Prelaunch
Mission Operation Report
No. M-933-72-16

3 April 1972

MEMORANDUM

TO: A/Administrator

FROM: MA/Apollo Program Director

SUBJECT: Apollo 16 Mission (AS-511)

We plan to launch Apollo 16 from Pad A of Launch Complex 39 at the Kennedy Space Center no earlier than 16 April 1972. This will be the fifth manned lunar landing and the second of the Apollo "J" series missions which carry the Lunar Roving Vehicle for surface mobility, added Lunar Module consumables for a longer surface stay time, and the Scientific Instrument Module for extensive lunar orbital science investigations.

Primary objectives of this mission are selenological inspection, survey, and sampling of materials and surface features in a preselected area of the Descartes region of the moon; emplacement and activation of surface experiments; and the conduct of in-flight experiments and photographic tasks. In addition to the standard photographic documentation of operational and scientific activities, television coverage is planned for selected periods in the spacecraft and on the lunar surface. The lunar surface TV coverage will include remote controlled viewing of astronaut activities at each major science station on the three EVA traverses.

The 12-day mission will be terminated with the Command Module landing in the mid-Pacific Ocean about 150 NM north of Christmas Island.

Rocco A. Petrone

APPROVAL:

Dale D. Myers
Associate Administrator for
Manned Space Flight

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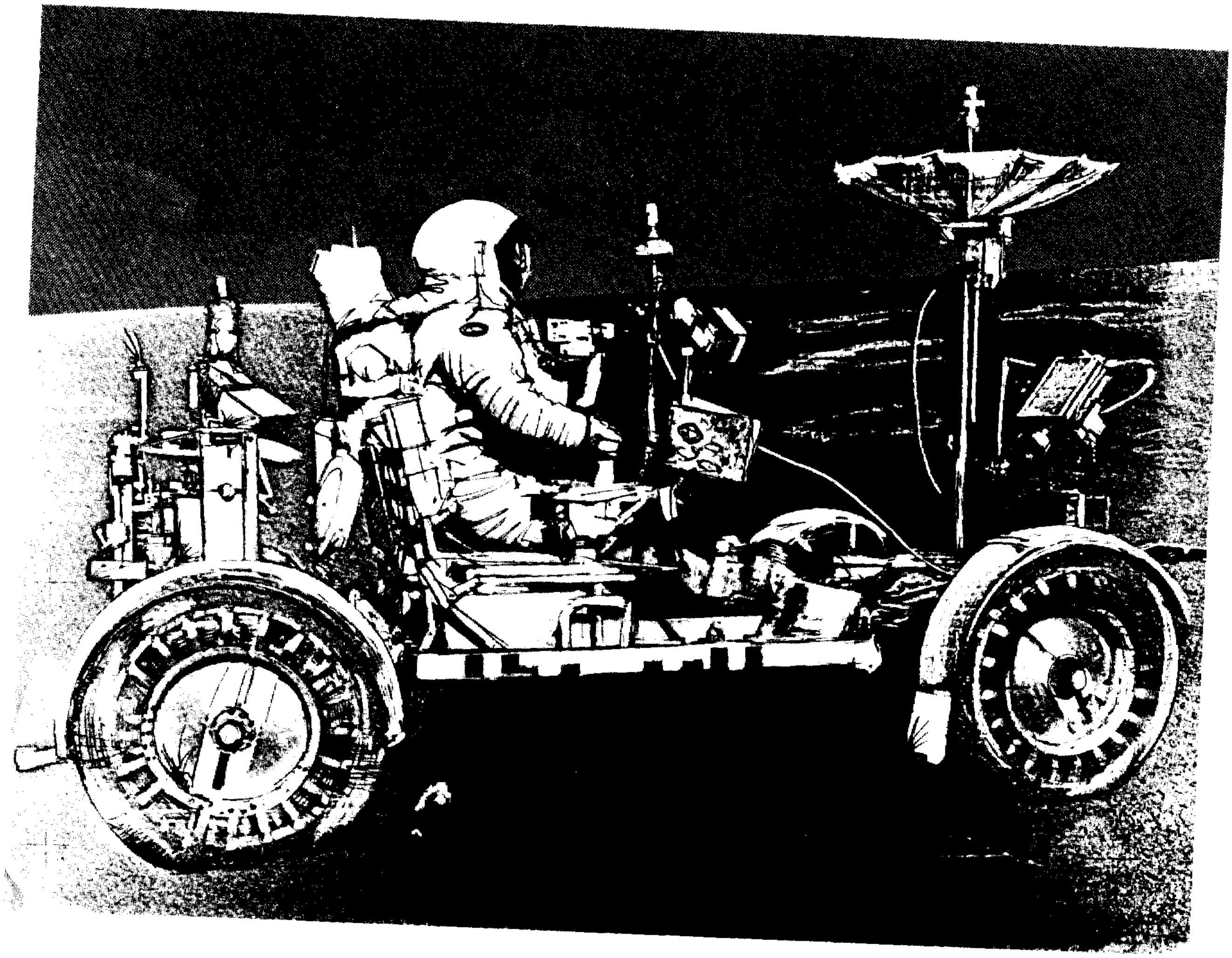
Report No. M-933-72-16

MISSION OPERATION REPORT



APOLLO 16 MISSION

OFFICE OF MANNED SPACE FLIGHT

FOREWORD

MISSION OPERATION REPORTS are published expressly for the use of NASA Senior Management, as required by the Administrator in NASA Management Instruction HQMI 8610.1, effective 30 April 1971. The purpose of these reports is to provide NASA Senior Management with timely, complete, and definitive information on flight mission plans, and to establish official Mission Objectives which provide the basis for assessment of mission accomplishment.

Prelaunch reports are prepared and issued for each flight project just prior to launch. Following launch, updating (Post Launch) reports for each mission are issued to keep General Management currently informed of definitive mission results as provided in NASA Management Instruction HQMI 8610.1.

Primary distribution of these reports is intended for personnel having program/project management responsibilities which sometimes results in a highly technical orientation. The Office of Public Affairs publishes a comprehensive series of reports on NASA flight missions which are available for dissemination to the Press.

