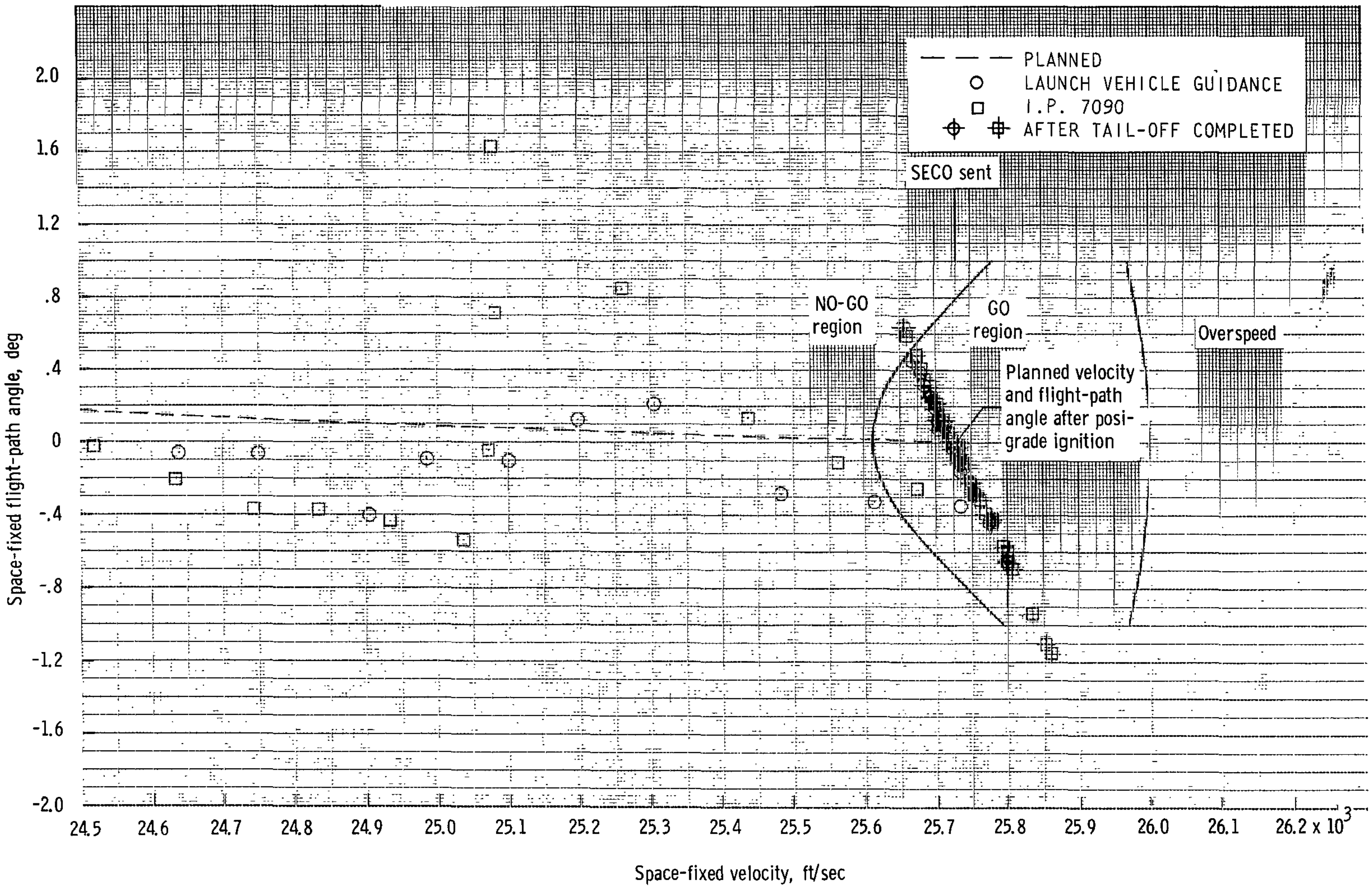


Figure 48. - Space-fixed flight-path angle versus space-fixed velocity in the region of cutoff.

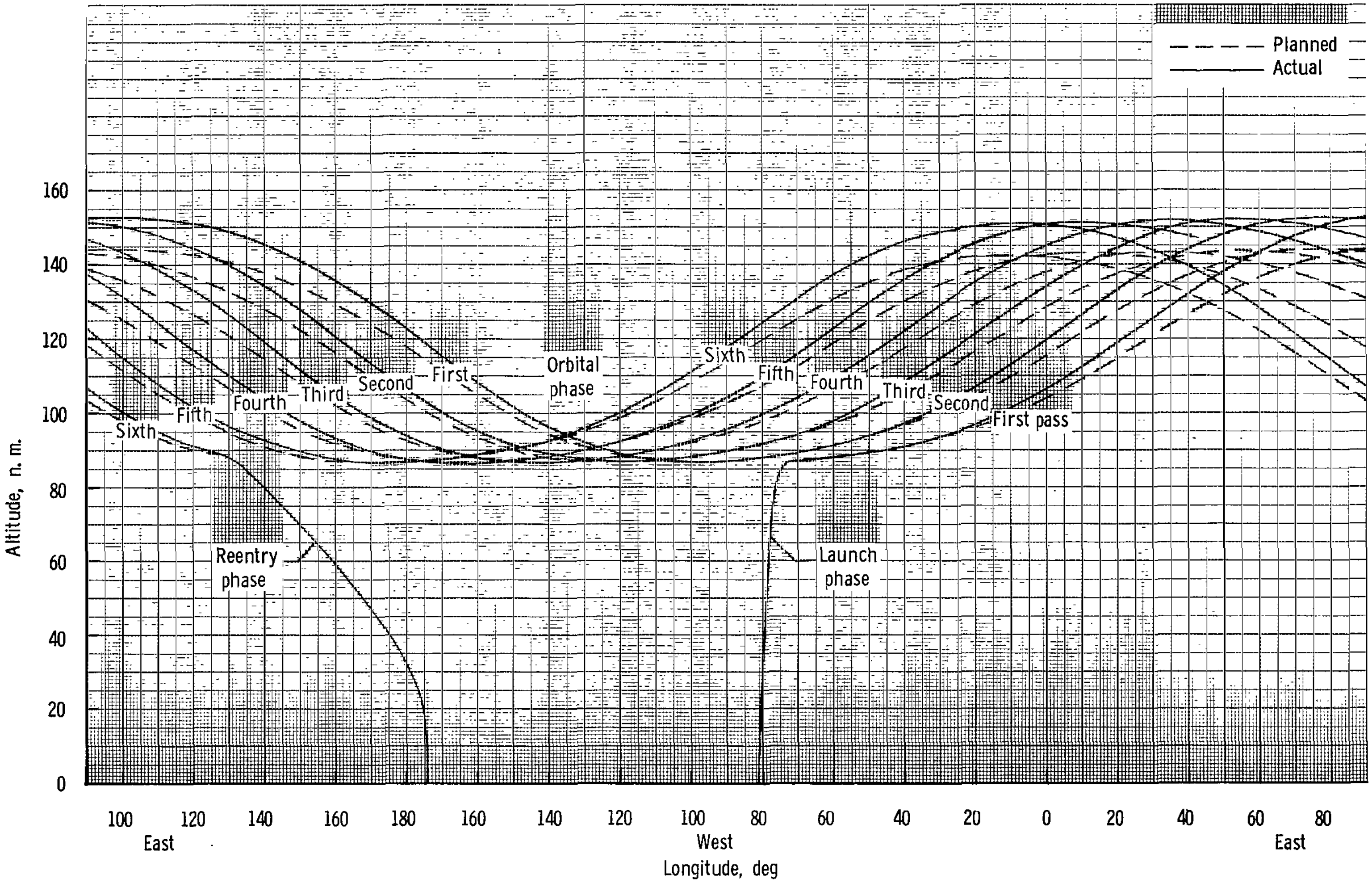
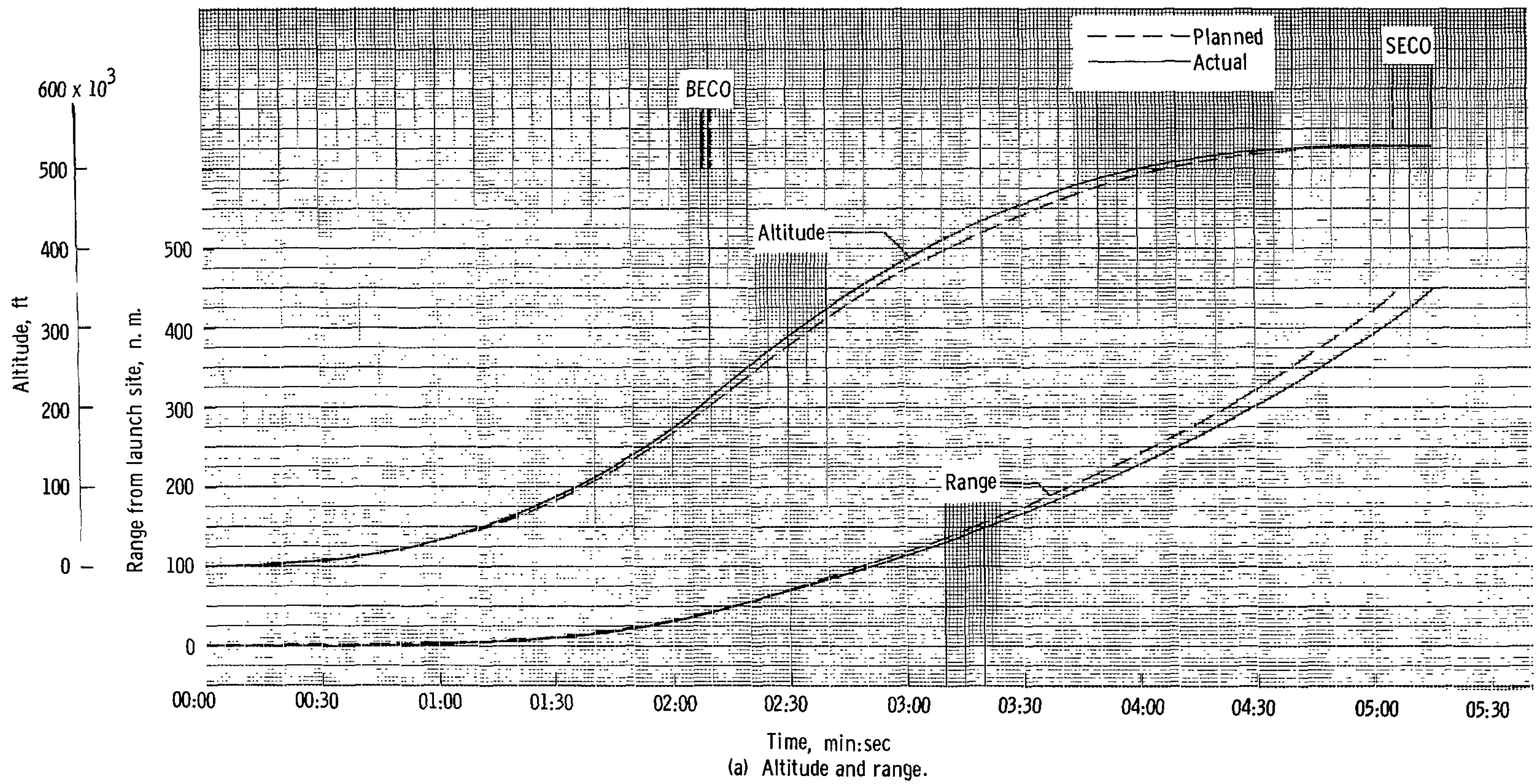
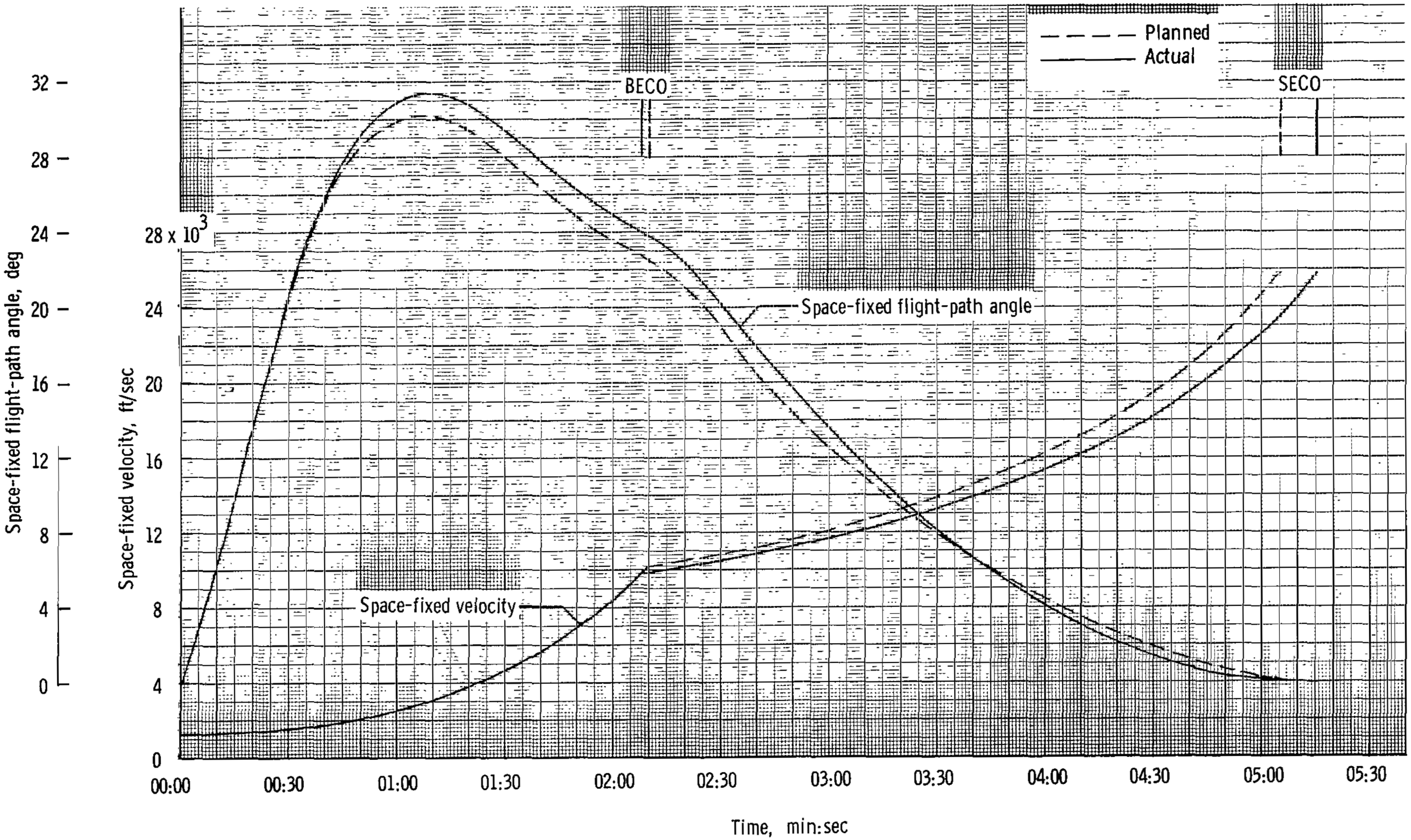


Figure 49. - Altitude versus longitude profile.



