MSC-PT-R-68-45

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 8 MISSION

3-DAY REPORT

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MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

DECEMBER 1968

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3-DAY REPORT

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December 1968

SUMMARY

The Apollo 8 space vehicle was launched from Kennedy Space Center, Florida, at 7:51:00 a.m. e.s.t. on December 21, 1968, after a satisfactory no-hold countdown. Following a nominal boost phase, the spacecraft and S-IVB combination was inserted into a parking orbit of 98 by 103 nautical miles. After a post-insertion checkout of spacecraft systems, the translunar injection maneuver was initiated at 02:50:36 by reigniting the S-IVB engine, and the nominal maneuver lasted for 5 minutes and 6 seconds.

The spacecraft separated from the S-IVB at 03:20:55, followed by two separation maneuvers using the service module reaction control system. The first midcourse correction of 24.5 ft/sec was conducted at 10:59:58. The translunar coast phase was devoted to navigation sightings, two television transmissions, and various systems checks. The second midcourse correction, consisting of 1.9 ft/sec, was conducted at 60:59:54.

The 246.5-second duration lunar orbit insertion maneuver was performed at 69:08:20, and the initial lunar orbit was 168.5 by 59.9 n. mi. A maneuver to circularize the orbit was conducted at 73:35:06 and resulted in a lunar orbit of 59.7 by 60.7 n. mi. The coast phase between maneuvers was devoted to orbit navigation and ground track determination. A total of ten revolutions were completed during the 20 hours 11 minutes spent in lunar orbit.

The lunar orbit coast phase involved numerous landing-site/landmark sightings, lunar photography, and preparation for transearth injection. The transearth injection maneuver, 203 seconds in duration, was conducted at 89:19:16 using the service propulsion system.

During both the translunar and transearth coast phases, passive thermal control maneuvers of about one revolution per hour were effected when possible to maintain temperatures within nominal limits. The transearth coast period involved a number of star/horizon navigation sightings using both the earth and moon horizons. The only transearth midcourse correction was a 4.8 ft/sec maneuver made at 103:59:53.

Command module/service module separation was at 146:29:00, and the spacecraft reached the entry interface (400 000 feet) at 146:46:13. Following normal deployment of all parachutes, the spacecraft landed in the Pacific Ocean at 08° 08' N latitude and 165° 02' W longitude, as determined by the primary recovery ship. The total flight duration was 146 hours 59 minutes 49 seconds, and the spacecraft and crew were recovered by the USS Yorktown after landing.

Almost without exception, spacecraft systems operated as intended. All temperatures varied within acceptable limits and essentially exhibited predicted behavior. Consumables usage was always maintained at a safe level. Communications quality was exceptionally good, and live television was transmitted on six occasions. The crew satisfactorily performed all flight-plan functions and achieved all photographic objectives.

INTRODUCTION

The evaluation in this report is based on preliminary data, and the stated values are subject to change in later reports. All times are referenced to range zero, the integral second before lift-off, which was 12:51:00 G.m.t., December 21, 1968.

All spacecraft systems performed satisfactorily throughout the flight, and only the more significant information is presented under appropriate systems headings. The following systems performed essentially as intended and will not be discussed until later reports: power distribution, sequential, displays and controls, earth landing, and pyrotechnics. The initial discussion of the crew medical evaluation will appear in the next official report.

TRAJECTORY

Lift-off of the Apollo 8 mission occurred at 12:51:00.9 G.m.t. (07:51:00.9 a.m. e.s.t.) on December 21, 1968, with subsequent orbital insertion at 00:11:38. At orbital insertion, velocity was 25 567 ft/sec, flight-path angle was 0.00 degrees, and altitude was 102.6 n. mi. The resultant parking-orbit elements are given in table I.