APOLLO MISSION OPERATION REPORTS are published in two volumes: the MISSION OPERATION REPORT (MOR); and the MISSION OPERATION REPORT, APOLLO SUPPLEMENT. This format was designed to provide a mission-oriented document in the MOR, with supporting equipment and facility description in the MOR, APOLLO SUPPLEMENT. The MOR, APOLLO SUPPLEMENT is a program-oriented reference document with a broad technical description of the space vehicle and associated equipment, the launch complex, and mission control and support facilities.

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EXECUTIVE SECRETARIAT - NASA HEADQUARTERS

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SUMMARY OF APOLLO/SATURN FLIGHTS

Mission	Launch Date	Launch Vehicle	Payload	Description
AS-201	2/26/66	SA-201	CSM-009	Launch vehicle and CSM development. Test of CSM subsystems and of the space vehicle. Demonstration of reentry adequacy of the CM at earth orbital conditions.
AS-203	7/5/66	SA-203	LH_2 in S-IVB	Launch vehicle development. Demonstration of control of LH_2 by continuous venting in orbit.
AS-202	8/25/66	SA-202	CSM-011	Launch vehicle and CSM development. Test of CSM subsystems and of the structural integrity and compatibility of the space vehicle. Demonstration of propulsion and entry control by G&N system. Demonstration of entry at 28,500 fps.
Apollo 4	11/9/67	SA-501	CSM-017 LTA-10R	Launch vehicle and spacecraft development. Demonstration of Saturn V Launch Vehicle performance and of CM entry at lunar return velocity.
Apollo 5	1/22/68	SA-204	LM-1 SLA-7	LM development. Verified operation of LM subsystems: ascent and descent propulsion systems (including restart) and structures. Evaluation of LM staging. Evaluation of S-IVB/IU orbital performance.
Apollo 6	4/4/68	SA-502	CM-020 SM-014 LTA-2R SLA-9	Launch vehicle and spacecraft development. Demonstration of Saturn V Launch Vehicle performance.

Mission	Launch Date	Launch Vehicle	Payload	Description
Apollo 7	10/11/68	SA-205	CM-101 SM-101 SLA-5	Manned CSM operations. Duration 10 days 20 hours.
Apollo 8	12/21/68	SA-503	CM-103 SM-103 LTA-B SLA-11	Lunar orbital mission. Ten lunar orbits. Mission duration 6 days 3 hours. Manned CSM operations.
Apollo 9	3/3/69	SA-504	CM-104 SM-104 LM-3 SLA-12	Earth orbital mission. Manned CSM/LM operations. Duration 10 days 1 hour.
Apollo 10	5/18/69	SA-505	CM-106 SM-106 LM-4 SLA-13	Lunar orbital mission. Manned CSM/LM operations. Evaluation of LM performance in cislunar and lunar environment, following lunar landing profile. Mission duration 8 days.
Apollo 11	7/16/69	SA-506	CM-107 SM-107 LM-5 SLA-14 EASEP	First manned lunar landing mission. Lunar surface stay time 21.6 hours. One dual EVA (5 man hours). Mission duration 8 days 3.3 hours.
Apollo 12	11/14/69	SA-507	CM-108 SM-108 LM-6 SLA-15 ALSEP	Second manned lunar landing mission. Demonstration of point landing capability. Deployment of ALSEP I. Surveyor III investigation. Lunar surface stay time 31.5 hours. Two dual EVAs (15.5 man hours). Mission duration 10 days 4.6 hours.

Mission	Launch Date	Launch Vehicle	Payload	Description
Apollo 13	4/11/70	SA-508	CM-109 SM-109 LM-7 SLA-16 ALSEP	Planned third lunar landing. Mission aborted at approximately 56 hours due to loss of SM cryogenic oxygen and consequent loss of capability to generate electrical power and water. Mission duration 5 days 22.9 hours.
Apollo 14	1/31/71	SA-509	CM-110 SM-110 LM-8 SLA-17 ALSEP	Third manned lunar landing mission. Selenological inspection, survey and sampling of materials of Fra Mauro Formation. Deployment of ALSEP. Lunar surface stay time 33.5 hours. Two dual EVAs (18.8 man hours). Mission duration 9 days.
Apollo 15	7/26/71	SA-510	CM-112 SM-112 LM-10 SLA-19 LRV-1 ALSEP Subsatellite	Fourth manned lunar landing mission. Selenological inspection, survey and sampling of materials of the Hadley-Apennine Formation. Deployment of ALSEP. Increased lunar stay time to 66.9 hours. First use of Lunar Roving Vehicle and direct TV and voice communications to earth during EVAs. Total distance traversed on lunar surface 27.9 km. Three dual EVAs (37.1 man hours). Mission duration 12 days 7.2 hours.

NASA OMSF MISSION OBJECTIVES FOR APOLLO 16

PRIMARY OBJECTIVES

- Perform selenological inspection, survey, and sampling of materials and surface features in a preselected area of the Descartes region.
- Emplace and activate surface experiments.
- Conduct in-flight experiments and photographic tasks.

Rocco A. Petrone
Apollo Program Director

Date: 29 March 1972

Dale D. Myers
Associate Administrator for
Manned Space Flight

Date: 31 March 1972

MISSION OPERATIONS

The following paragraphs contain a brief description of the nominal launch, flight, recovery, and post-recovery operations. For the second and third months launch opportunities, which may involve a T-24 or T+24 hour launch, there will be a revised plan. Overall mission profile is shown in Figure 1.

LAUNCH WINDOWS

The mission planning considerations for the launch phase of a lunar mission are, to a major extent, related to launch windows. Launch windows are defined for two different time periods: a "daily window" has a duration of a few hours during a given 24-hour period; a "monthly window" consists of a day or days which meet the mission operational constraints during a given month or lunar cycle.

Launch windows are based on flight azimuth limits of 72° to 100° (earth-fixed heading of the launch vehicle at end of the roll program), on booster and spacecraft performance, on insertion tracking, and on lighting constraints for the lunar landing sites.

The Apollo 16 launch windows and associated lunar landing sun elevation angles are presented in Table 1.