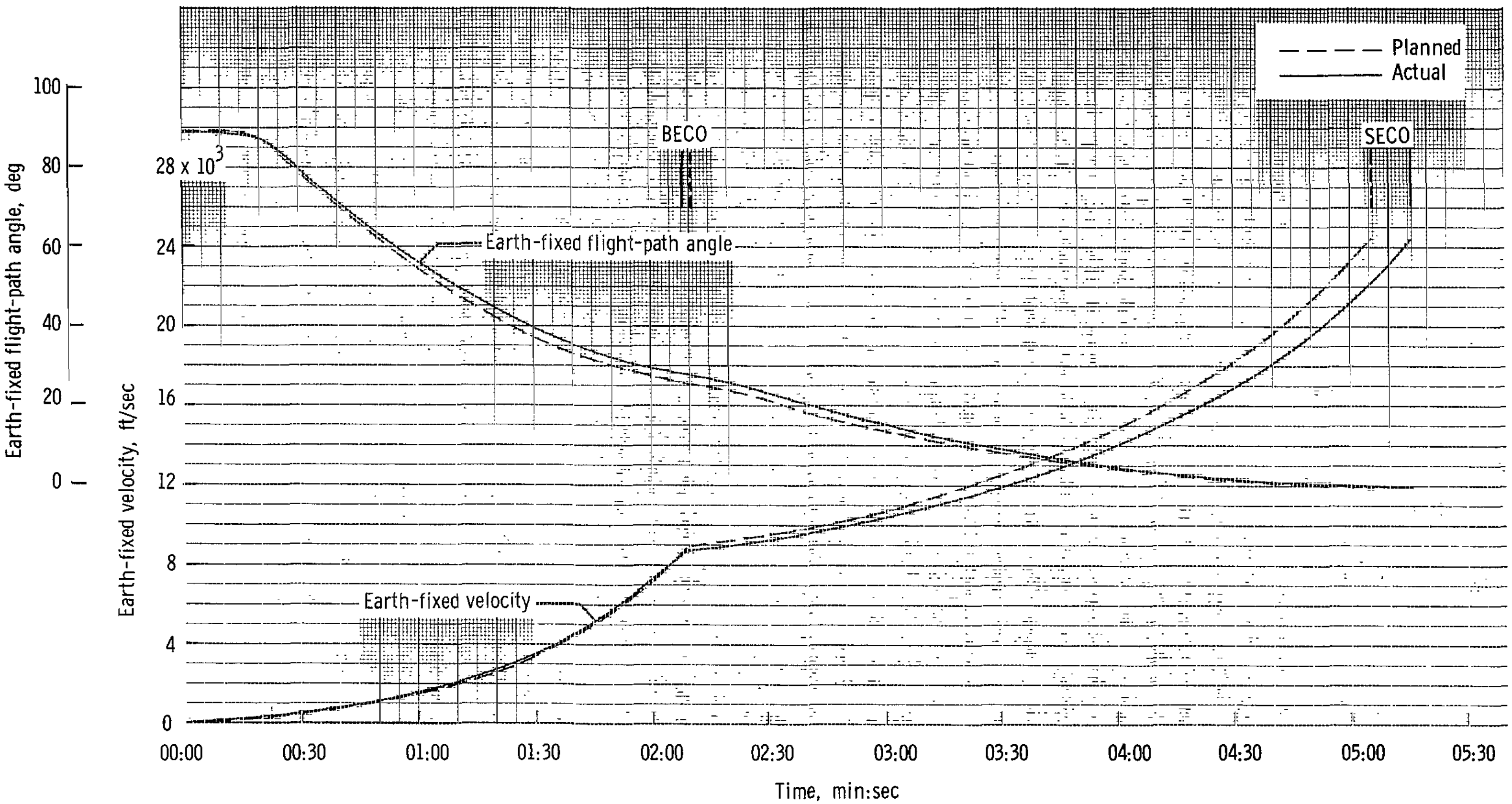
(a) Altitude and range.

Figure 50. - Time histories of trajectory parameters for MA-8 mission launch phase.



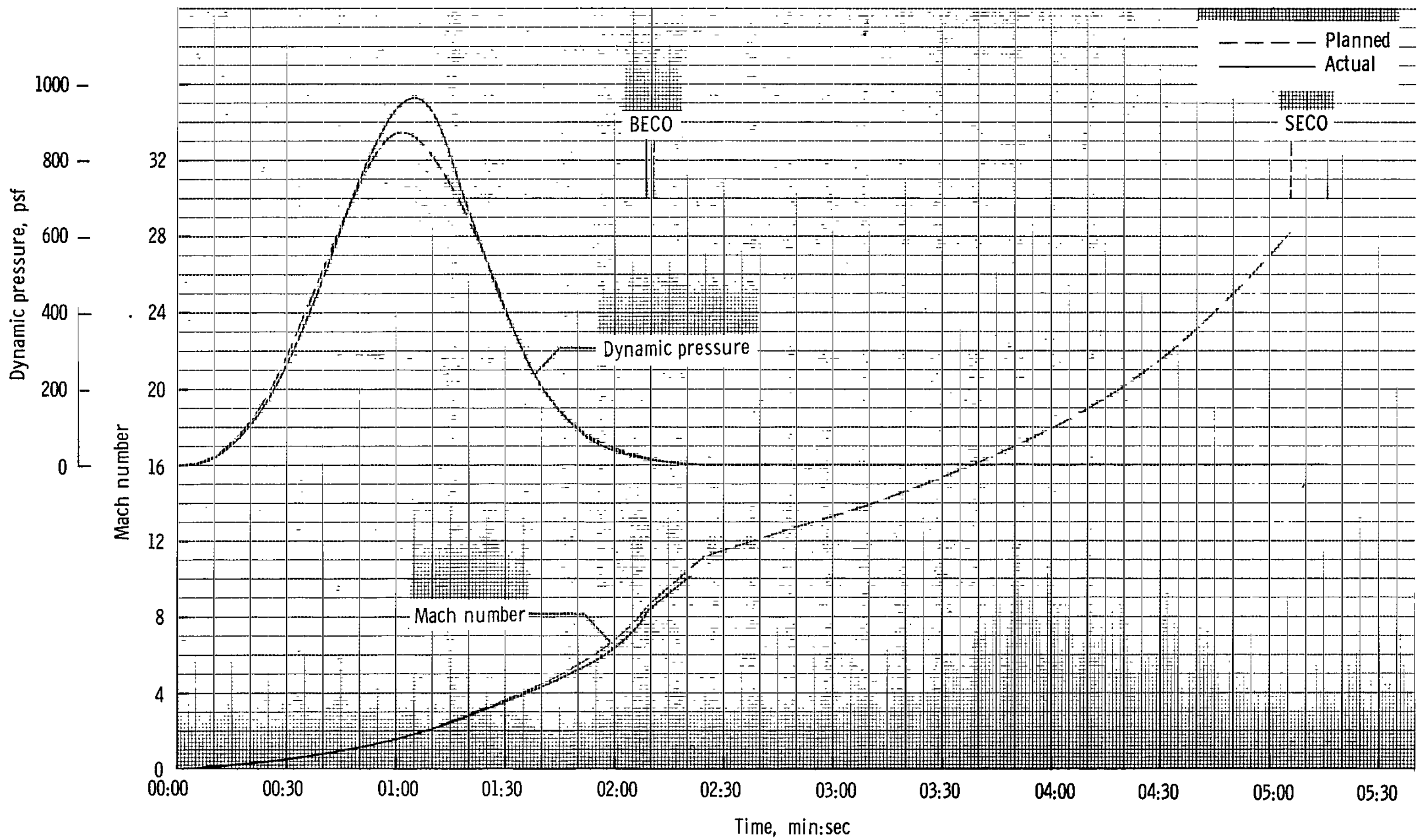
(b) Space-fixed velocity and flight-path angle.

Figure 50. - Continued.



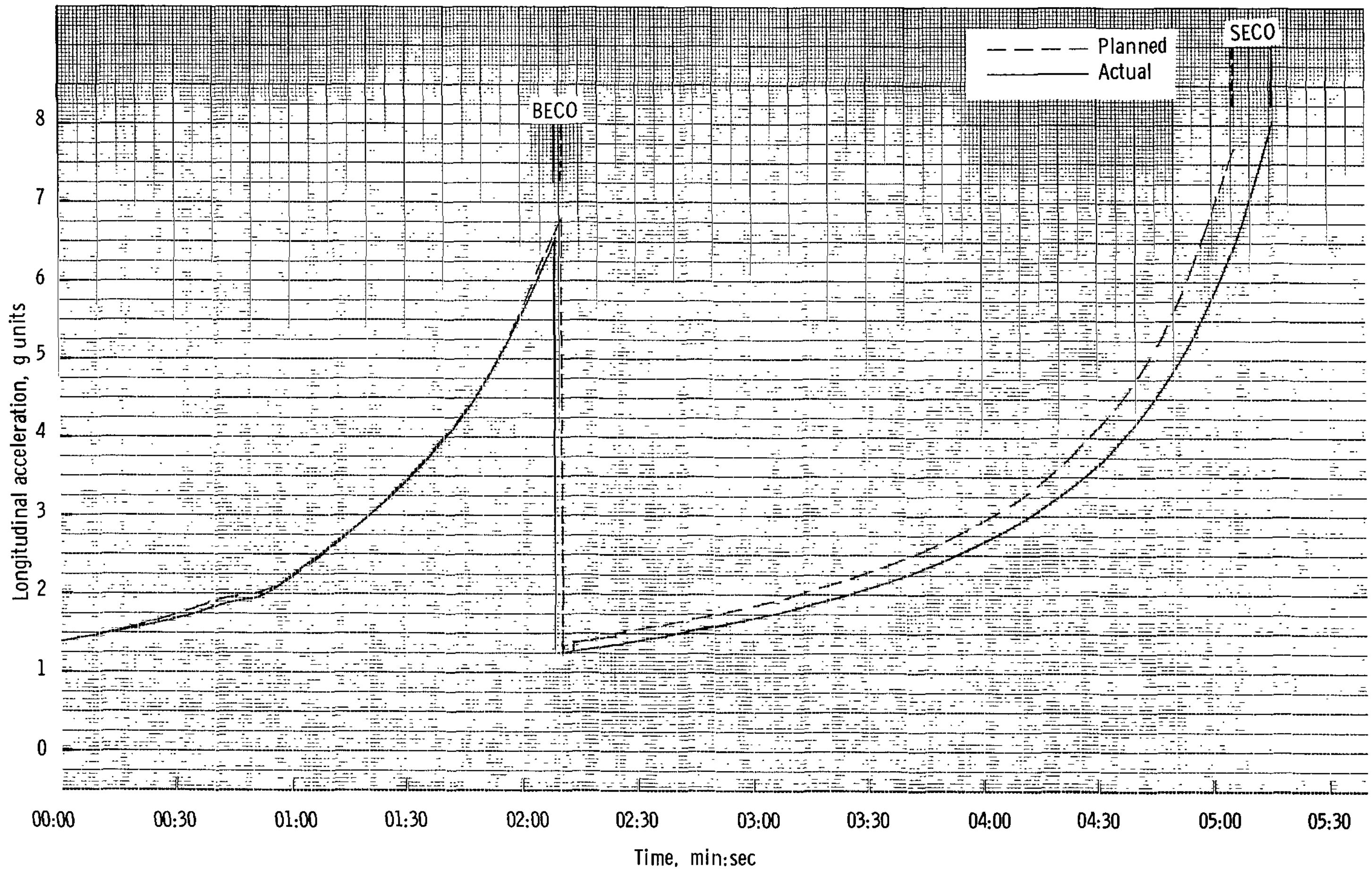
(c) Earth-fixed velocity and flight-path angle.

Figure 50. - Continued.



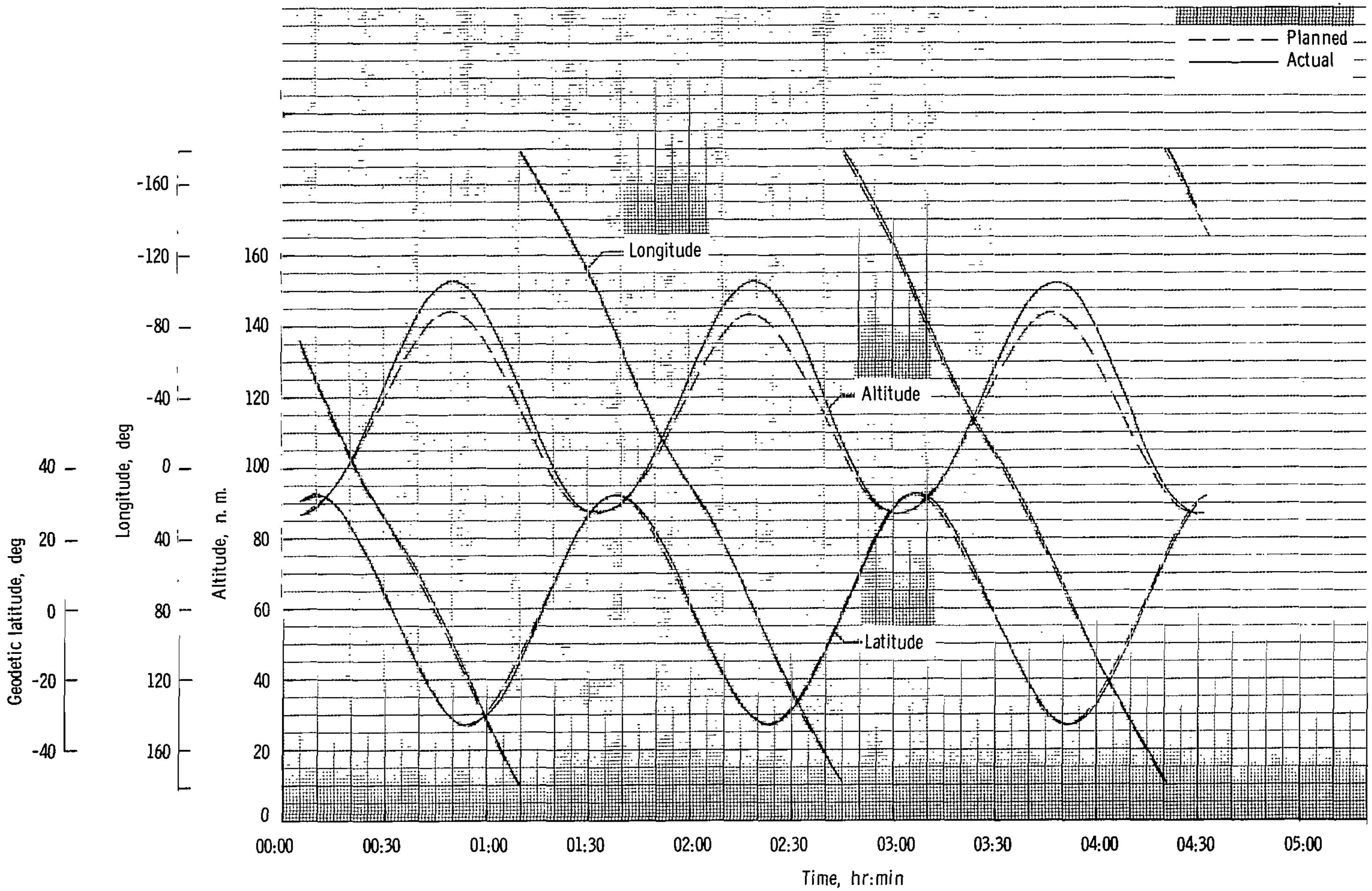
(d) Dynamic pressure and Mach number.

Figure 50. - Continued.



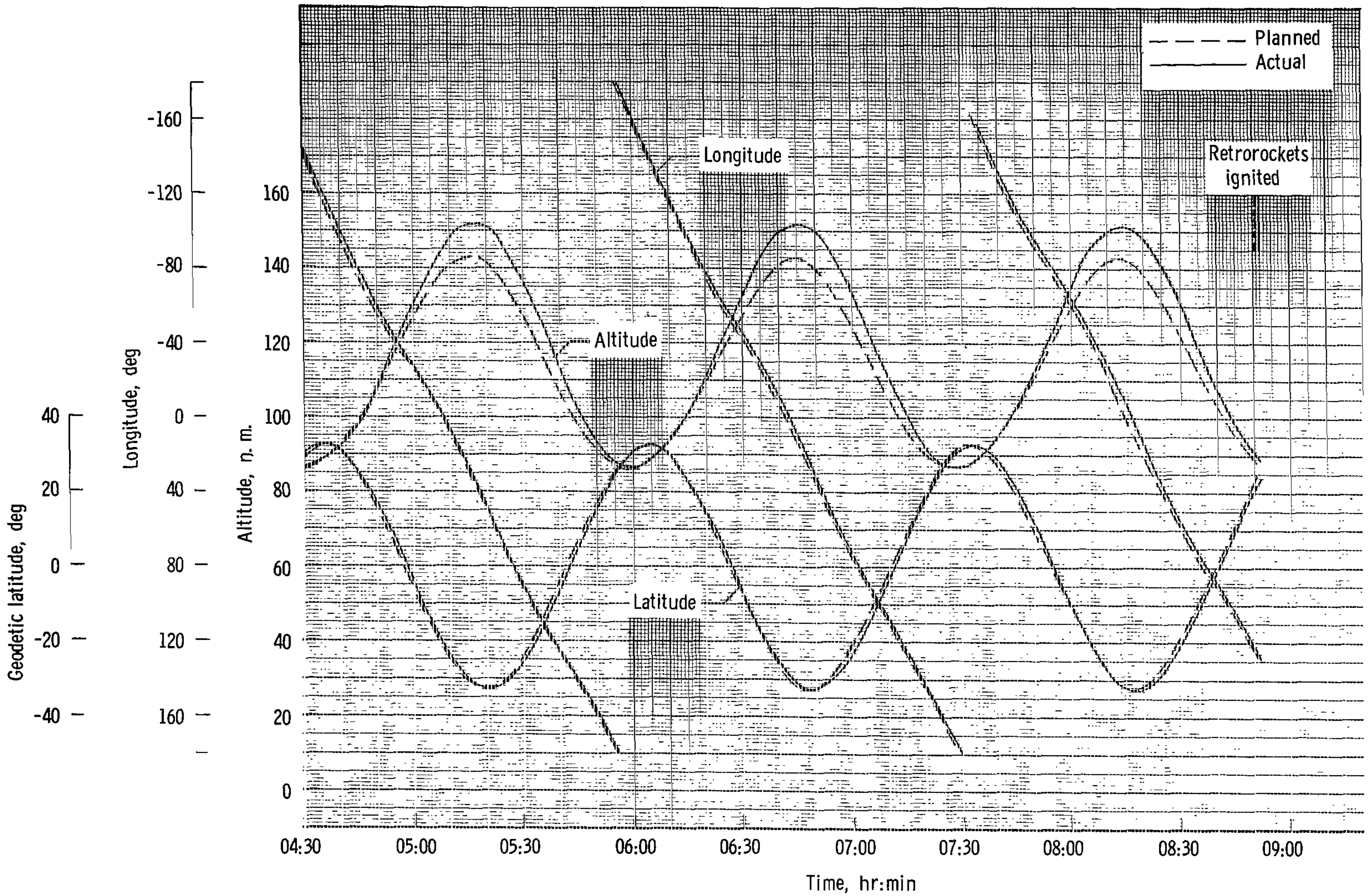
(e) Longitudinal acceleration along spacecraft Z-axis.