Translunar injection with the S-IVB was initiated at 02:50:36, and spacecraft/S-IVB separation occurred at 03:20:55. Following a period of station-keeping, a small reaction control system maneuver was made to increase the separation distance from the S-IVB. Because of S-IVB proximity, an additional thrusting using the reaction control system was performed to increase the separation distance. These maneuvers are summarized in table II.

Only two midcourse corrections were required in the translunar portion of flight, 24.5 ft/sec at approximately 11 hours and 1.9 ft/sec at about 61 hours. The pericynthion altitude resulting from the second correction was 63.4 n. mi. Lunar orbit insertion was performed in two stages; the initial orbit, made with a maneuver of approximately 3000 ft/sec, was 60 by 170 n. mi., and the final lunar orbit, made with a maneuver of 134.8 ft/sec, was nearly circular at 60 n. mi. The initial orbit was maintained for about 4-1/2 hours, and the final orbit for an additional 15-1/2 hours.

The transearth injection maneuver was performed at 89:19:16, lasted for 303 seconds, and resulted in a velocity change of approximately 3500 ft/sec. The accuracy of this maneuver was such that only a 5 ft/sec midcourse correction was required at about 104 hours to achieve targeted entry conditions. Command module/service module separation was effected at 146:29:00.

Entry interface (400 000 feet altitude) occurred at 146:46:13, with subsequent landing at 146:59:49. The entry conditions were a velocity of 36 221 ft/sec and a flight-path angle of -6.5 degrees. Landing occurred at 08° 08' N and 165° 02' W longitude, based on recovery ship coordinates. Event times for the mission are shown in table III.

SYSTEMS PERFORMANCE

STRUCTURAL AND MECHANICAL SYSTEMS

All structural and mechanical systems performed satisfactorily with the exception of spacecraft window fogging. The hatch (center) window was completely fogged over by about 6 hours. The two side windows (1 and 5) were similarly affected, but to a lesser degree. The rendezvous windows (2 and 4) remained usable throughout the flight. This fogging was consistent with what was expected as a result of the Apollo 7 analysis of window fogging, which was caused by a deposit of silicone oil on the inner surface of the outer heat-shield pane. The fogging results from the outgassing of the RTV compound which seals insulation around the window area. A cure has been developed and will be used on all windows of Apollo 9 and subsequent spacecraft.

THERMAL CONTROL

Temperature measurements indicate that both passive and active thermal control elements performed satisfactorily. Passive thermal control during the translunar and transearth coast periods stabilized spacecraft propellant temperatures within the expected nominal range. Tank temperatures were maintained within the fracture-mechanics limits by varying spacecraft orientation. All temperatures were within predicted limits during lunar orbit operations.

FUEL CELLS

Fuel cell performance was excellent and no anomalies were observed throughout the mission. All parameters were in good agreement with preflight predictions.

The fuel cells provided 291.7 kilowatt hours of energy, and the bus voltage was maintained between 28.2 and 30.0 V dc at total load currents ranging from 56 to 92 amperes. Thermal control was excellent, with condenser exit temperatures remaining between 157° and 163° F during all phases of the mission, indicating satisfactory performance of the secondary coolant bypass valve. Radiator performance was normal and agreed well with predicted lunar-orbit performance.

BATTERIES

The entry and postlanding batteries and pyrotechnic batteries performed all required functions satisfactorily throughout the mission. The entry batteries could be charged to full capacity as required. The total capacity of the entry batteries at separation was 113.9 ampere-hours and the lowest battery-bus voltage reading following separation was 28.4.

CRYOGENICS

The cryogenic storage system performed satisfactorily throughout the mission, and usage was slightly less than predicted. All heaters were operated automatically and all fans were cycled manually to preclude the ac bus-voltage problem caused by the arcing motor switch noted on Apollo 7. Quantity balancing between the respective cryogenic tanks was satisfactory.

COMMUNICATIONS

The overall performance of the spacecraft-to-network communication system was nominal. The received downlink carrier power, telemetry, and voice performance corresponded to preflight predictions.