TABLE 1
LAUNCH WINDOWS

LAUNCH DATE	WINDOWS* OPEN	WINDOWS* CLOSE	SUN ELEVATION ANGLE
16 April 1972	1254	1643	11.9°
14 May 1972	1217	1601	6.8°
15 May 1972	1230	1609	6.8°
16 May 1972	1238	1613	18.6°
13 June 1972	1050	1423	13.0°
14 June 1972	1057	1426	13.0°
15 June 1972	(Still Under Review)		

* April times are Eastern Standard Time; all others are Eastern Daylight Time

LAUNCH THROUGH TRANSLUNAR INJECTION

The space vehicle will be launched from Pad A of launch complex 39 at the Kennedy Space Center. The boost into a 90-NM earth parking orbit (EPO) will be accomplished by sequential burns and staging of the S-IC and S-II launch vehicle stages and a partial

APOLLO 16
FLIGHT PROFILE

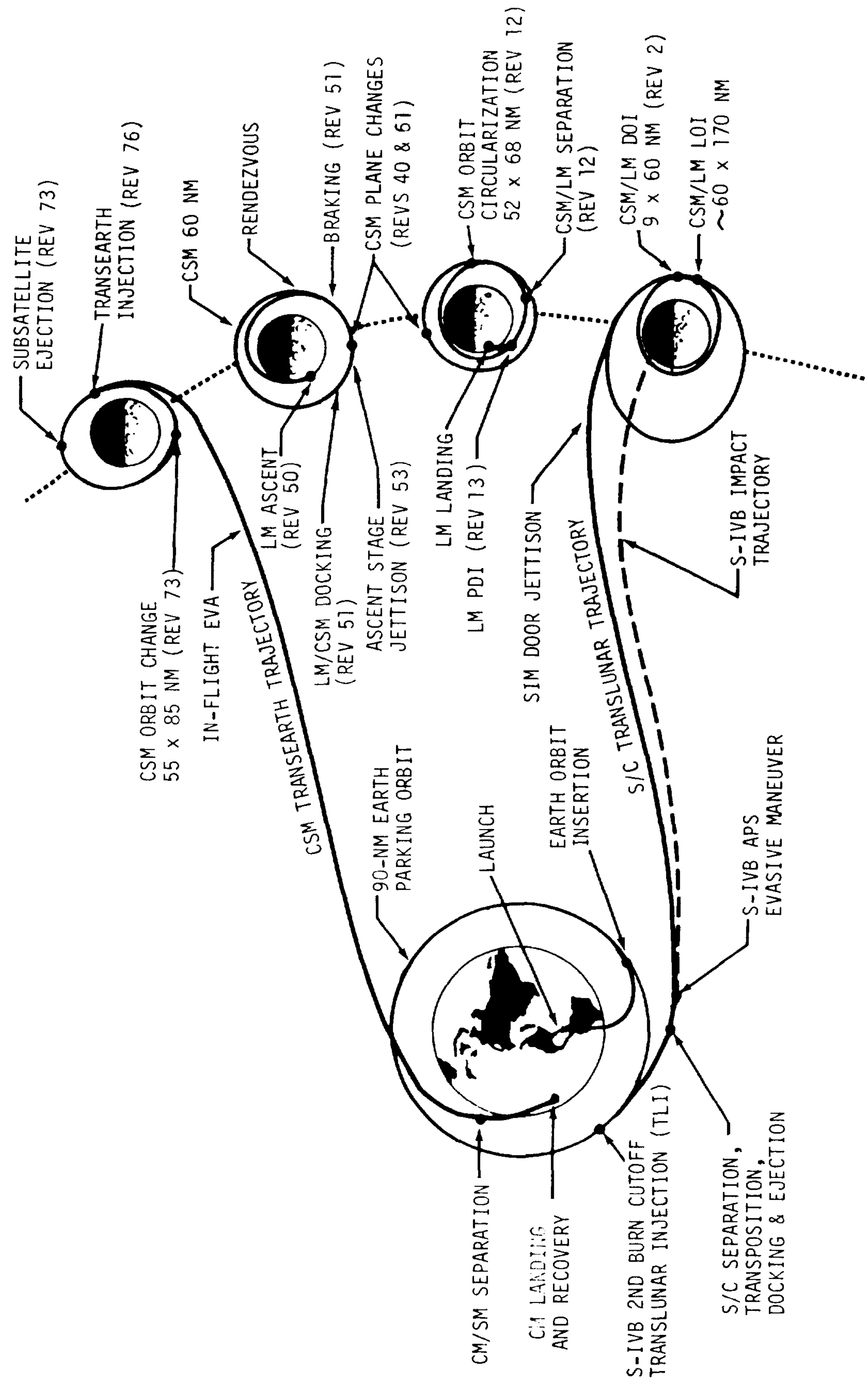


Fig. 1

burn of the S-IVB stage. The S-IVB/instrument unit (IU) and spacecraft will coast in a circular EPO for approximately 1.5 revolutions while preparing for the first opportunity S-IVB translunar injection (TLI) burn, or 2.5 revolutions if the second opportunity TLI burn is required. Both injection opportunities are to occur over the Pacific Ocean. The S-IVB TLI burn will place the S-IVB/IU and spacecraft on a translunar trajectory targeted such that transearth return to an acceptable entry corridor can be achieved with the use of the reaction control system (RCS) during at least 5 hours (7 hours 39 minutes ground elapsed time (GET)) after TLI cutoff. For this mission the RCS capability will actually exist from 51-57 hours GET for the command service module/ lunar module (CSM/LM) combination and from 61-63 hours GET for the CSM only. TLI targeting will permit an acceptable earth return to be achieved using the service propulsion system (SPS) or LM descent propulsion system (DPS) until at least pericynthian plus 2 hours, if lunar orbit insertion (LOI) is not performed.

TRANSLUNAR COAST THROUGH LUNAR ORBIT INSERTION

Within 2 hours after injection the CSM will separate from the S-IVB/IU and spacecraft-LM adapter (SLA) and will transpose, dock with the LM, and eject the LM/CSM from the S-IVB/IU. Subsequently, the S-IVB/IU will perform an evasive maneuver to alter it's circumlunar coast trajectory clear of the spacecraft trajectory.