Figure 50. - Concluded.



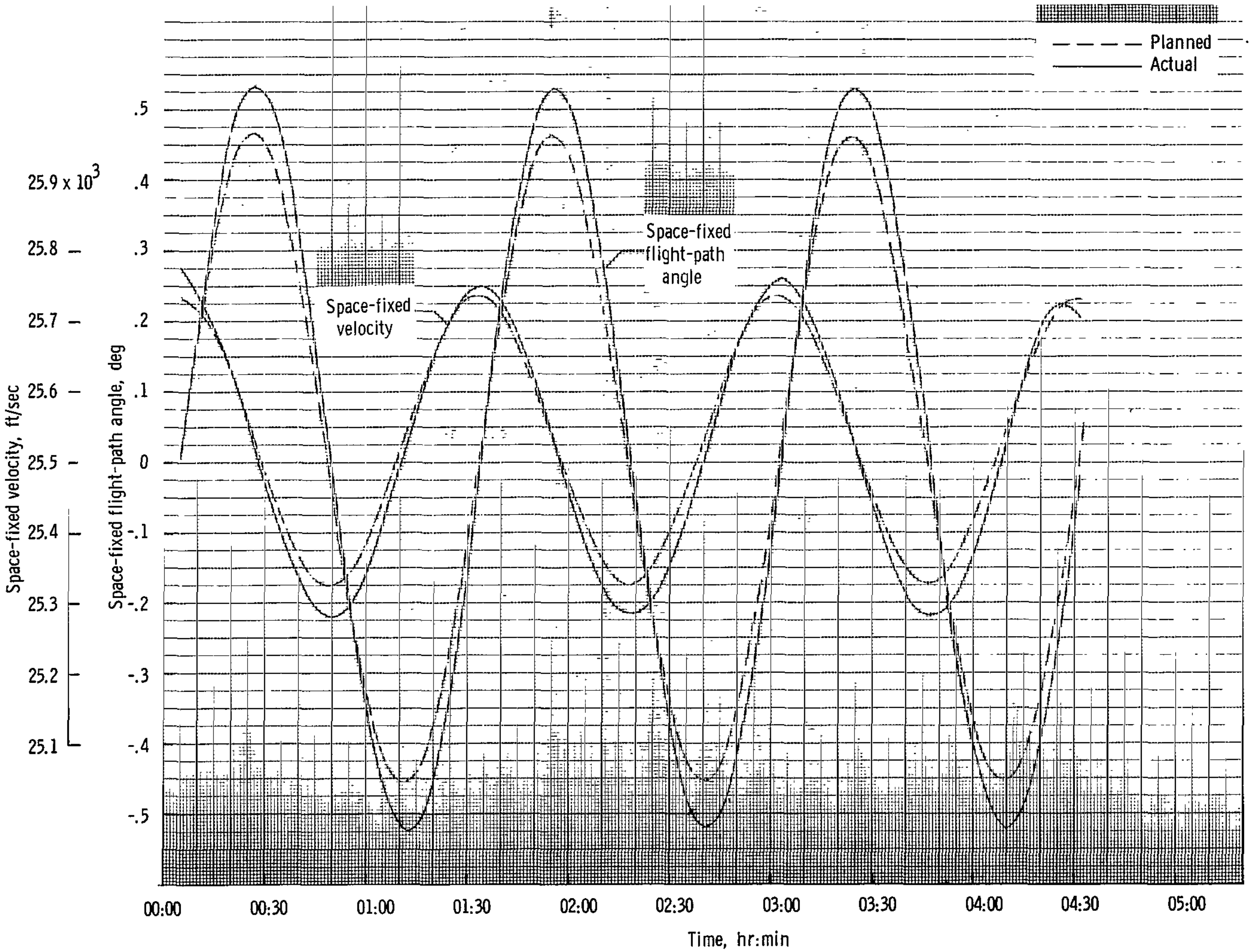
(a) Latitude, longitude, and altitude.

Figure 51. - Time histories of trajectory parameters for MA-8 mission orbital phase.



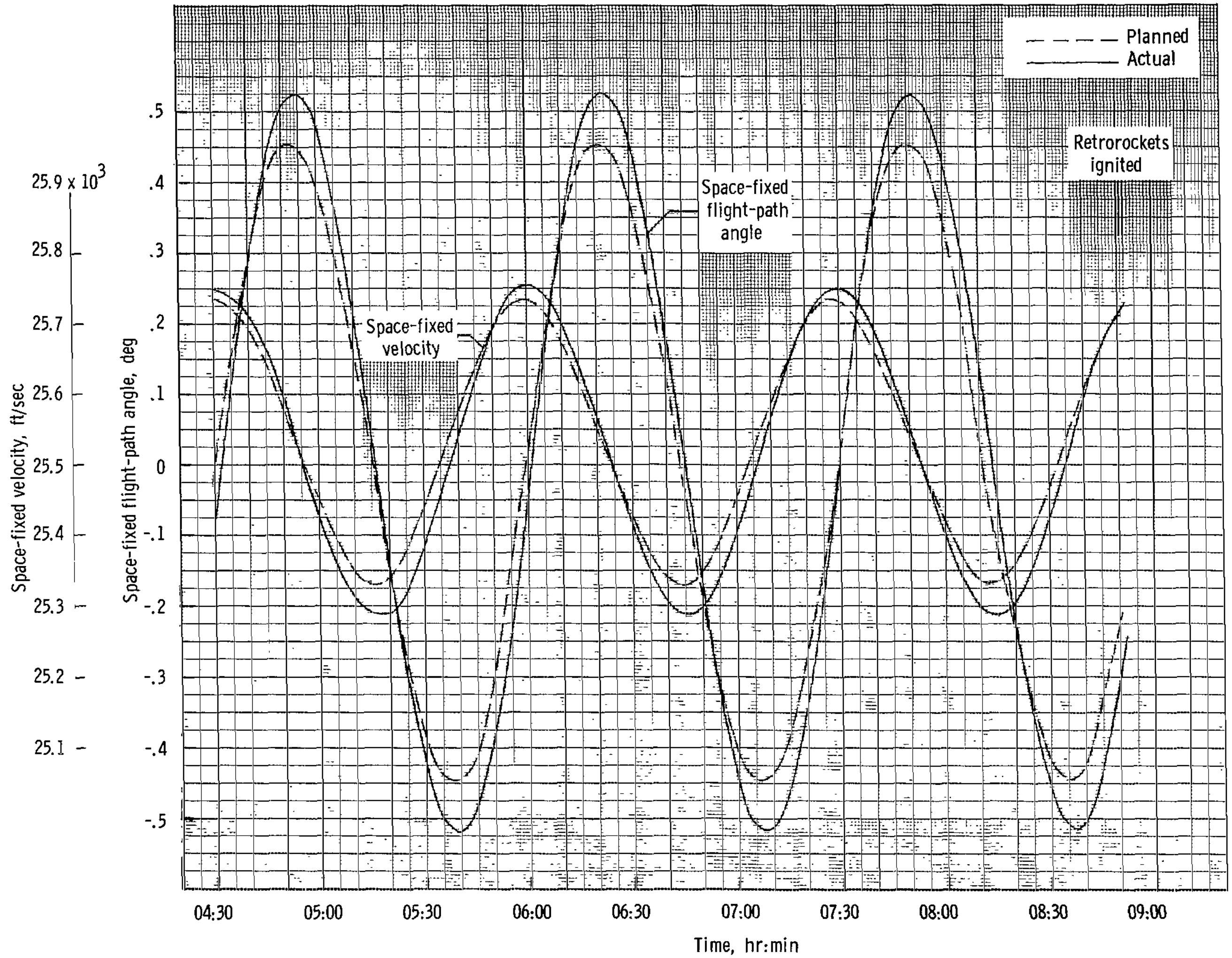
(a) Latitude, longitude, and altitude - Concluded.

Figure 51. - Continued.



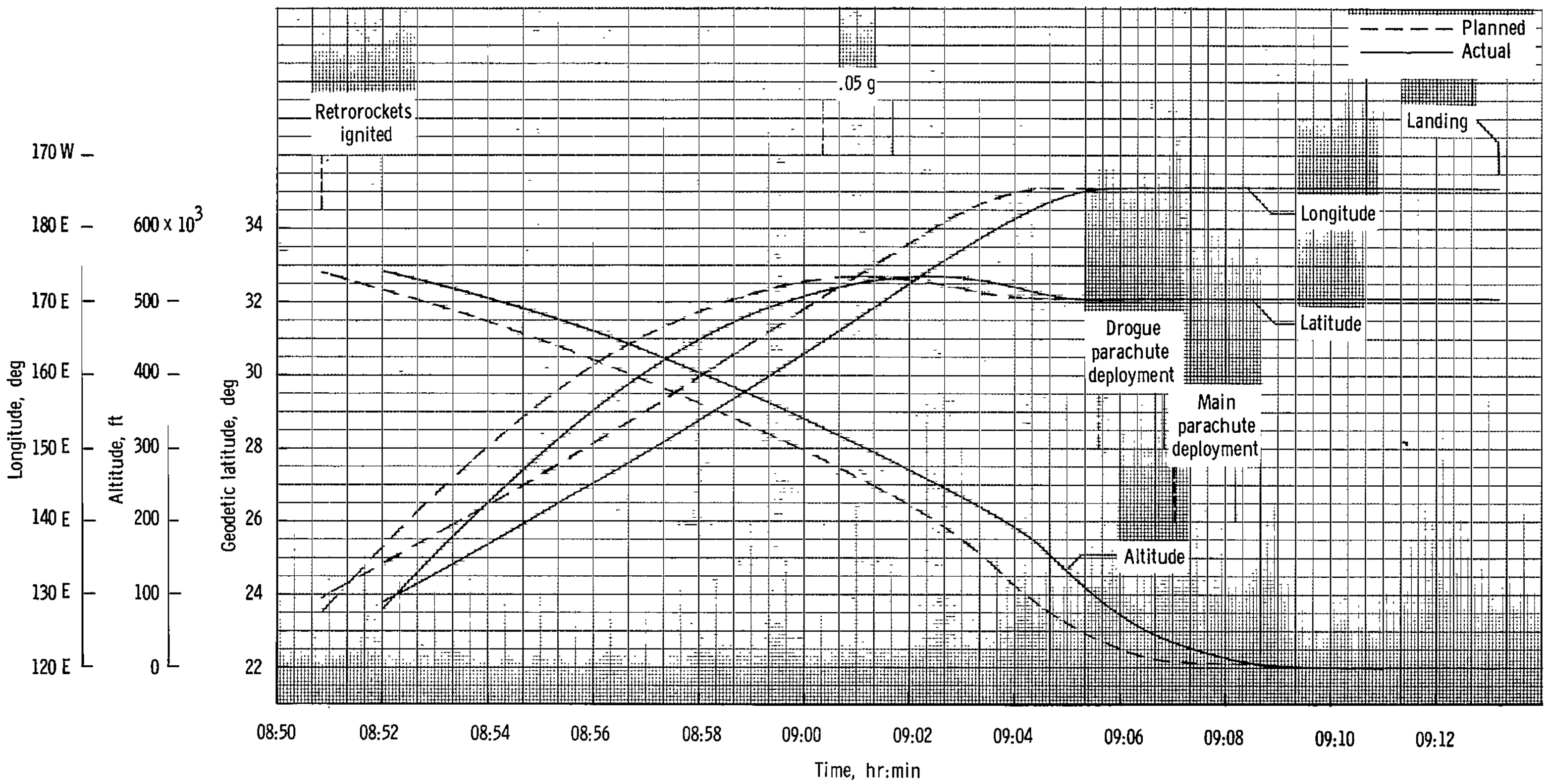
(b) Space-fixed velocity and flight-path angle.

Figure 51. - Continued.



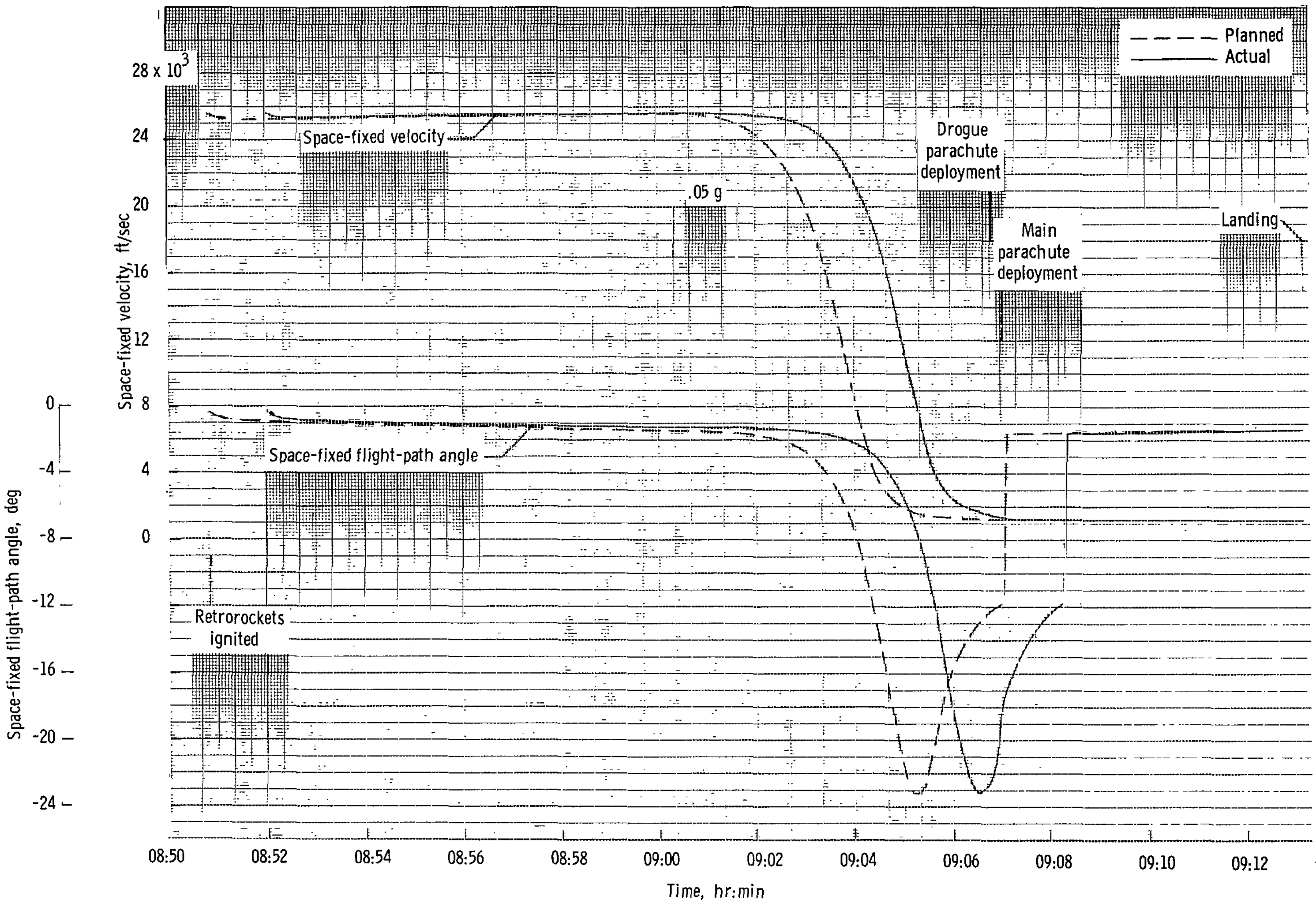
(b) Space-fixed velocity and flight-path angle - Concluded.