Communications system management, including antenna switching during the mission was very good. Communications during passive thermal control were maintained by sequentially switching between the four omni antennas, switching between diametrically opposite omnis, or switching between the high-gain antenna and one or more omni antennas. All four omni antennas and the high-gain antenna were selected periodically, with performance equal to or greater than preflight predictions. All modes of the high-gain antenna were used successfully.

The data quality of both high- and low-bit-rate telemetry was good. High-bit-rate telemetry was received through the 85-foot antennas at slant ranges of up to 160 000 nautical miles while the spacecraft was transmitting on omni antennas.

The voice quality, both normal and backup, received throughout the mission was excellent. The MSFN sites reported receipt of good-quality telemetry data during data storage equipment dumps.

Communications were satisfactory during entry until blackout at 146:46:38. Air-to-ground voice contact was reestablished at approximately

146:52 through the Apollo Range Instrumentation Aircraft. The USS Yorktown established voice contact during parachute descent. Although postlanding voice communications were momentarily interrupted when the spacecraft was in a stable II flotation attitude, the recovery operation was satisfactorily supported.

A total of six television transmissions were made during the flight. For the first telecast, the telephoto lens (100 mm focal length) was used to view the earth. Because of camera motion and the higher than expected light intensity of the earth, the pictures were of very poor quality. A procedure for use of the filters from the Hasselblad camera was developed and subsequent telecasts of the earth using the telephoto lens with a red filter were satisfactory. Excellent views of the lunar surface were taken in lunar orbit using the extra-wide-angle lens (9 mm focal length) and suitable filters.

INSTRUMENTATION

The data storage equipment and instrumentation system performance was satisfactory throughout the mission, and only three measurements failed.

The fuel cell 2 radiator-outlet temperature indicated a temperature 6 to 12 degrees higher than expected. Proper system performance of the fuel cell and radiator was verified by other system measurements, thus indicating a failed sensor.

The radiator-outlet temperature measurement in the environmental control system failed at approximately 120 hours elapsed time and went to full-scale reading. Systems analysis verified proper radiator operation.

The measurement of potable water quantity in the ECS apparently failed at approximately 145 hours elapsed time. Normal tank-pressurization and water production data indicated the measurement to be questionable.

GUIDANCE AND CONTROL

Performance of the guidance and control system was excellent throughout the mission. All monitoring functions and navigation comparisons required during ascent, earth orbit, and translunar injection were normal. Platform alignments were performed during all coast phases with good results. Gyro bias drift estimates, made from evaluating successive alignments, indicate performance within one-sigma variations. Accelerometer bias measurements made throughout the mission also indicate stability well within one sigma. Onboard midcourse navigation techniques were thoroughly exercised. Star-horizon measurements were made during translunar and transearth coast, and preliminary comparisons indicate close agreement with ground tracking. Onboard orbital navigation was performed in lunar orbit with nominal results.

Spacecraft attitude control was satisfactory using both the digital autopilot and the stabilization and control system. Service propulsion maneuvers were performed using the digital autopilot with nominal results. Entry guidance and navigation was excellent.

Two guidance and control system problems occurred during the mission. The first involved abnormal shifts in the computer readout of the optics trunnion angle. Several times during periods of no optics activity, the read-out shifted from 0 to 45 degrees. In each case, the correct reading was restored with a normal optics zeroing procedure, and no optics utilization capability was lost. The symptoms have been duplicated in the laboratory by inducing a malfunction in the read circuit of the optics coupling data unit.

REACTION CONTROL SYSTEMS

All command and service module reaction control system parameters were normal throughout the mission.

The thermal control system in the service module reaction control system maintained package temperatures within nominal limits. All regulated pressures were normal and propellant usage was within acceptable limits during the flight. A total of 654 pounds of propellant were used during the mission with 94 pounds used in lunar orbit.