The spent S-IVB/IU will be impacted on the lunar surface at 2°18'S and 31°42'W providing a stimulus for the Apollo 12, 14, and 15 emplaced seismology experiments. The necessary delta velocity (ΔV) required to alter the S-IVB/IU circumlunar trajectory to the desired impact trajectory will be derived from dumping of residual liquid oxygen (LOX) and burn(s) of the S-IVB/auxiliary propulsion system (APS) and ullage motors. The final maneuver will occur within about 10 hours of liftoff. The IU will have an S-band transponder for trajectory tracking. A frequency bias will be incorporated to insure against interference between the S-IVB/IU and LM communications during translunar coast.

Spacecraft passive thermal control will be initiated after the first midcourse correction (MCC) opportunity and will be maintained throughout the translunar-coast phase unless interrupted by subsequent MCCs and/or navigational activities. The scientific instrument module (SIM) bay door will be jettisoned shortly after the MCC-4 point, about 4.5 hours before LOI.

Multiple-operation covers over the SIM bay experiments and cameras will provide thermal and contamination protection whenever they are not in use.

A retrograde SPS burn will be used for LOI of the docked spacecraft into a 60 x 170-NM orbit, where they will remain for approximately two revolutions.

DESCENT ORBIT INSERTION THROUGH LANDING

The descent orbit insertion (DOI) maneuver, a SPS second retrograde burn, will place the CSM/LM combination into a 60 x 9-NM orbit.

A "soft" undocking will be made during the 12th revolution, using the docking probe capture latches to reduce the imparted $\triangle V$. Spacecraft separation will be executed by the SM RCS, providing a $\triangle V$ of approximately 1 foot per second (fps) radially downward toward the center of the moon. The CSM will circularize its orbit to 60 NM near the end of the 12th revolution. During the 13th revolution the LM DPS will be used for powered descent, which will begin approximately at pericynthian. These events are shown in Figure 2. A lurain profile model will be available in the LM