Figure 51. - Concluded.



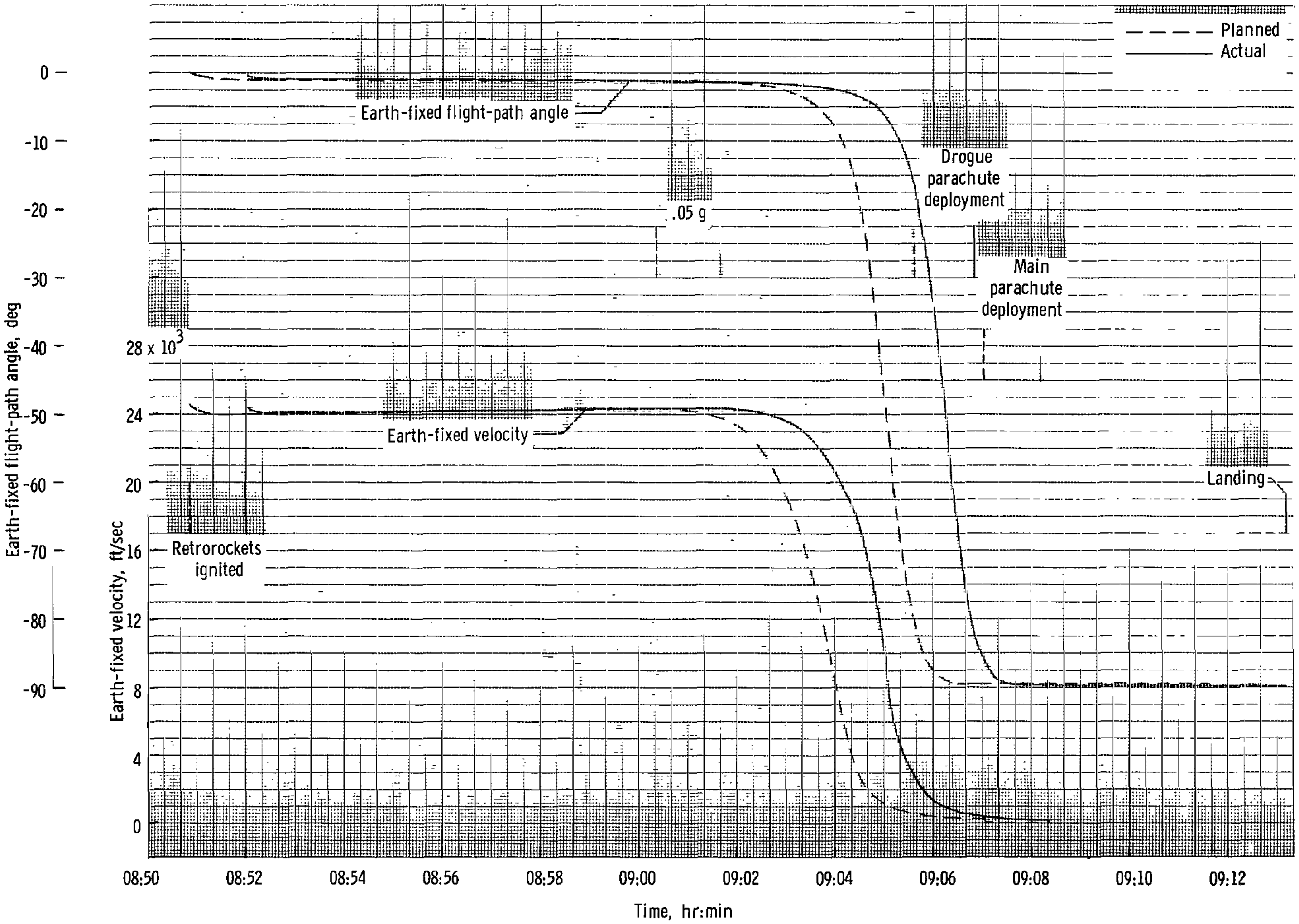
(a) Latitude, longitude, and altitude.

Figure 52. - Time histories of trajectory parameters for MA-8 mission reentry phase.



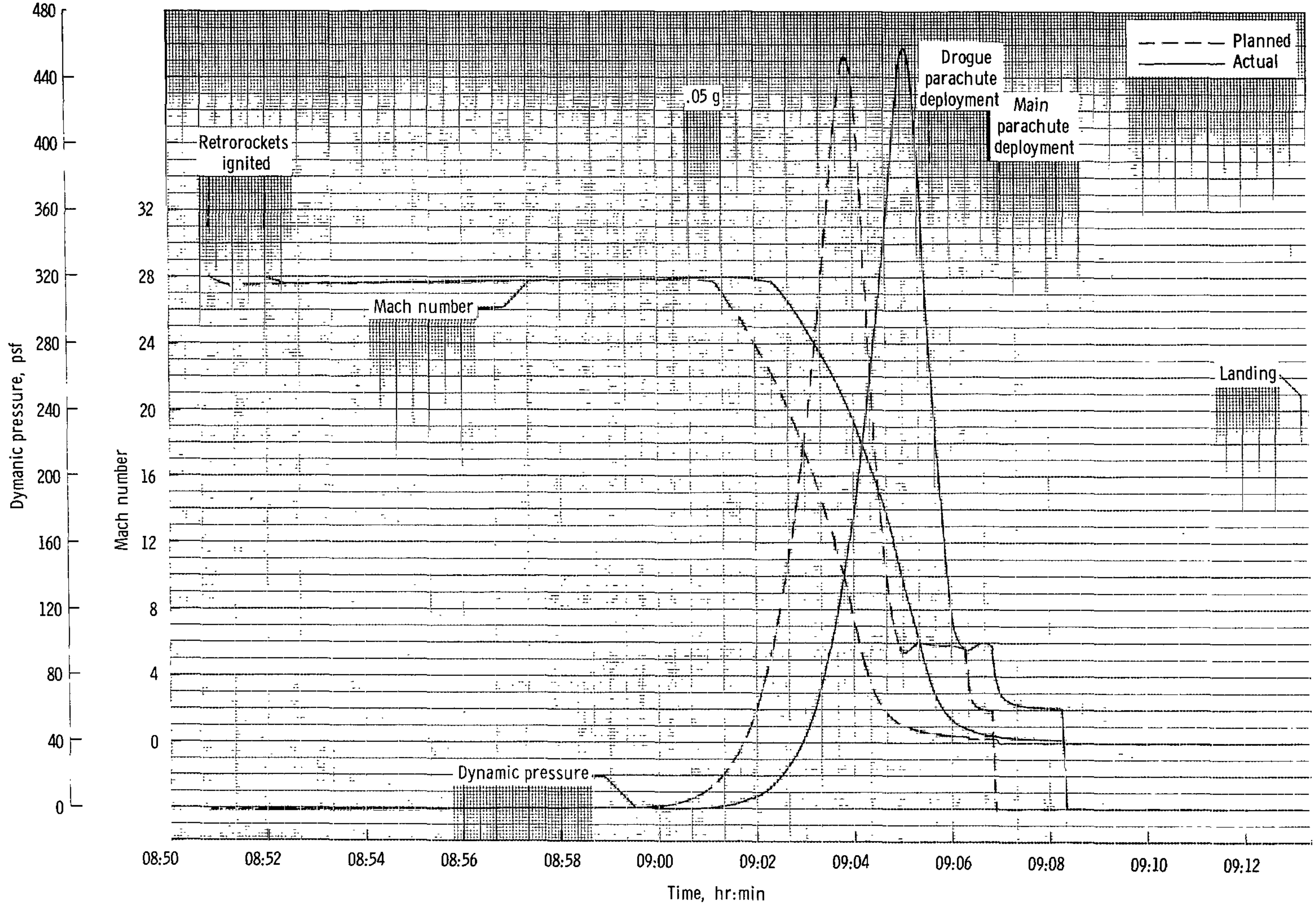
(b) Space-fixed velocity and flight-path angle.

Figure 52. - Continued.



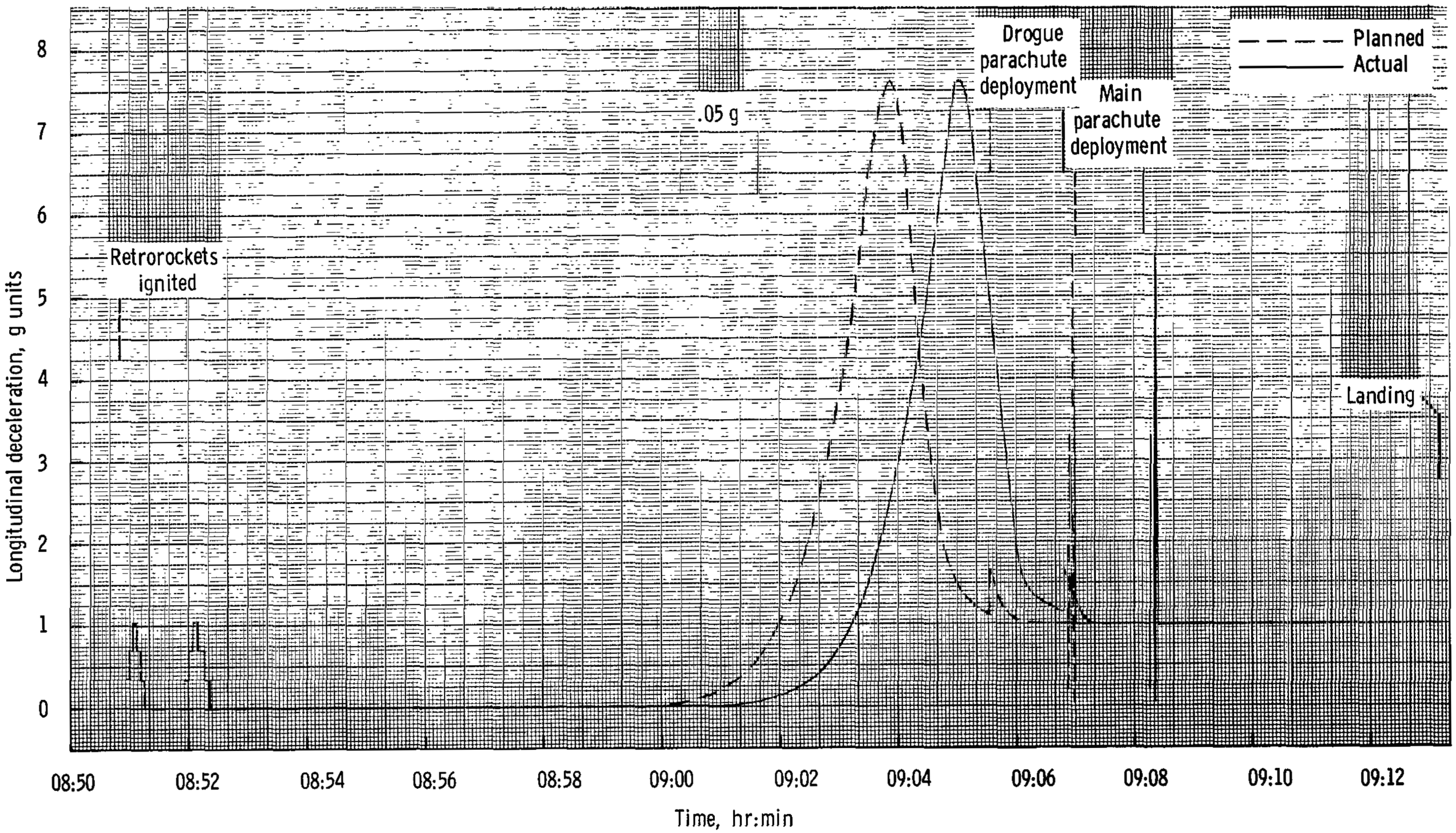
(c) Earth-fixed velocity and flight-path angle.

Figure 52. - Continued.



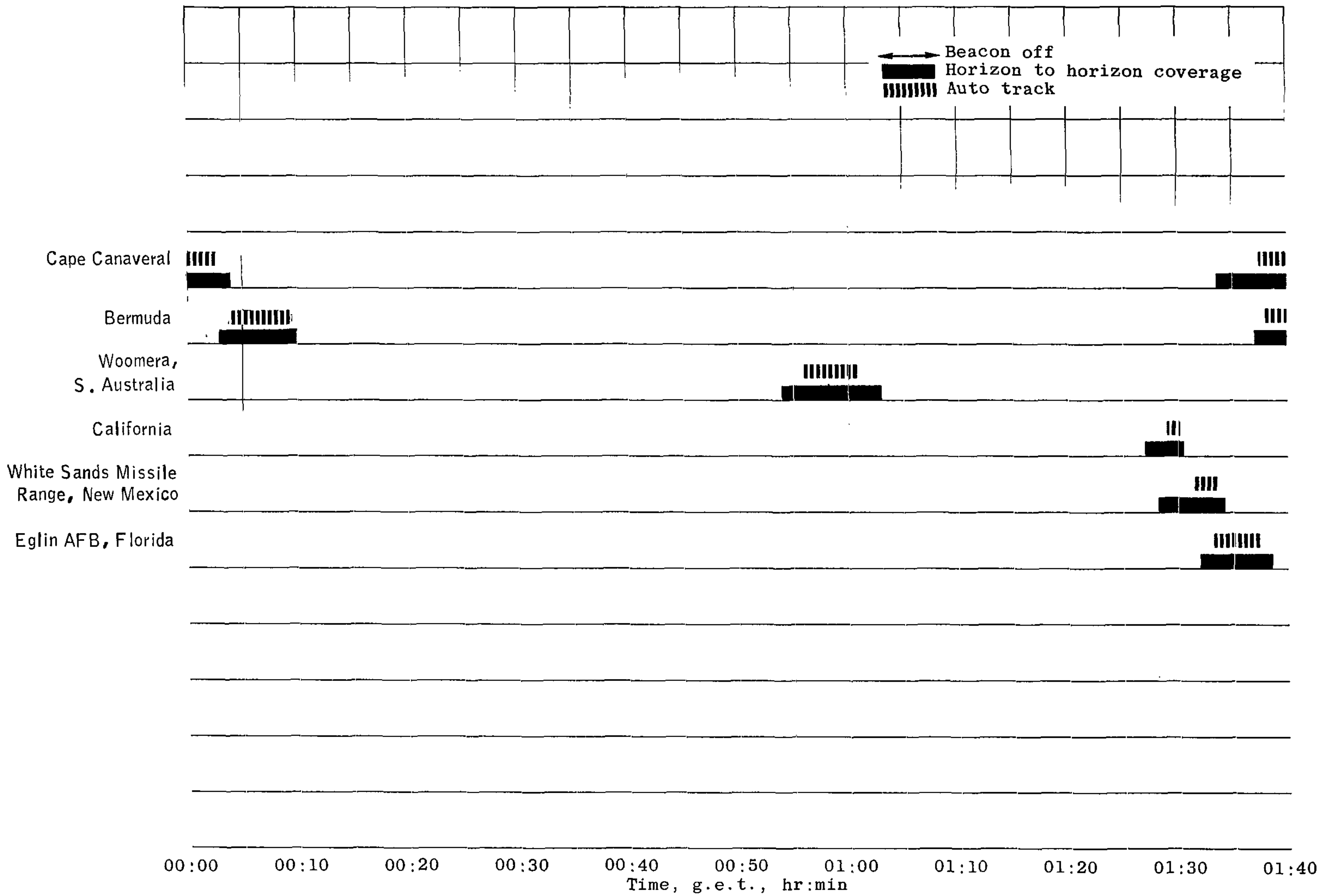
(d) Dynamic pressure and Mach number.

Figure 52. - Continued.