SERVICE PROPULSION SYSTEM

Four maneuvers were accomplished using the service propulsion system, the longest being the 246.5-second lunar orbit insertion maneuver, and system operation was satisfactory. All maneuvers were no-ullage starts.

A momentary drop in chamber pressure was experienced early in the first service propulsion maneuver which was attributed to the presence of a small helium bubble in the oxidizer feed line. This bubble is thought to have resulted from an inadequate engine-oxidizer bleed during preflight servicing. The chamber pressure was satisfactory throughout the remainder of the the burn and for the three subsequent maneuvers.

Feed-line temperatures were more favorable than anticipated and remained reasonably steady within their upper and lower redline limits. As a result, no heater operation was required.

ENVIRONMENTAL CONTROL SYSTEM

Performance of the environmental control system was satisfactory. The radiators satisfactorily rejected the spacecraft heat loads during the translunar and transearth coasts, maintaining water/glycol temperatures below the evaporator turn-on level. The evaporators were therefore turned off during this time. The primary evaporator was used in the automatic mode during lunar orbit. Evaporator dryout occurred several times; however, the dryout did not impose any restraints on the mission. Evaporator dryout occurred on Apollo 7 at low heat loads and was anticipated to occur on Apollo 8 under similar load conditions. The evaporator was reserviced at the end of the first orbit and operated satisfactorily until evaporator dryout recurred during the fourth orbit. The evaporator was again reserviced and operated satisfactorily for the remainder of lunar orbital flight. Primary evaporator dryout occurred again during entry; however, the crew activated the secondary coolant loop, which operated properly throughout entry and maintained normal cabin temperatures near 61° F and the suit-heat-exchanger outlet-gas temperatures near 44° F. The fans, which were not needed during the mission, were noisy when activated on the occasion to circulate the cabin atmosphere for a valid cabin temperature reading.

CREW PROVISIONS

All crew equipment operated satisfactorily during the mission. Excessive noise on the Lunar Module Pilot's electrocardiogram was corrected when harnesses were swapped. The astronauts' boots were reported to be frayed but usable.

FLIGHT CREW

The Apollo 8 mission was accomplished essentially in accordance with the nominal flight plan, with the following minor exceptions.

The S-IVB separation rate from the spacecraft was less than predicted, and the crew spent a longer time in keeping the S-IVB in sight and eventually used an additional reaction control system maneuver to increase separation distance.

Because of the heavy work load in lunar orbit, the orbital activities after the eighth revolution were sharply reduced to allow the crew to get some rest. Normal activities were resumed in preparation for the transearth injection, after which the flight plan was again modified to allow for additional crew rest. At about 100 hours the mission returned to the nominal flight plan with only minor rescheduling of rest and meal periods.

Despite the long duty hours, crew performance was good throughout the mission, and many valuable observations of the lunar surface and its environment were made.

Entry and landing were performed in darkness, with no apparent problems. The spacecraft assumed a stable II (apex down) flotation attitude upon landing approximately 5200 yards from USS Yorktown, and the crew successfully returned the vehicle to the upright flotation position. A decision had previously been made to delay the deployment of swimmers until daylight; therefore, crew transfer to the prime recovery ship by helicopter occurred about 80 minutes after landing.

MISSION SUPPORT PERFORMANCE

FLIGHT CONTROL

Flight control support was excellent during the Apollo 8 mission.

NETWORK

Network performance was excellent for this mission. All communications, tracking, command, telemetry, and the real-time computation functions supported the mission satisfactorily with no significant loss of data at any time.

RECOVERY

Recovery of the Apollo 8 spacecraft and crew was successfully completed in the Pacific Ocean by the prime recovery ship, the USS Yorktown. The major recovery events on December 27, 1968, are listed in the following table.