DOI, SEPARATION, & CSM CIRCULARIZATION

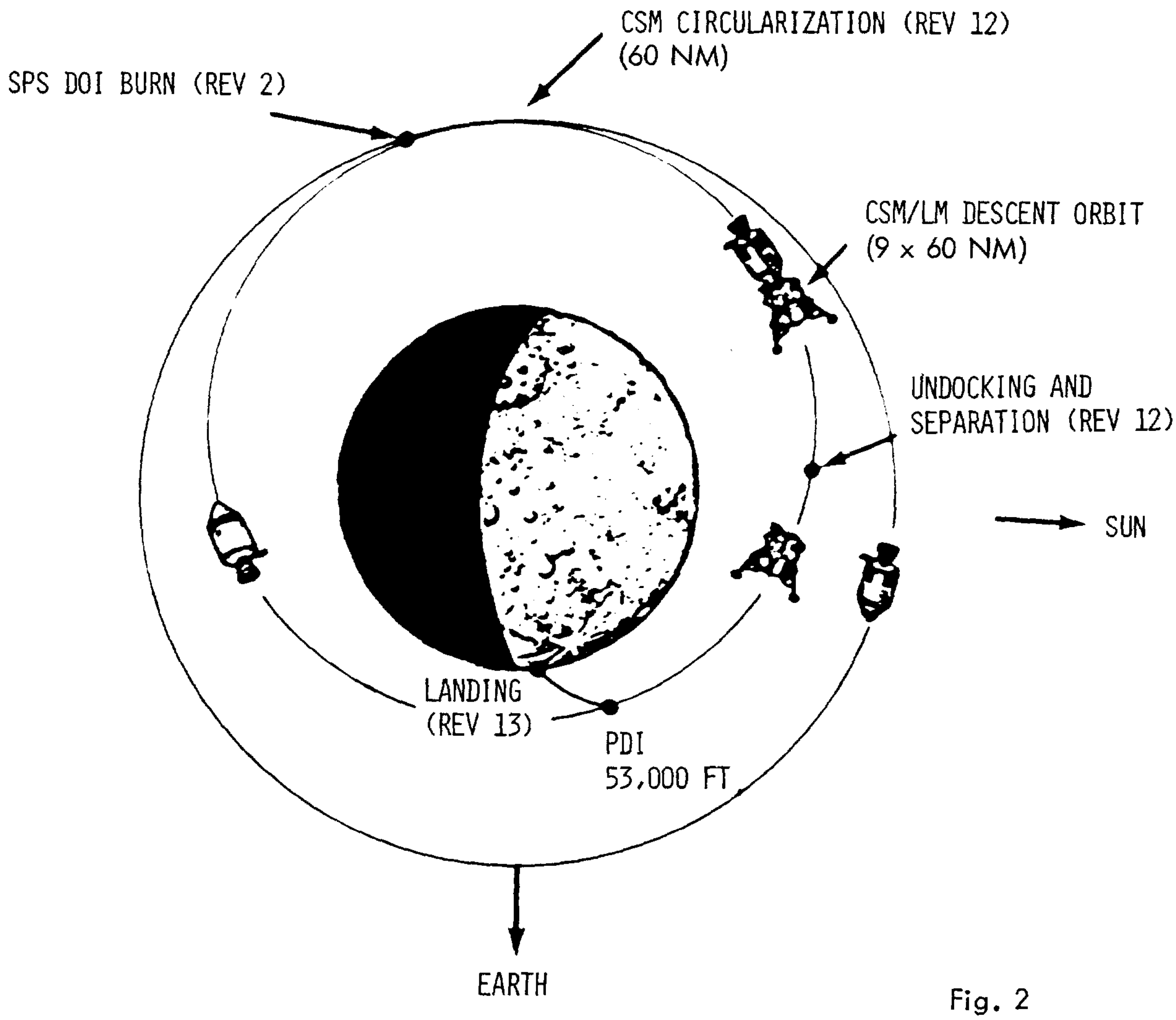


Fig. 2

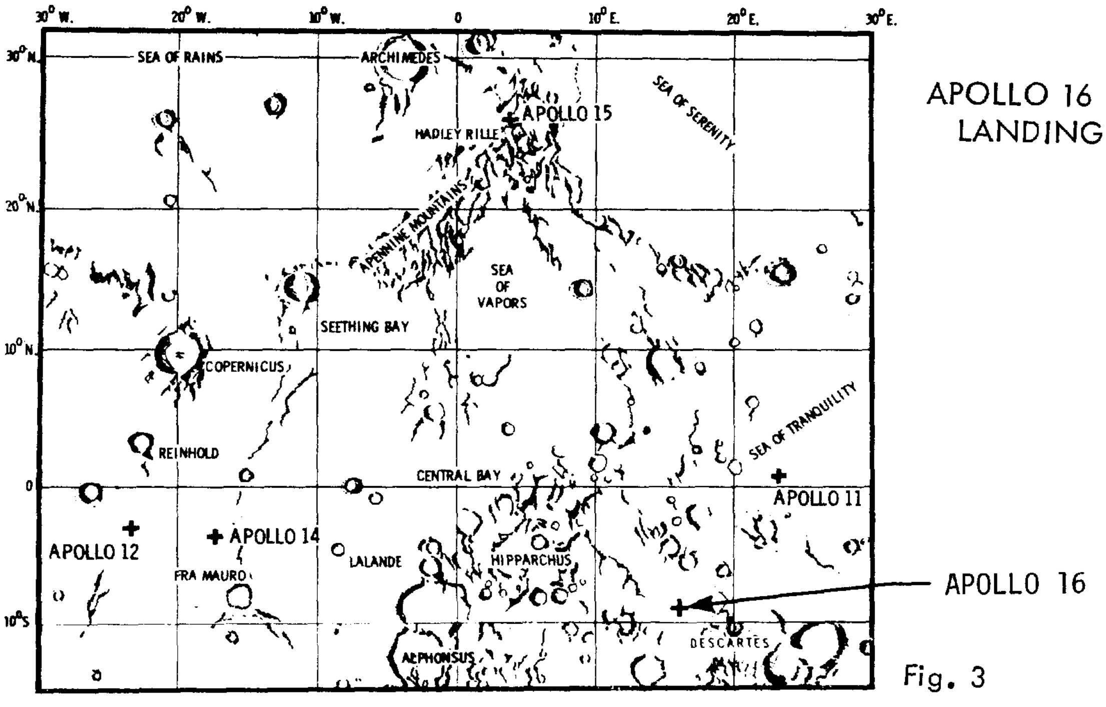
guidance computer (LGC) program to minimize unnecessary LM pitching or thrusting maneuvers. A descent path of 25° will be used during the terminal portion of powered descent (from high gate) to enhance landing site visibility. The automatic vertical descent portion of the landing phase will start at an altitude of about 200 feet at a rate of 5 fps, and will be terminated at touchdown on the lunar surface.

LANDING SITE (DESCARTES REGION)

Descartes is designated as the landing site for the Apollo 16 Mission. The Descartes landing site lies in the central lunar highlands several hundred kilometers west of Mare Nectaris, and in hilly, grooved, and furrowed lurain which is morphologically similar to many terrestrial areas of volcanism. The Descartes area is also the site of extensive development of highland plains-forming material, a geologic unit of widespread occurrence in the lunar highlands.

There are three major units in the area: the first is a constructional unit which continues from the area of the site southward to the crater Descartes itself; the second is a highland unit controlled by the fracture system of Mare Imbrium; and the third unit is relatively flat, smooth, highland plains formation where the landing will be made. Knowledge of the composition, age, and extent of magmatic differentiation in a highland volcanic complex will be particularly important in understanding lunar volcanism and its contribution to the lunar highlands. Comparison of these highland materials with the mare samples of Apollo 11, 12, and 15 and the upland materials collected on Apollo 14 and 15 will provide a basis for conclusions relative to the gross compositional variations and early evolution of the lunar crust.

The planned landing point coordinates are 9°00'01"S, 15°30'59"E (Figure 3).



APOLLO 16
LANDING SITE

Fig. 3

LUNAR SURFACE OPERATIONS

The nominal stay time on the lunar surface is planned for about 73 hours, with the overall objective of optimizing effective surface science time relative to hardware margins, crew duty cycles, and other operational constraints. Photographs of the lunar surface will be taken through the LM cabin window after landing. The nominal extra-vehicular activity (EVA) is planned for three periods of up to 7 hours each. The duration of each EVA period will be based upon real time assessment of the remaining consumables. As in Apollo 15 this mission will employ the lunar roving vehicle (LRV) which will carry both astronauts, experiment equipment, and independent communications systems for direct contact with the earth when out of the line-of-sight of the LM relay system. Voice communication will be continuous and color TV coverage will be provided at each major science stop (Figure 4) where the crew will align the high gain antenna. The ground controllers will then assume control of the TV through the ground controlled television assembly (GCTA) mounted on the LRV. A TV panorama is planned at each major science stop, followed by coverage of the astronauts' scientific activities.

The radius of crew operations will be constrained by the LRV capability to return the crew to the LM in the event of a portable life support system (PLSS) failure or by the PLSS walkback capability in the event of an LRV failure, whichever is the most limiting at any point in the EVA. If a walking traverse must be performed, the radius of operations will be constrained by the buddy secondary life support system (BSLSS) capability to return the crew to the LM in the event of a PLSS failure.

EVA PERIODS

The activities to be performed during each EVA period are described below. Rest periods are scheduled prior to the second and third EVAs and prior to LM liftoff. Traverses performed after arming of the active seismic experiment (ASE) have been planned so as to avoid the line of fire of the ASE mortars. The lunar communications relay unit (LCRU) and the GCTA will be used in conjunction with LRV operations. Television coverage will be provided by the GCTA during each major science stop when using the LRV. The three traverses planned for Apollo 16 are designed for flexibility in selection of science stops as indicated by the enclosed areas shown along traverses II and III (Figure 4).

First EVA Period

The first EVA will include: LM inspection, LRV deployment and checkout, deployment of the far UV camera/spectroscope and cosmic ray detector experiments, and deployment and activation of the Apollo lunar surface experiments package (ALSEP). Television will be deployed as soon as possible in this period for observation of crew activities near the LM (Figure 5). ALSEP deployment will be approximately 300 feet west of the LM (Figure 6). After ALSEP activation the crew will perform a geology traverse (see Figure 4).