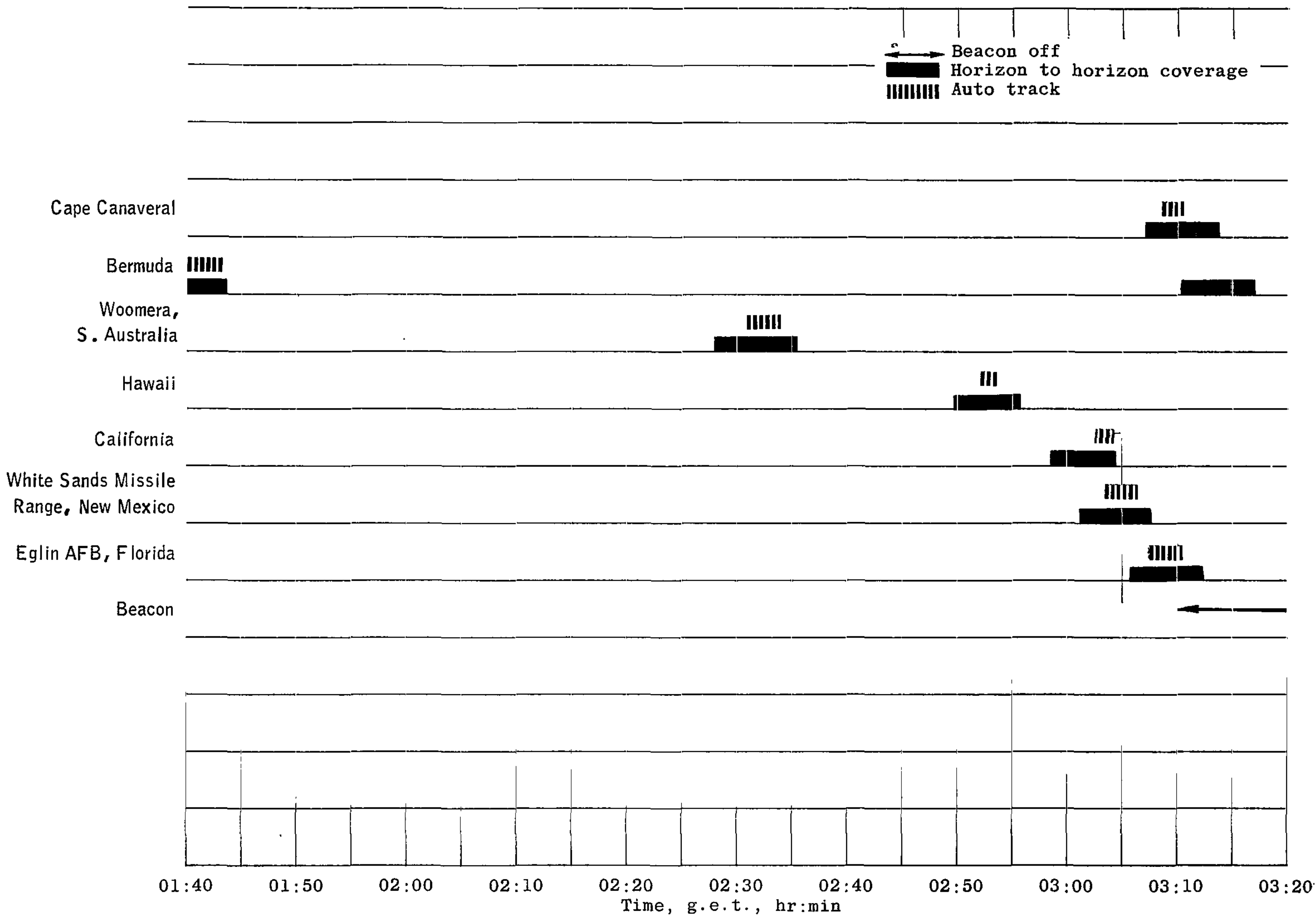
(e) Longitudinal deceleration along spacecraft Z-axis.

Figure 52. - Concluded.



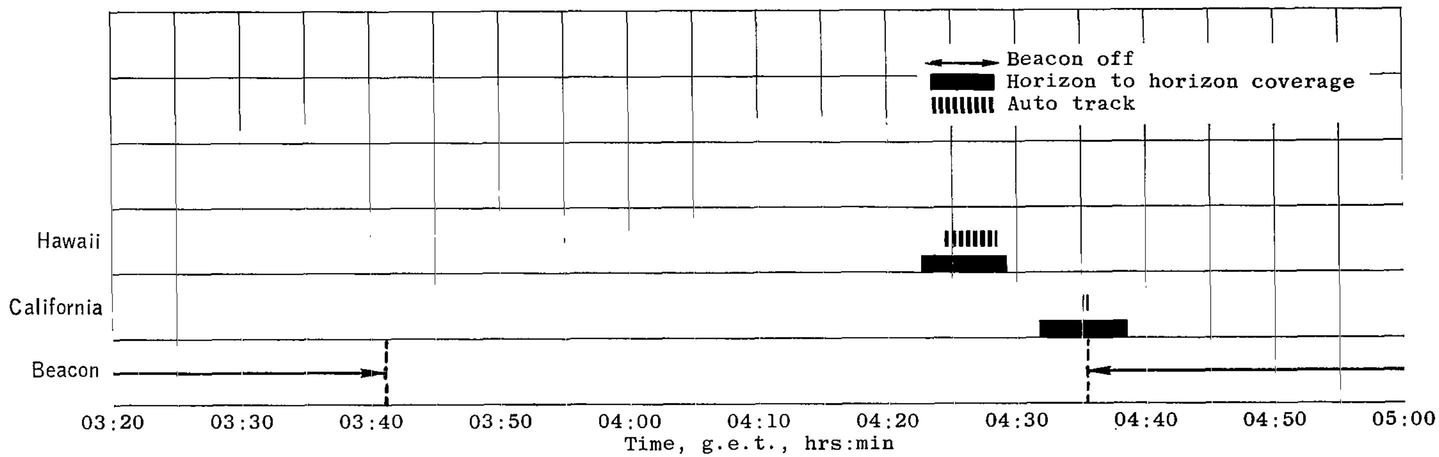
(a) 00:00 to 01:40.

Figure 53. - C-band radar coverage for MA-8 mission.

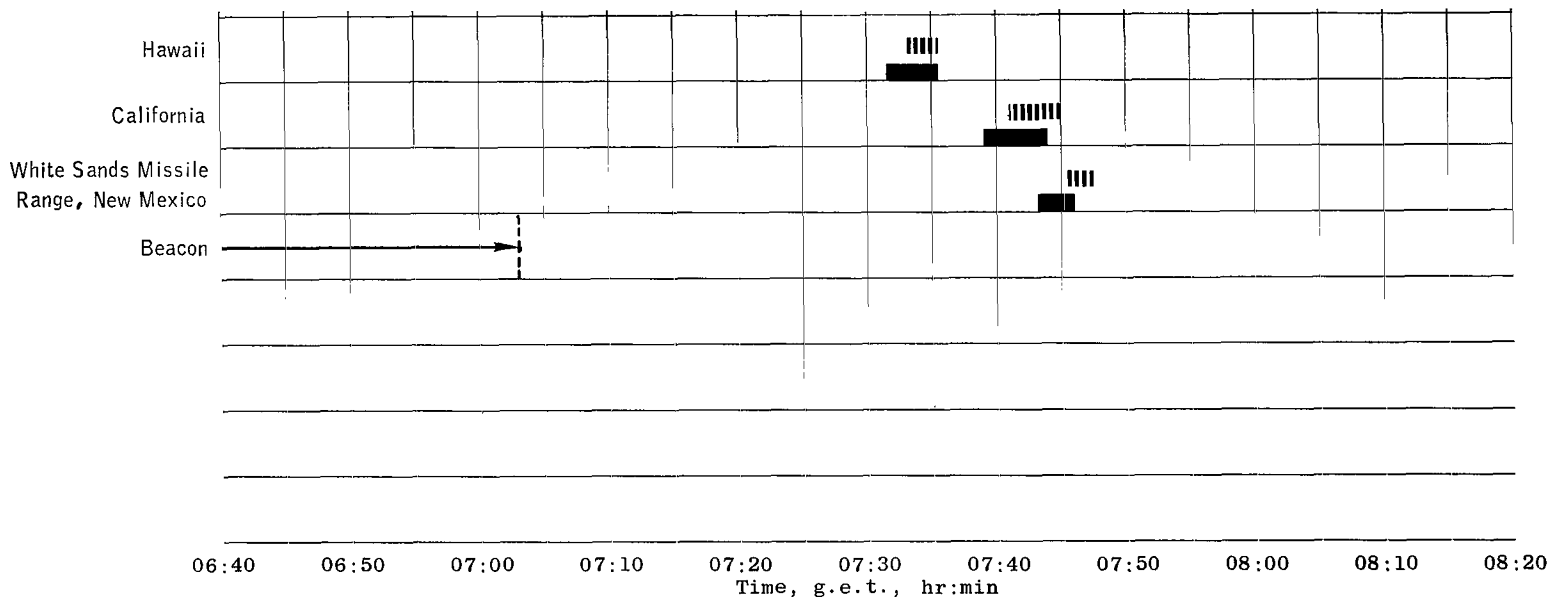


(b) 01:40 to 03:20.

Figure 53. - Continued.

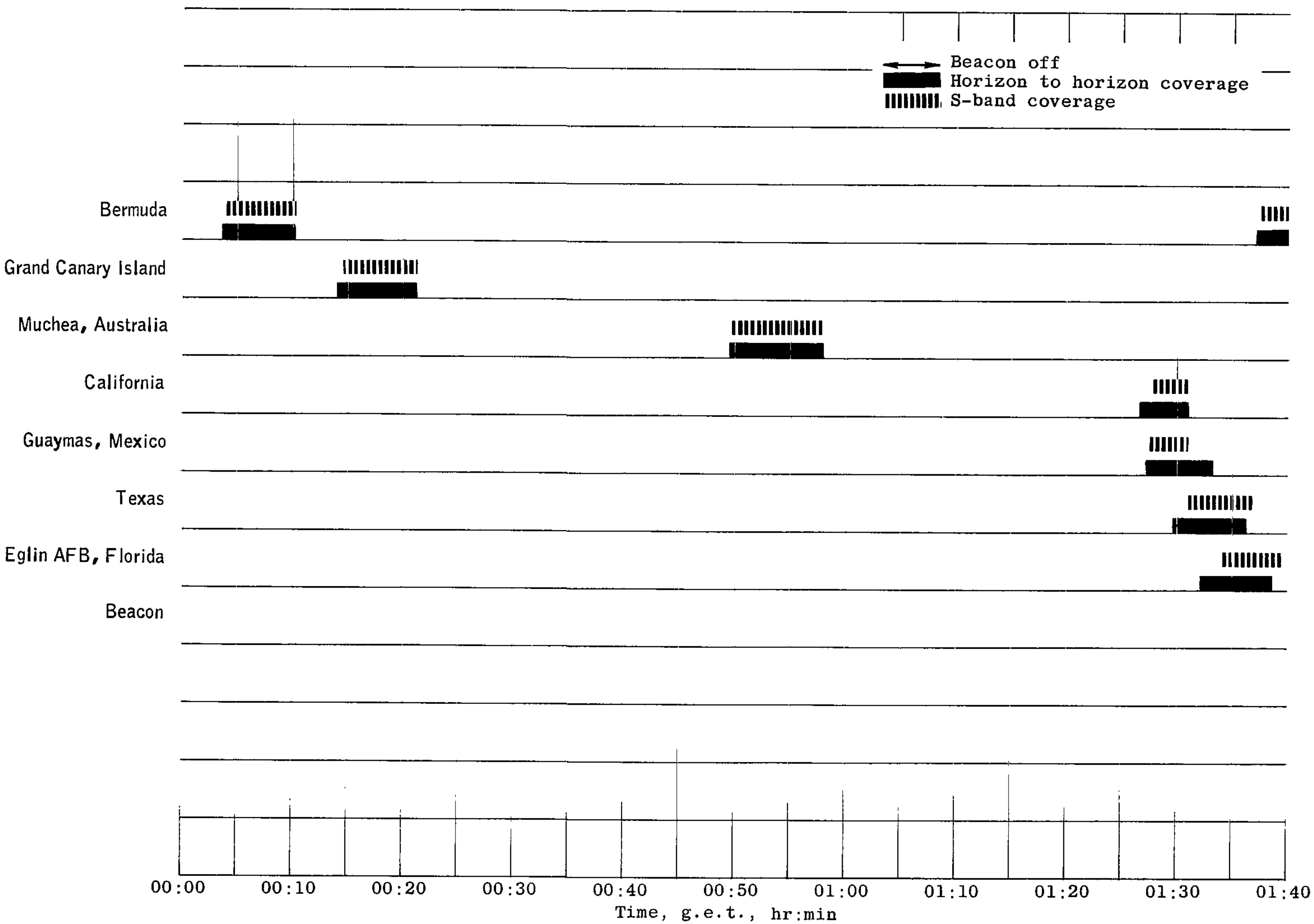


(c) 03:20 to 05:00.



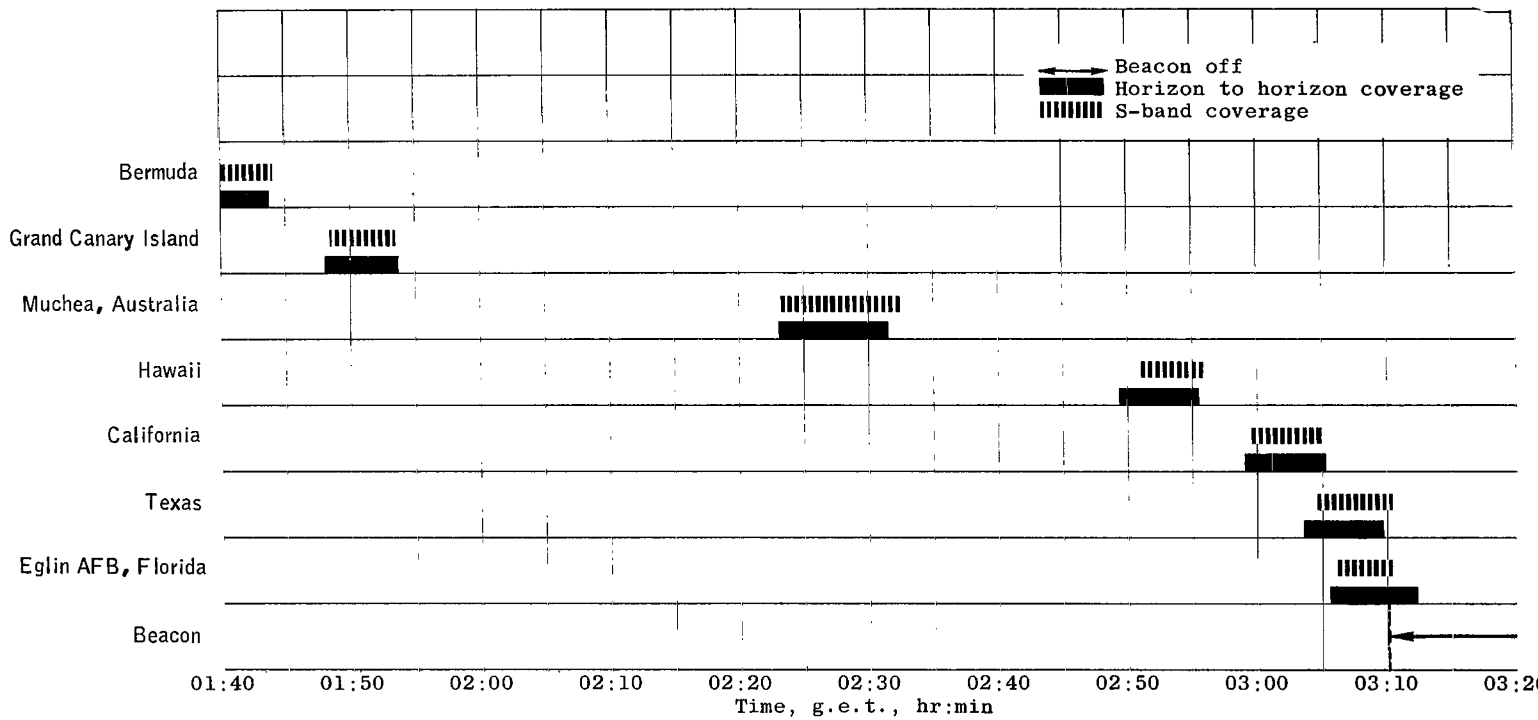
(d) 06:40 to 08:20.

Figure 53. - Concluded.