G.m.t., hr:min (December 27)	Event
15:41	First visual sighting of spacecraft by Hawaii Rescue 1
15:43	Radar contact by USS Yorktown
15:49	First sighting of CM flashing light by Yorktown
15:51	Landing
16:48	Flotation collar installed and inflated
17:20	Astronauts onboard recovery ship
18:18	CM onboard recovery ship

Both S-band and VHF contacts were established with the recovery forces. Visual contact with the flashing light and voice contact with the flight crew ceased at landing, indicating that the command module went into a stable-II position before uprighting. The uprighting bags were inflated, with one bag reported to be only partially inflated. Although a recovery helicopter was directly over the spacecraft as early as 16:08 G.m.t., it was decided previously to wait until daylight before deploying swimmers.

The pertinent location data for the recovery operation are listed below:

Predicted target coordinates	08° 08'N, 165° 02'W
Ship position at landing*	08° 09.3N, 165° 02.1N
Estimated range to spacecraft at landing	5200 yards
Retrieval coordinates	08° 07.5N, 165° 01.2W

*As determined aboard the recovery ship.

TABLE I.- ORBIT SUMMARY

Parameter	Earth orbit insertion	Lunar orbit insertion 1	Lunar orbit insertion 2
Apoapsis, n. mi.	102.6	168.5	60.7
Periapsis, n. mi.	98.3	59.9	59.7
Period, min	88.18	128.74	118.97
Inclination, deg	32.51	146.33	146.34

TABLE II.- MANEUVER SUMMARY

Maneuver	System	Time, hr:min:sec	Duration, sec	Velocity change, ft/sec
Translunar injection	S-IVB	2:50:36.4	317.0	505.0
Separation 1	RCS	3:40:00.0	a	1.1
Separation 2	RCS	4:45:00.0	a	7.7
Midcourse correction 1	SPS/RCS	10:59:58.3	2.4[a]	24.5
Midcourse correction 2	RCS	60:59:54.3	15.7	1.9
Lunar orbit insertion 1	SPS	69:08:19.5	246.5	2989.4
Lunar orbit insertion 2	SPS	73:35:05.7	9.6	134.8
Transearth injection	SPS	89:19:15.6	203.0	3516.8
Midcourse correction 3	RCS	103:59:52.9	13.7	4.8

[a]Burn times for the RCS maneuvers shown are not known at this time.

TABLE III.- APOLLO 8 SEQUENCE OF EVENTS

Event	Time, hr:min:sec
Launch phase	
Range zero (12:51:00 G.m.t.)	
Lift-off	00:00:00
S-IC center engine cutoff	00:02:06
S-IC outboard engine cutoff	00:02:34
S-IC/S-II separation	00:02:34
S-II engine ignition	00:02:35
Interstage jettison	00:03:05
Launch escape tower jettison	00:03:09
S-II engine cutoff	00:08:44
S-II/S-IVB separation	00:08:45
S-IVB engine ignition	00:08:45
S-IVB engine cutoff	00:11:25
Insertion	00:11:35
Orbital phase	
Translunar injection ignition Translunar injection cutoff	02:50:36 02:55:42
S-IVB/Command module separation	03:20:55
Separation maneuver 1	03:40:00
Separation maneuver 2	04:45:00
Midcourse correction 1 ignition Midcourse correction 1 cutoff	10:59:58 11:00:01
Midcourse correction 2	60:59:54
Lunar orbit insertion 1 ignition Lunar orbit insertion 1 cutoff	69:08:20 69:12:27
Lunar orbit insertion 2 ignition Lunar orbit insertion 2 cutoff	73:35:06 73:35:16
Transearth injection ignition Transearth injection cutoff	89:19:16 89:22:39
Midcourse correction 3 ignition Midcourse correction 3 cutoff	103:59:53 104:00:07

TABLE III.- APOLLO 8 SEQUENCE OF EVENTS - Concluded

Event	Time, hr:min:sec
CSM/SM separation	146:29:00
Entry interface (400 000 ft.)	146:46:13
Begin blackout	146:46:38
End Blackout	146:51:44
Drogue deployment	146:54:26
Main parachute deployment	146:55:20
Landing	146:59:49