DESCARTES LRV TRAVERSES

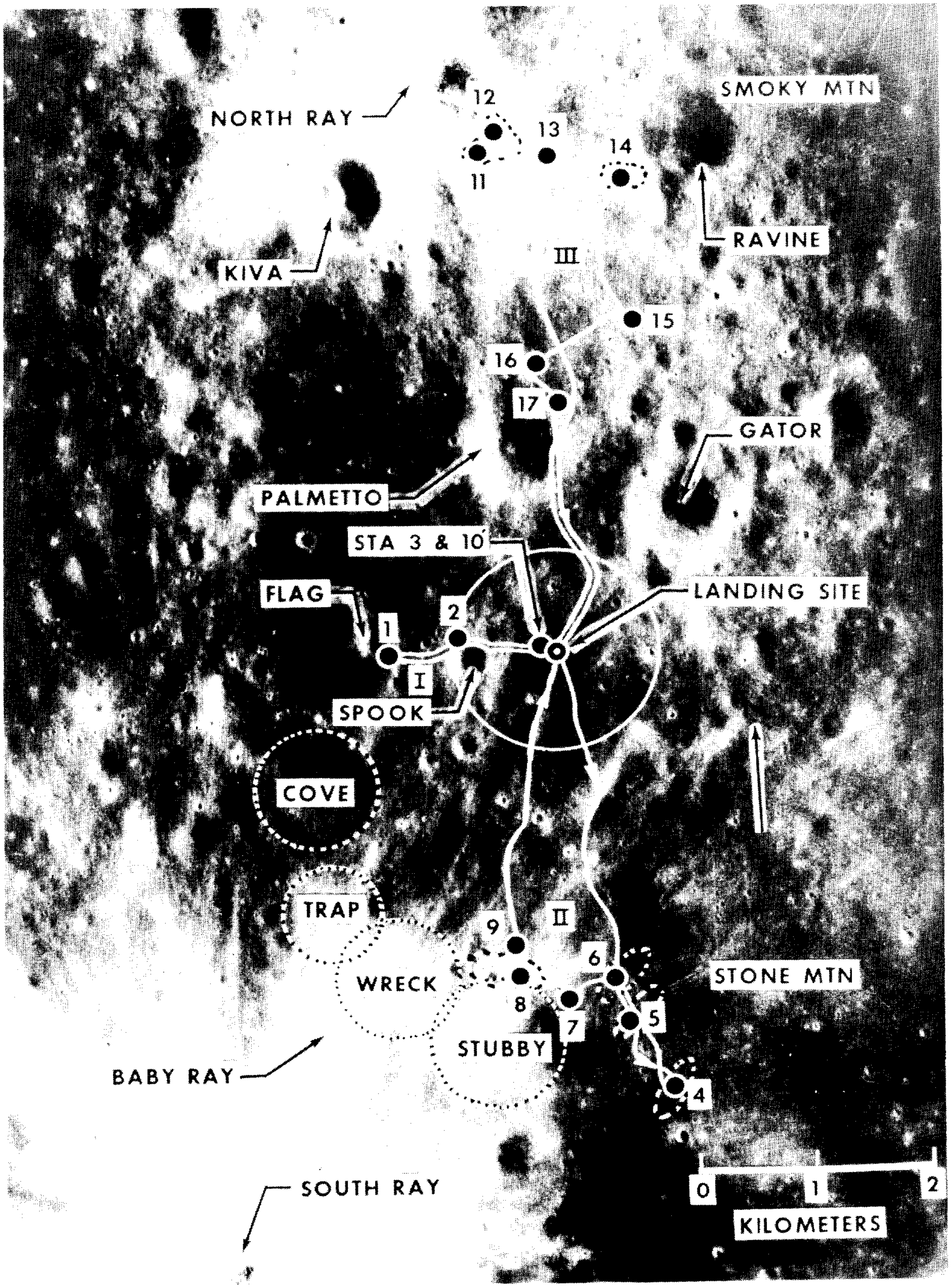


Fig. 4

NEAR LM LUNAR SURFACE ACTIVITY

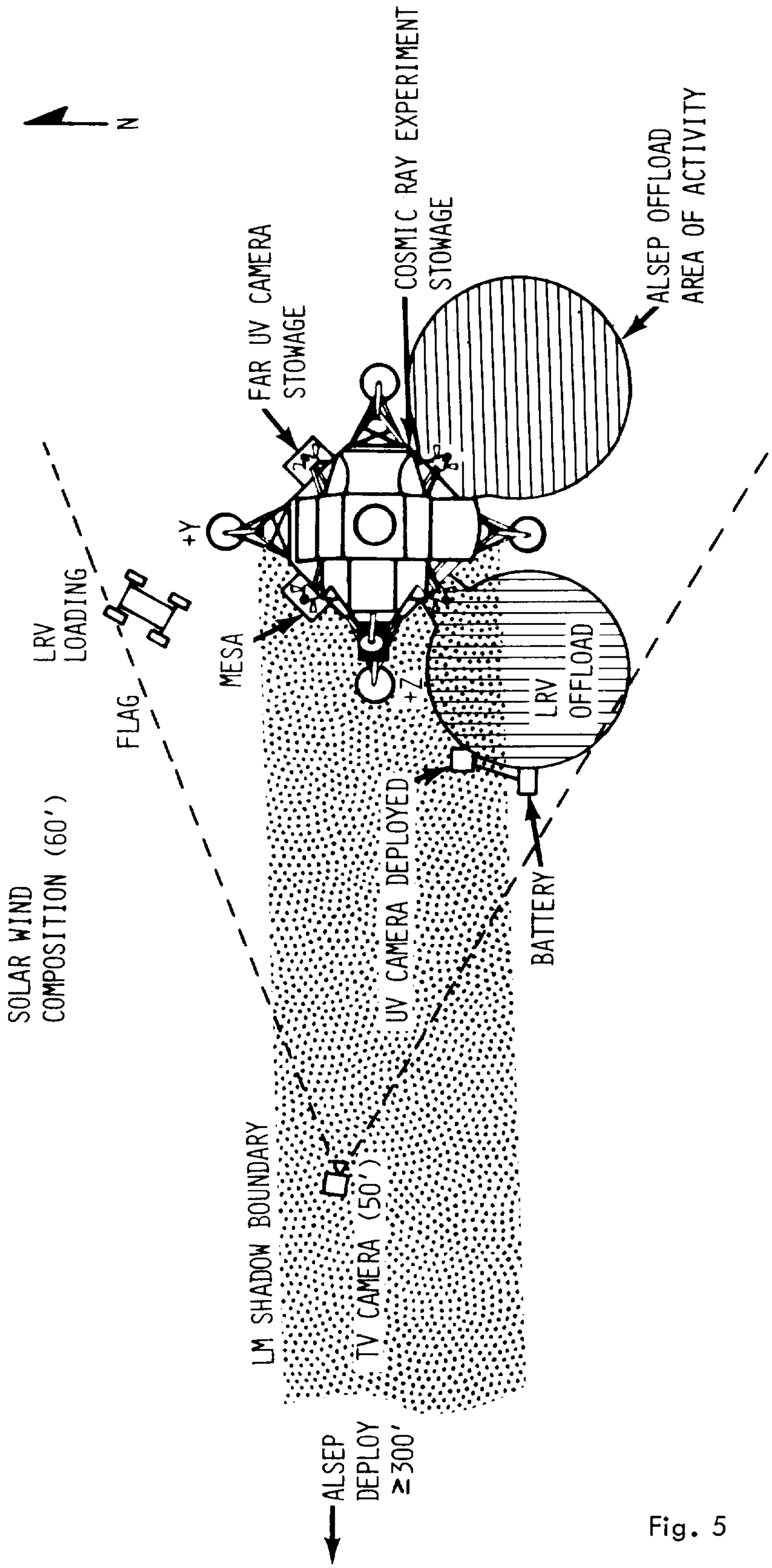


Fig. 5

APOLLO 16 ALSEP DEPLOYMENT

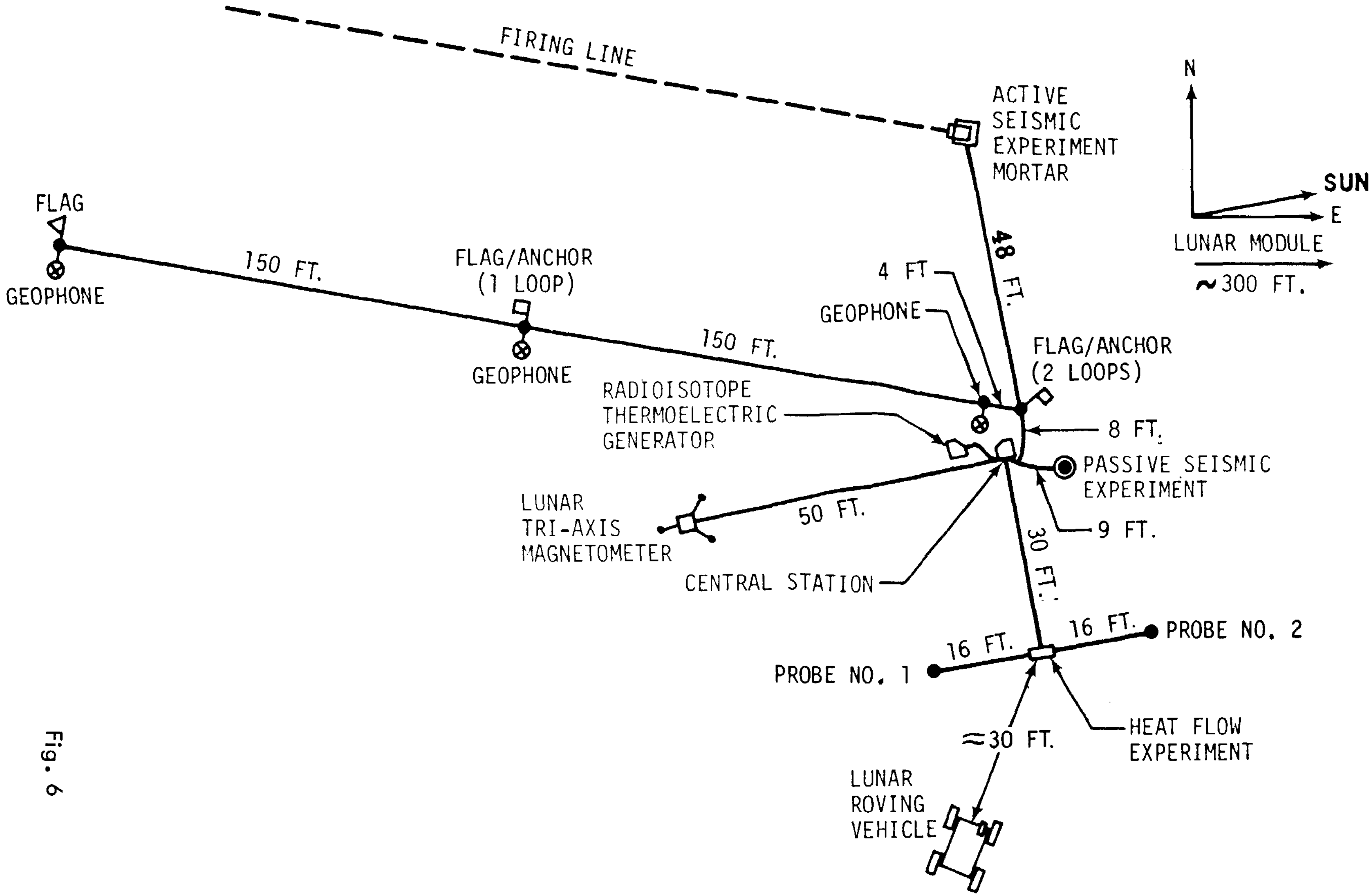


Fig. 6

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The data acquisition camera and Hasselblad cameras, using color film, will be used during the EVA to record lunar surface operations. High resolution photographic survey of surface features will be accomplished with the Hasselblad camera equipped with the 500mm lens. Lunar samples collected will be verbally and photographically documented. Sample return must be assured; therefore, a contingency sample of lunar soil will be collected in the event of a contingency during the EVA, but only if no other soil sample has been collected and is available for return to earth. The planned timeline for all EVA-1 activities is presented in Figure 7.