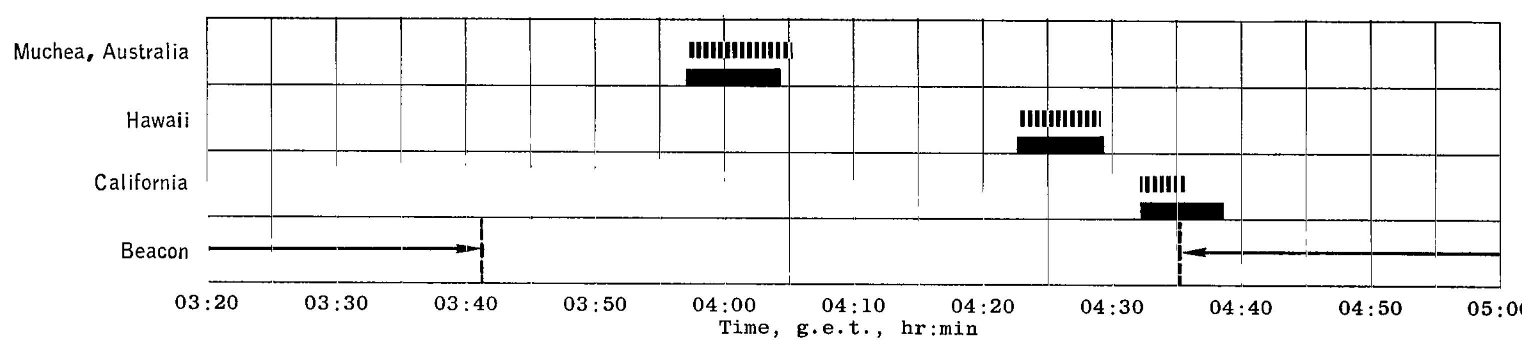


(a) 00:00 to 01:40.

Figure 54. - S-band radar coverage for MA-8 mission.

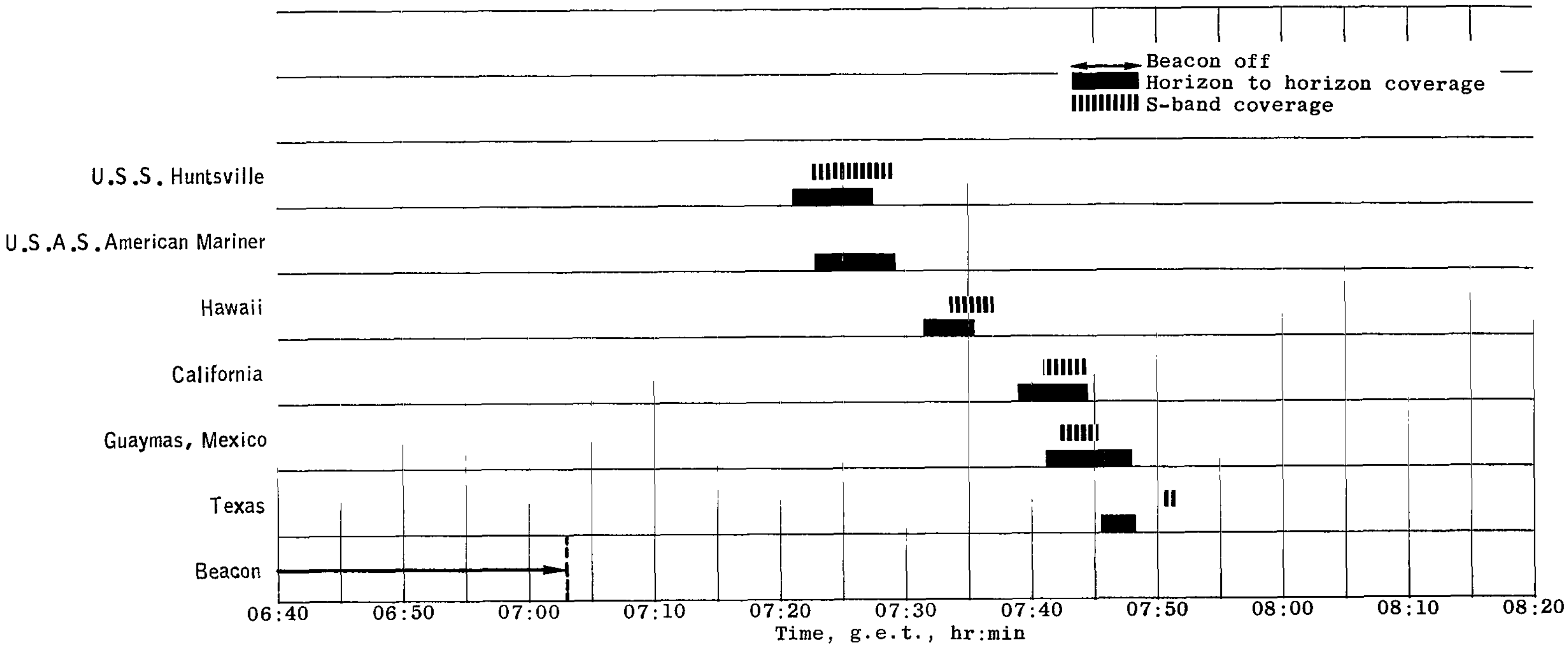


(b) 01:40 to 03:20.

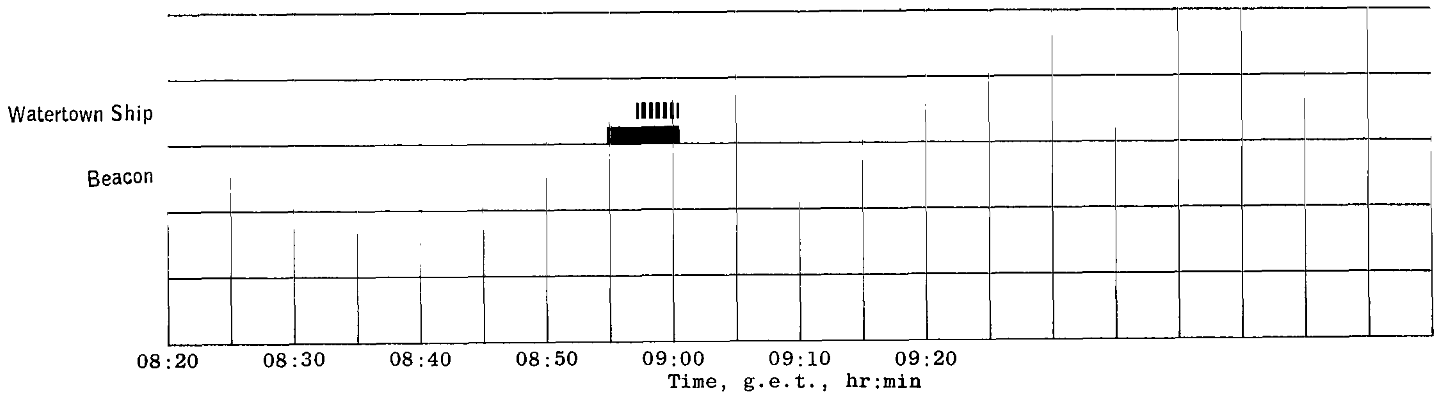


(c) 03:20 to 05:00.

Figure 54. - Continued.

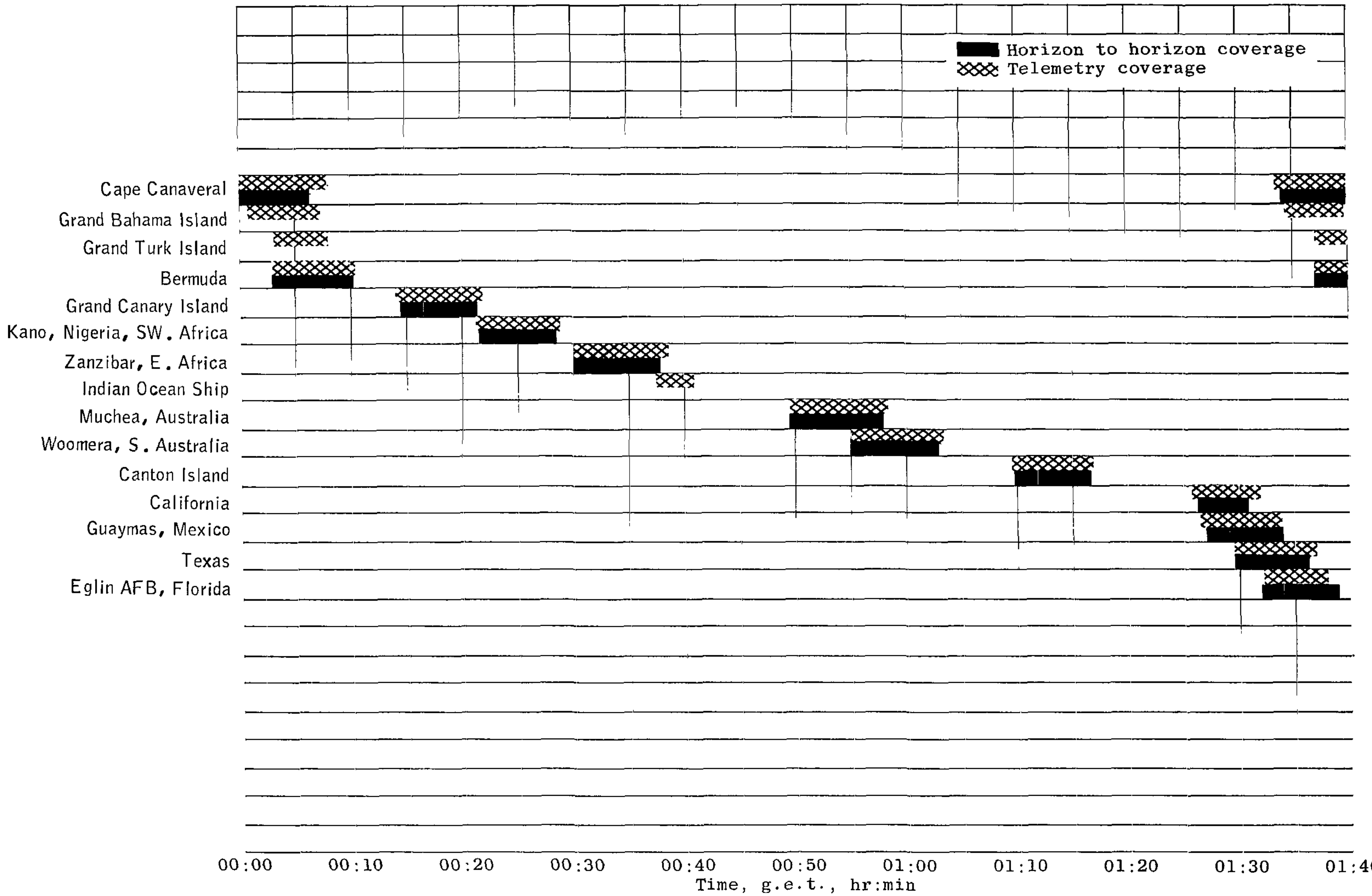


(d) 06:40 to 08:20.



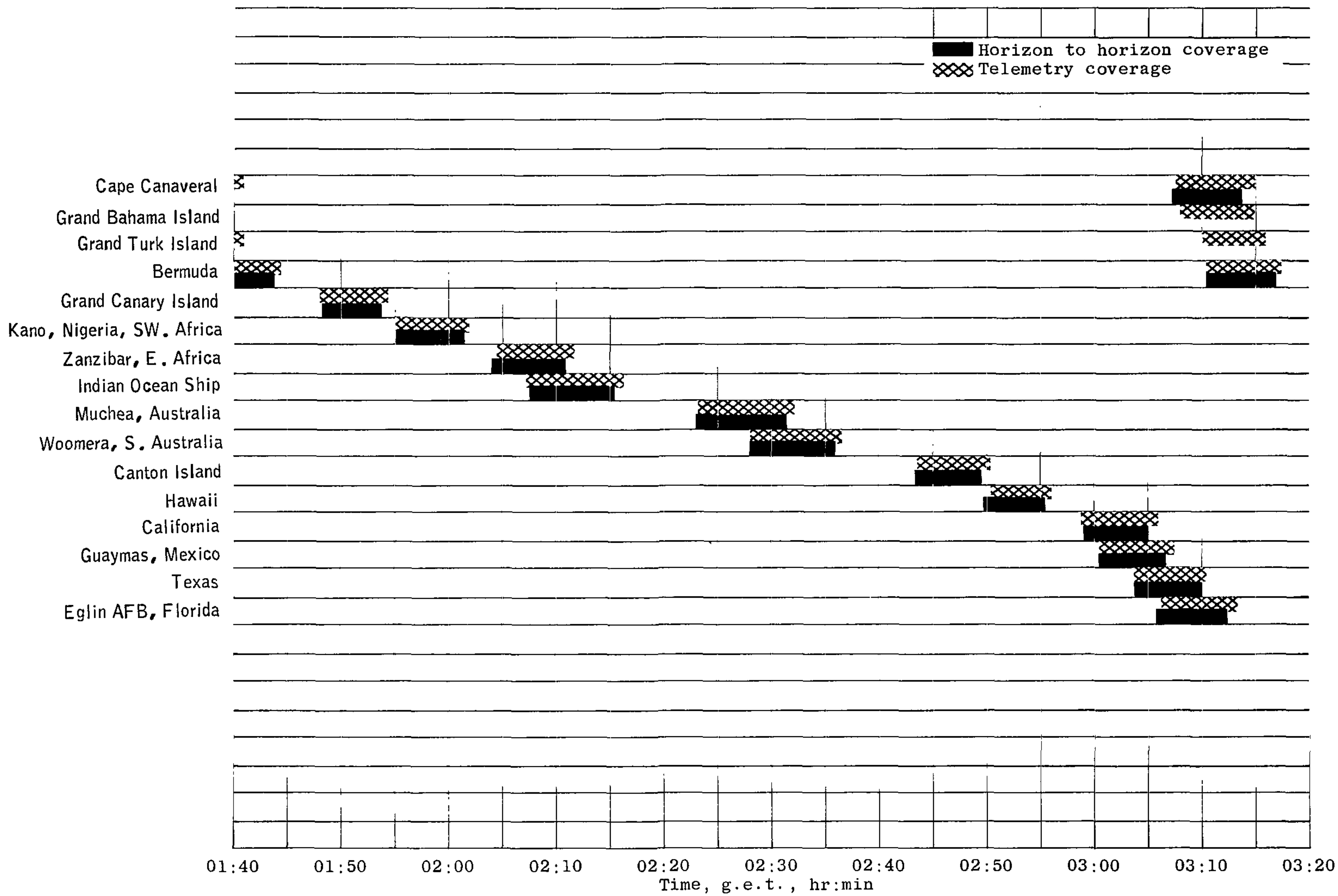
(e) 08:20 to 09:20.

Figure 54. - Concluded.



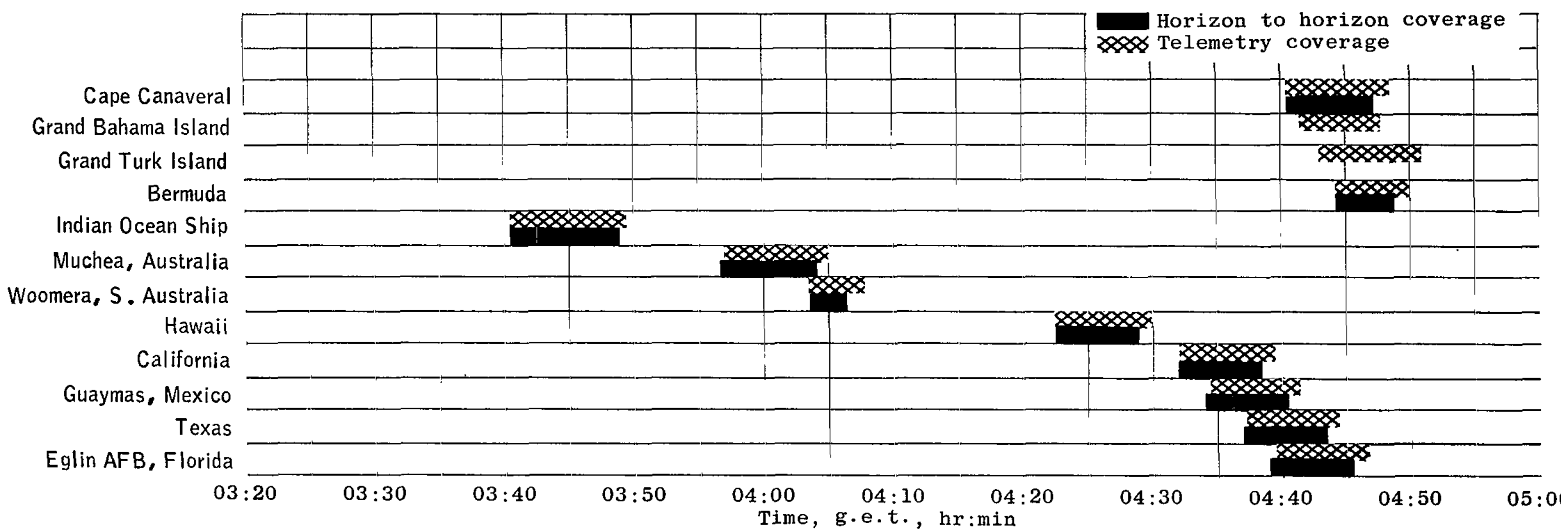
(a) 00:00 to 01:40.

Figure 55. - Telemetry coverage for MA-8 mission.

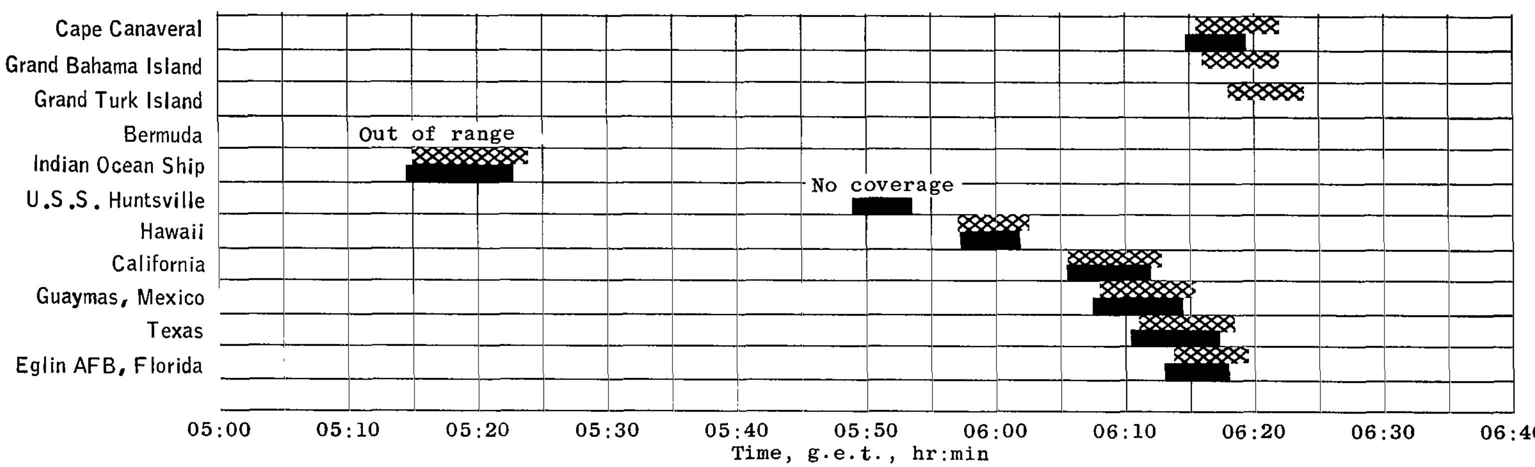


(b) 01:40 to 03:20.

Figure 55. - Continued.

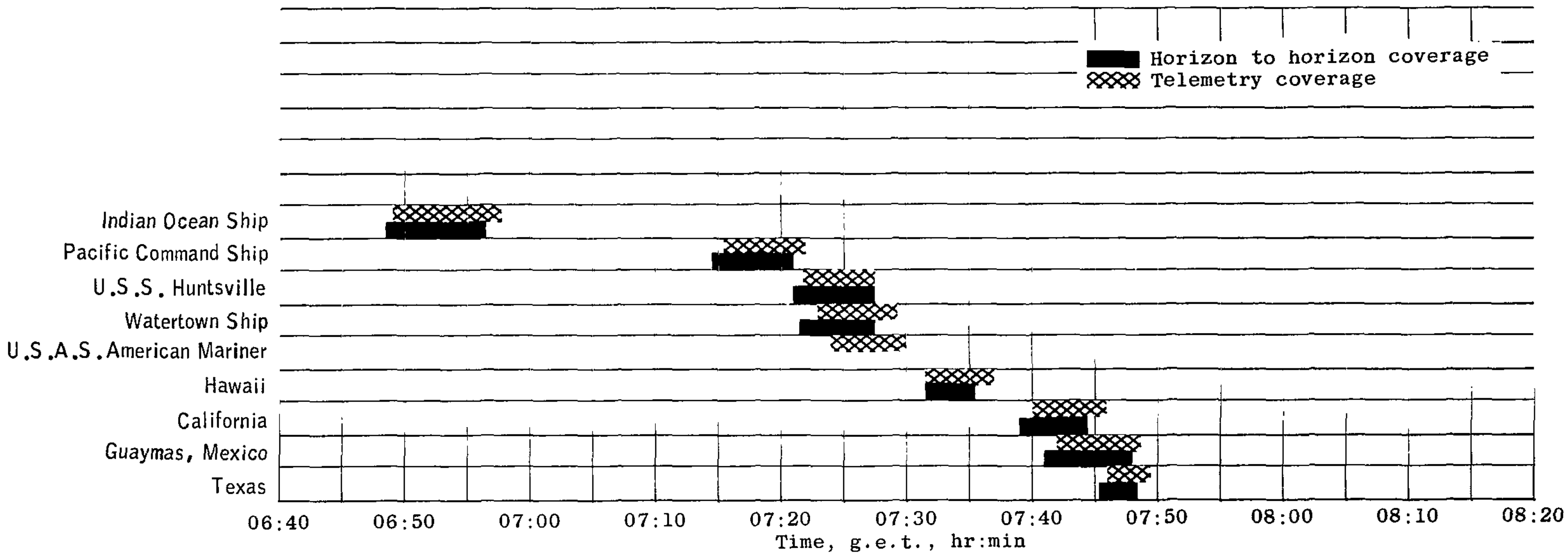


(c) 03:20 to 05:00.

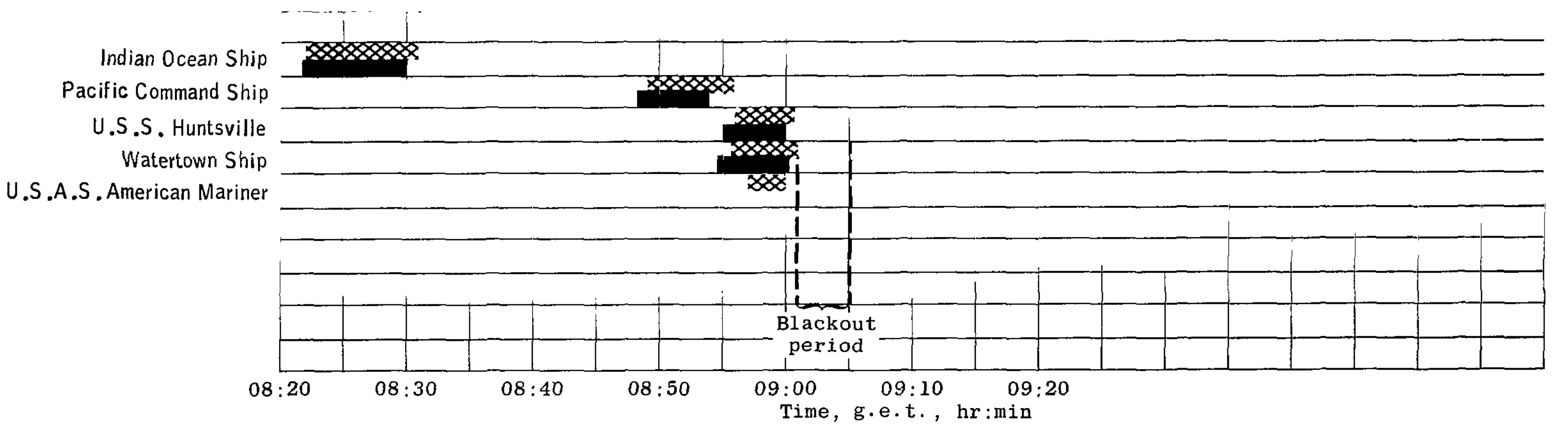


(d) 05:00 to 06:40.

Figure 55. - Continued.

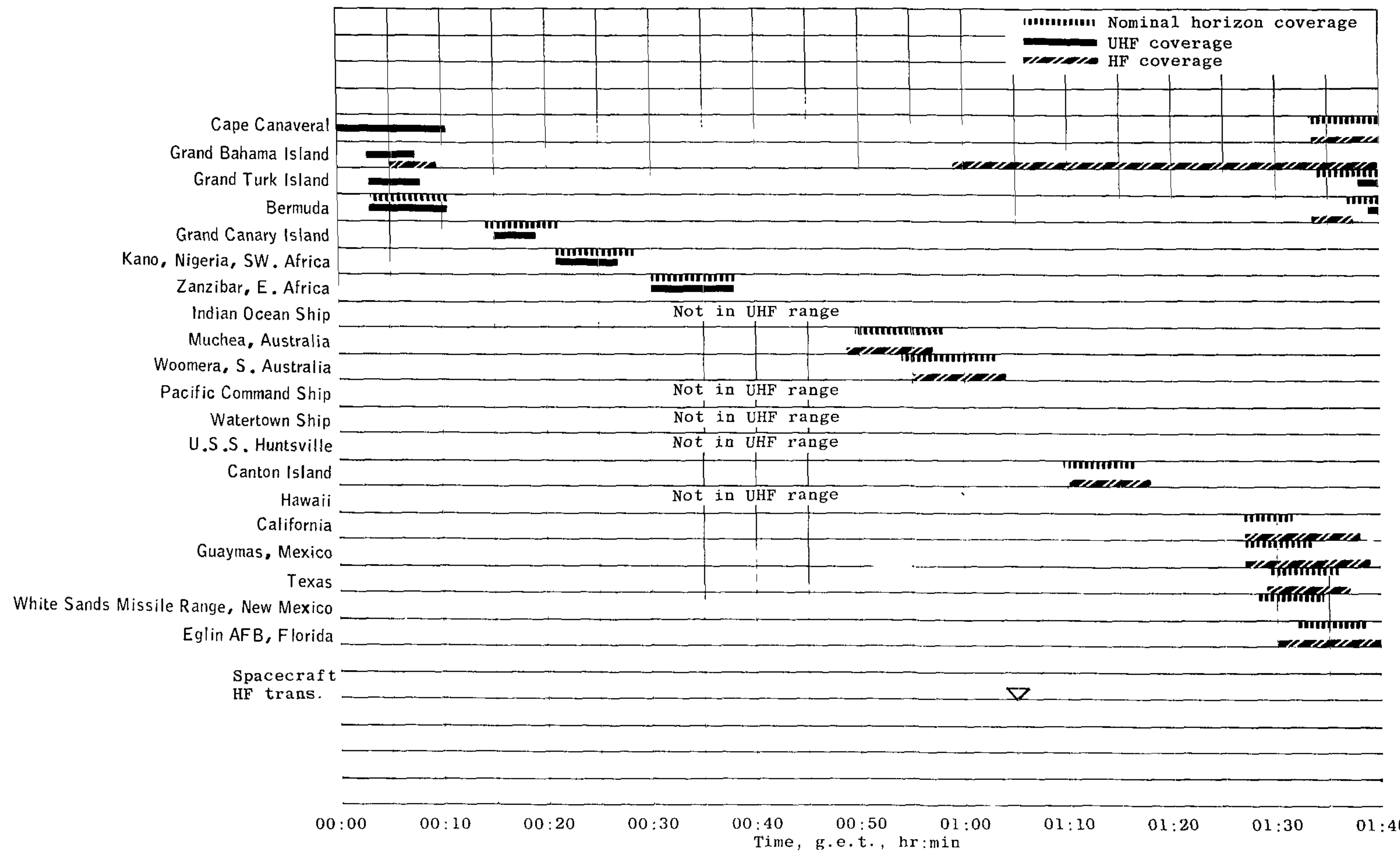


(e) 06:40 to 08:20.



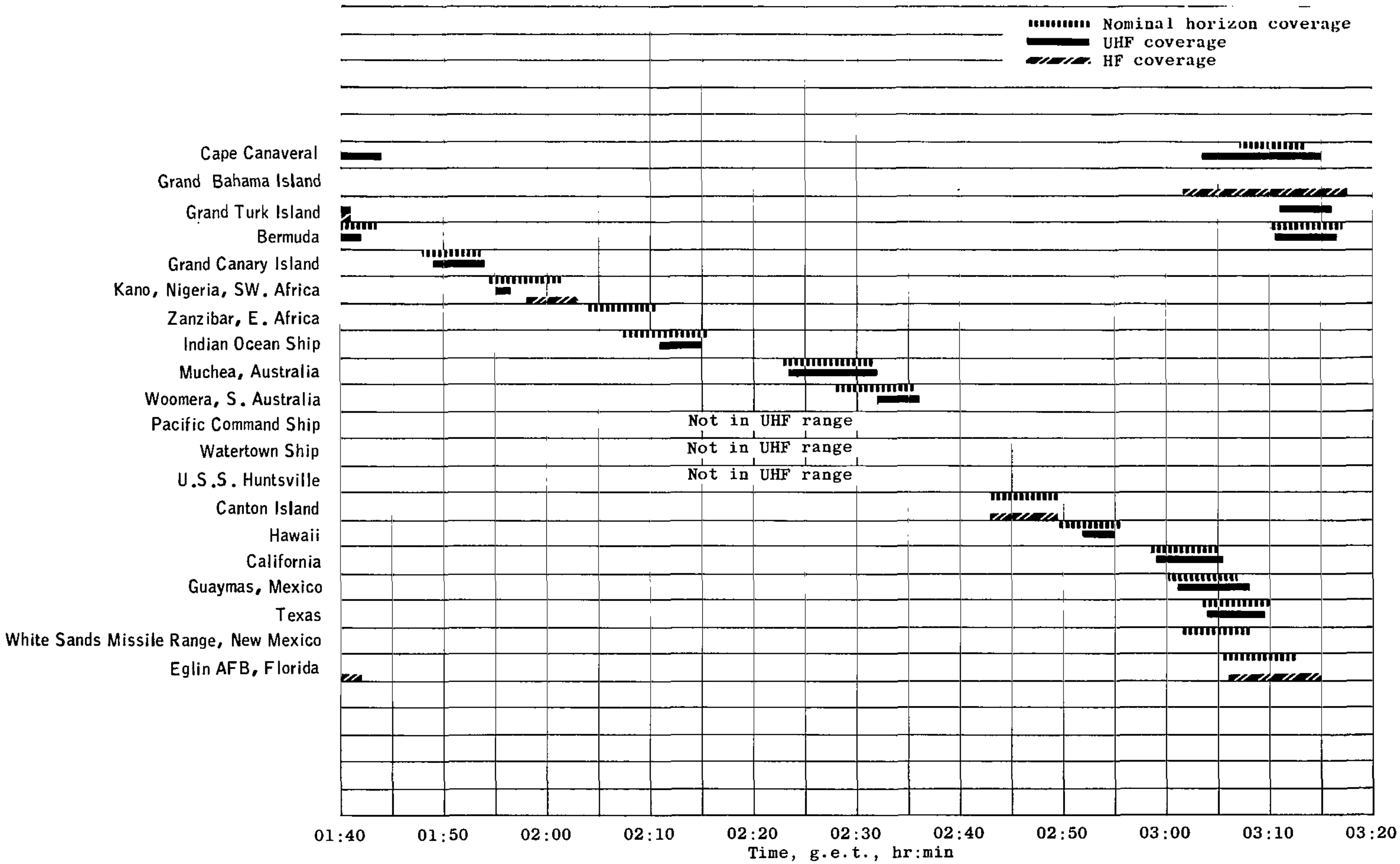
(f) 08:20 to 09:20.

Figure 55. - Concluded.



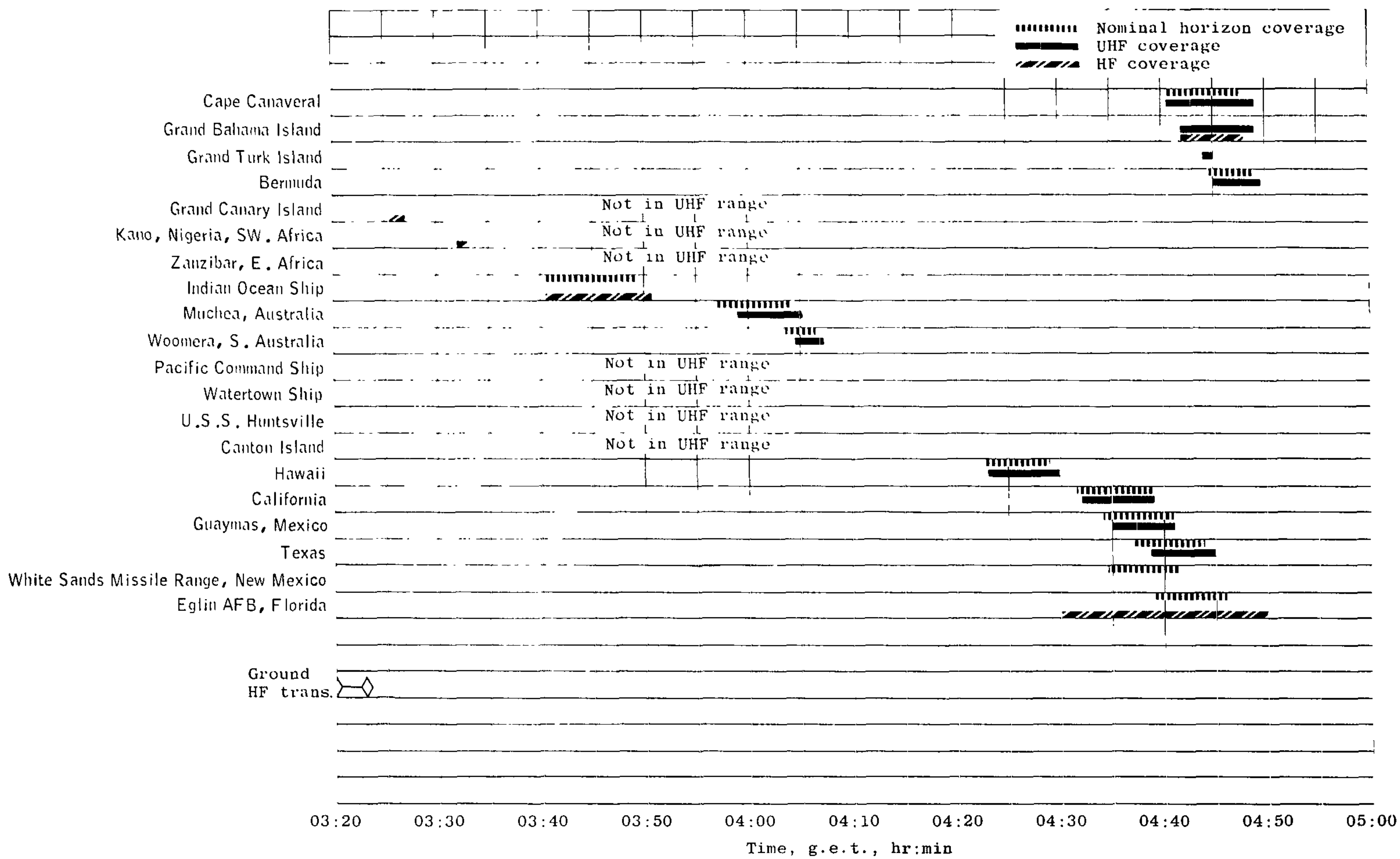
(a) 00:00 to 01:40.

Figure 56. - High-frequency/ultrahigh-frequency coverage for MA-8 mission.



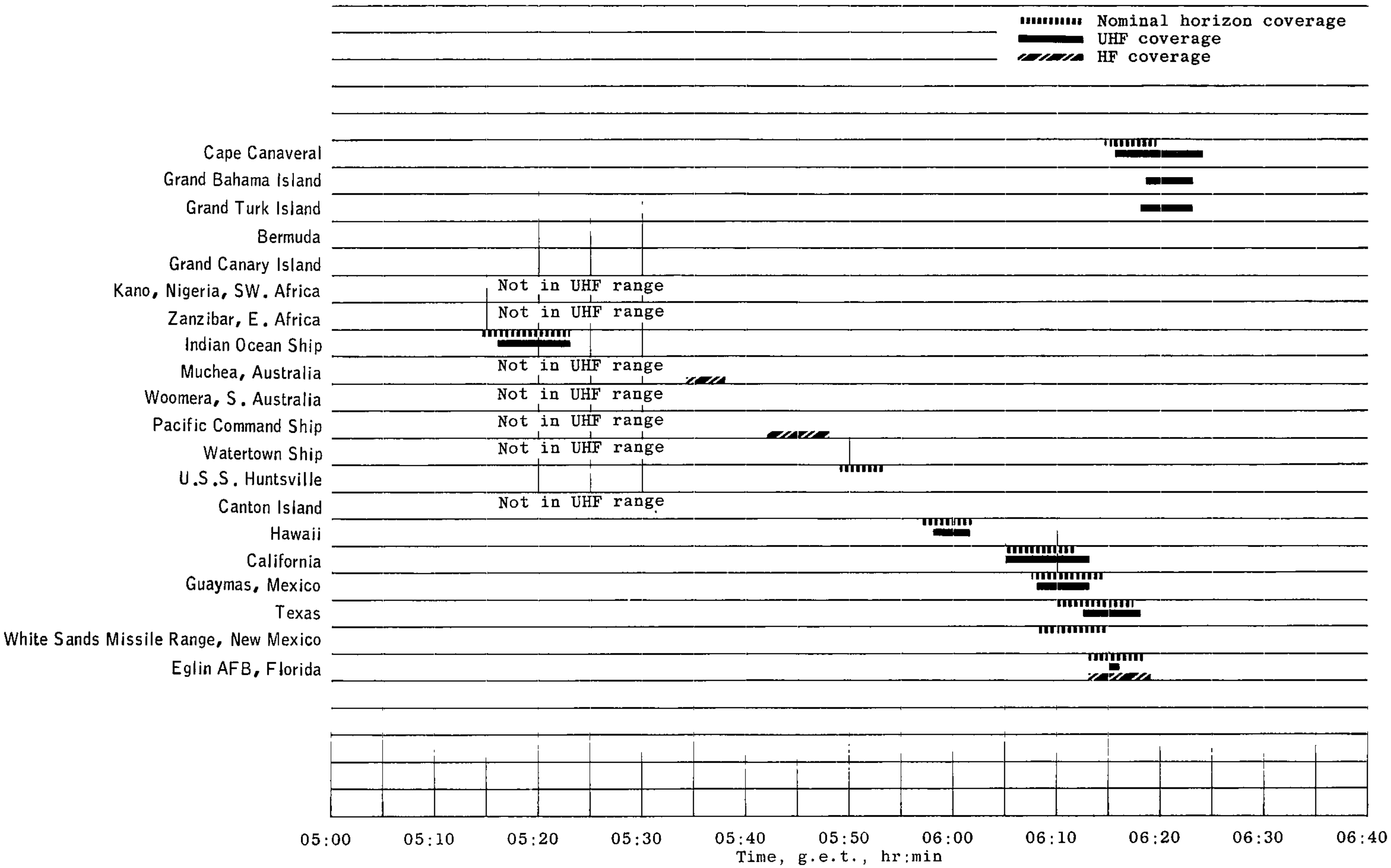
(b) 01:40 to 03:20.

Figure 56. - Continued.



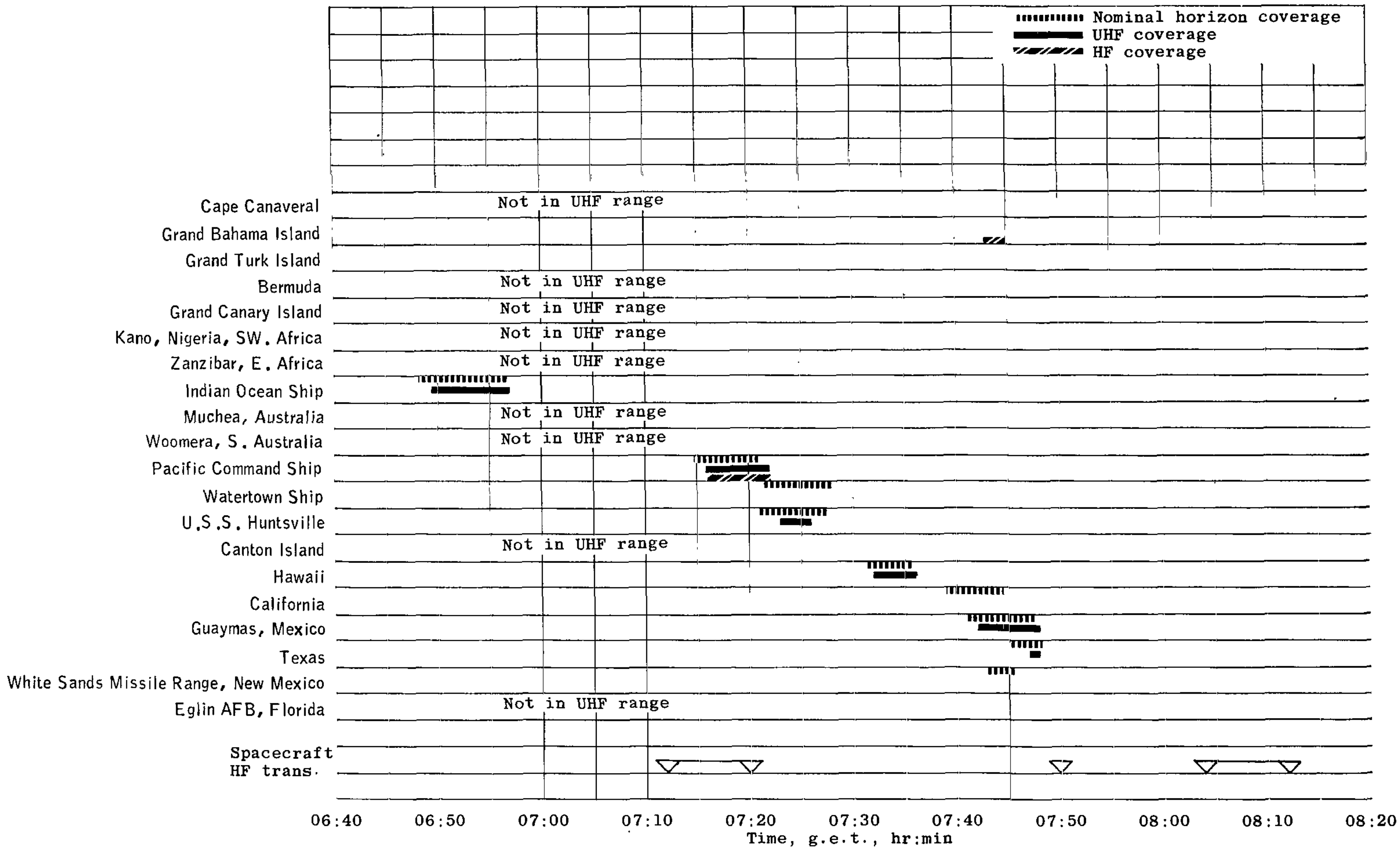
(c) 03:20 to 05:00.

Figure 56. - Continued.



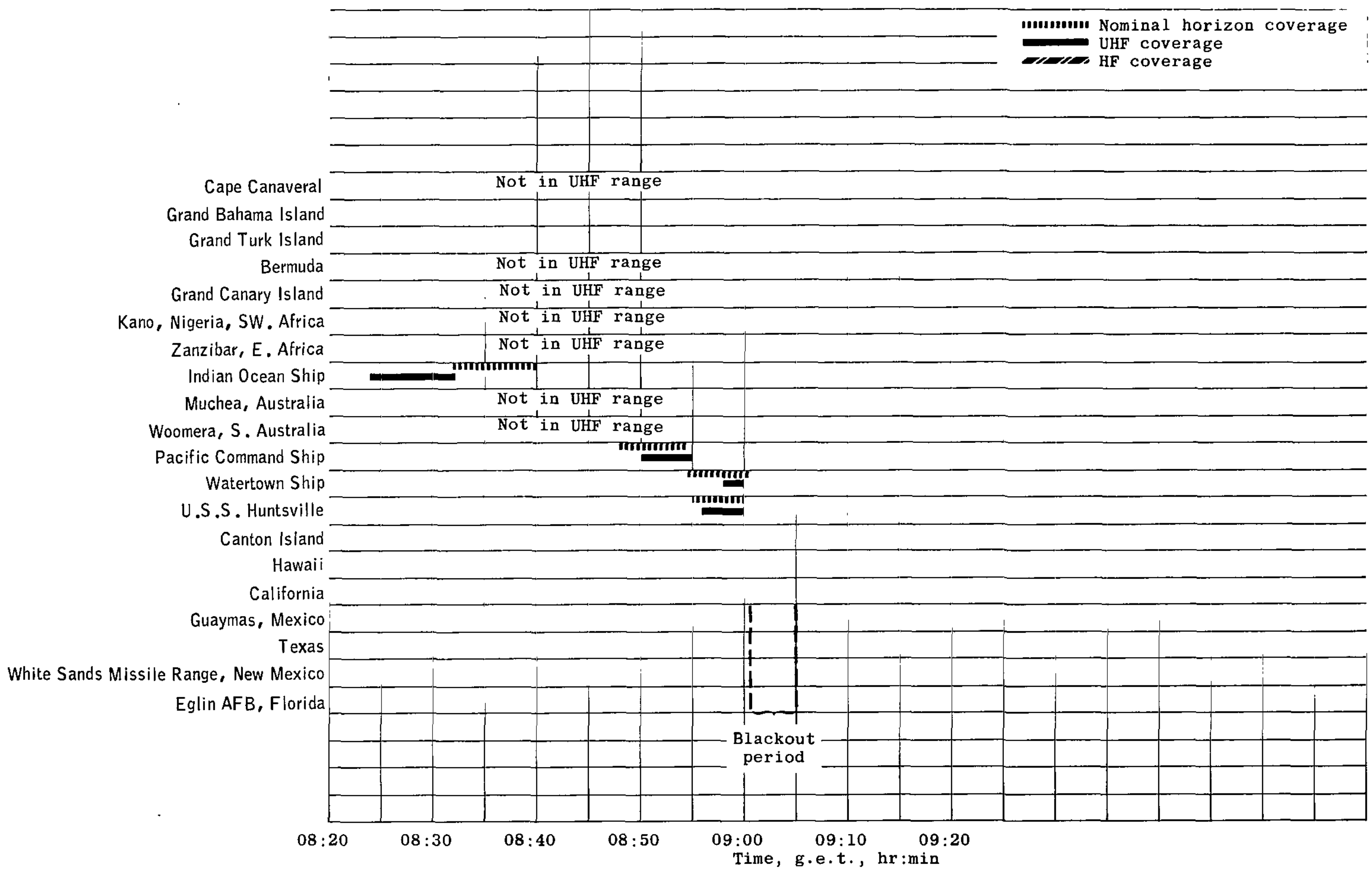
(d) 05:00 to 06:40.

Figure 56. - Continued.



(e) 06:40 to 08:20.

Figure 56. - Continued.



(f) 08:20 to 09:20.

Figure 56. - Concluded.

CONCLUDING REMARKS

The third U.S. manned orbital mission, because its duration was greater than that of the two previous missions, was intended to increase the knowledge and capability in manned space operations. The decision to proceed with the Mercury-Atlas 8 mission was largely based upon the experience gained in the previous manned orbital and suborbital flights conducted as a part of Project Mercury. The spacecraft systems operated satisfactorily throughout the 9-hour flight, although some concern was caused by the inability of the environmental control system to stabilize the temperature in the pressure suit at a comfortable level in the first 2 hours of flight. However, the methodical adjustment of the suit coolant control valve by the pilot brought the temperature under control, and the flight proceeded without further anomalies. Postflight inspection revealed that coagulated lubricant in the control valve partially blocked the flow of coolant in the system. The instrumentation system did not perform as satisfactorily as might be desired, but the data collected were adequate to conduct the comprehensive postflight analysis, from which this document is derived. A number of scientific experiments were completed successfully, and the results of these experiments extended the knowledge of the space environment. The physiological responses of the pilot during his 9-hour exposure to space flight were considered to be well within normal ranges; however, during the postflight period soon after recovery he did exhibit a reaction to weightlessness. This cardiac response, known as orthostatic hypotension, was exhibited by a drop in blood pressure with a corresponding rise in heart rate. The pilot performed a series of in-flight activities, including precise attitude maneuvers, satisfactorily, and through close observation of the spacecraft operation, the pilot was able to participate actively in the postflight systems performance analysis and debriefings. The Mercury Worldwide Network performed well in support of the flight-control and monitoring task, and although the communications were not as satisfactory as those of previous flights, the flight-control team was able to assist the pilot in his regulation of the environmental control system during the initial phase of the flight. Because the remainder of the mission was performed according to the preestablished plan, the flight-control responsibility became one of system monitoring and assisting the pilot in his scheduled activities. For the first time in Project Mercury, planned recovery areas were located in the Pacific Ocean; but with the proper coordination of the available recovery personnel and vehicles, the overall recovery effort was comparable to that of each of the two previous manned orbital missions. The spacecraft systems effectively accomplished the retrograde maneuver and brought the spacecraft to a landing approximately 4 nautical miles from the intended recovery ship. Recovery was completed quickly and efficiently, and the spacecraft and the pilot were transported to the launch site for the postflight analysis activities. Because there were no malfunctions which compromised in any way the success of the mission and because the flight activities were completed as planned, the knowledge and experience derived from the Mercury-Atlas 8 mission provided valid application to future manned space operations.

Manned Spacecraft Center
National Aeronautics and Space Administration
Houston, Texas, July 1, 1968
039-00-00-00-72

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