Second and Third EVA Periods

Traverses in the second and third EVA periods (Figures 8 and 9) are planned to maximize the scientific return in support of the primary objectives. LRV sorties will be planned for flexibility in selecting stops and conducting experiments. Consumables usage will be monitored at Mission Control Center (MCC) to assist in real time traverse planning.

The major portion of the lunar geology investigation (S-059), portable magnetometer (S-198), and the soil mechanics experiment (S-200) will be conducted during the second and third EVAs and will include voice and photographic documentation of sample material as it is collected and descriptions of lurain features. If time does not permit filling the sample containers with documented samples, the crew may fill the containers with samples selected for scientific interest.

The LRV will be positioned at the end of the EVA-3 traverse to enable GCTA-monitored ascent and other TV observations of scientific interest.

LUNAR ORBIT OPERATIONS

The Apollo 16 Mission is the second with the modified Block II CSM configuration. An increase in cryogenic storage provides increased mission duration for the performance of both an extended lunar surface stay time and a lunar orbit science period. The SIM in the SM provides for the mounting of scientific experiments and for their operation in flight.

After the SIM door is jettisoned by pyrotechnic charges and until completion of lunar orbital science tasks, selected RCS thrusters will be inhibited or experiment protective covers will be closed to minimize contamination of experiment sensors during necessary RCS burns. Attitude changes for thermal control and experiment alignment with the lunar surface and deep space (and away from direct sunlight) will be made with the active RCS thrusters. Orbital science activities have been planned at appropriate times throughout the lunar phase of the mission and consist of the operation of five cameras (35mm Nikon, 16mm data acquisition, 70mm Hasselblad, 24-inch panoramic and a 3-inch mapping), a color TV camera, a laser altimeter, a gamma ray spectrometer, X-ray fluorescence equipment, alpha particle spectrometer equipment and mass spectrometer equipment.

APOLLO 16 EVA-1 TIMELINE

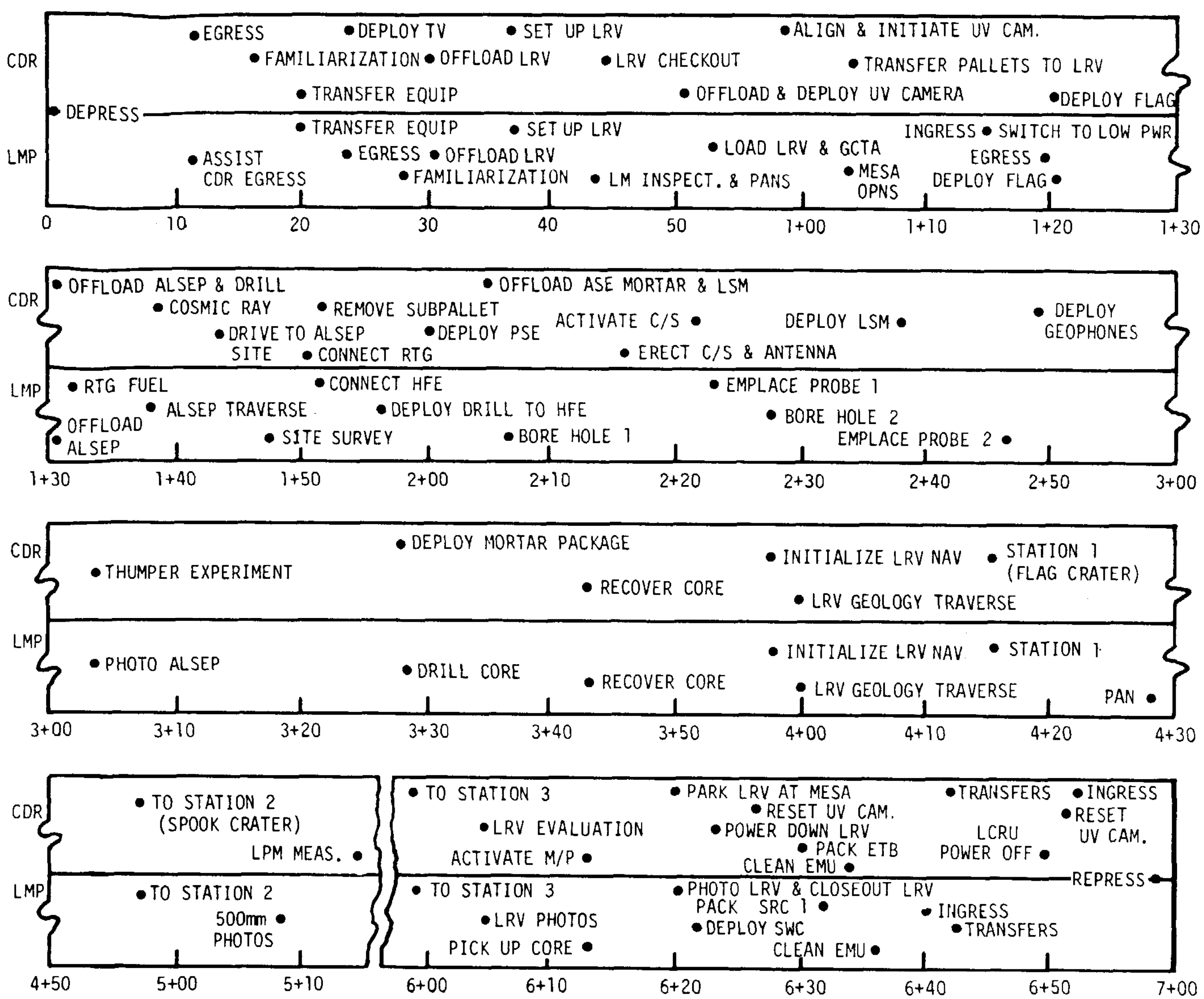

Fig. 7

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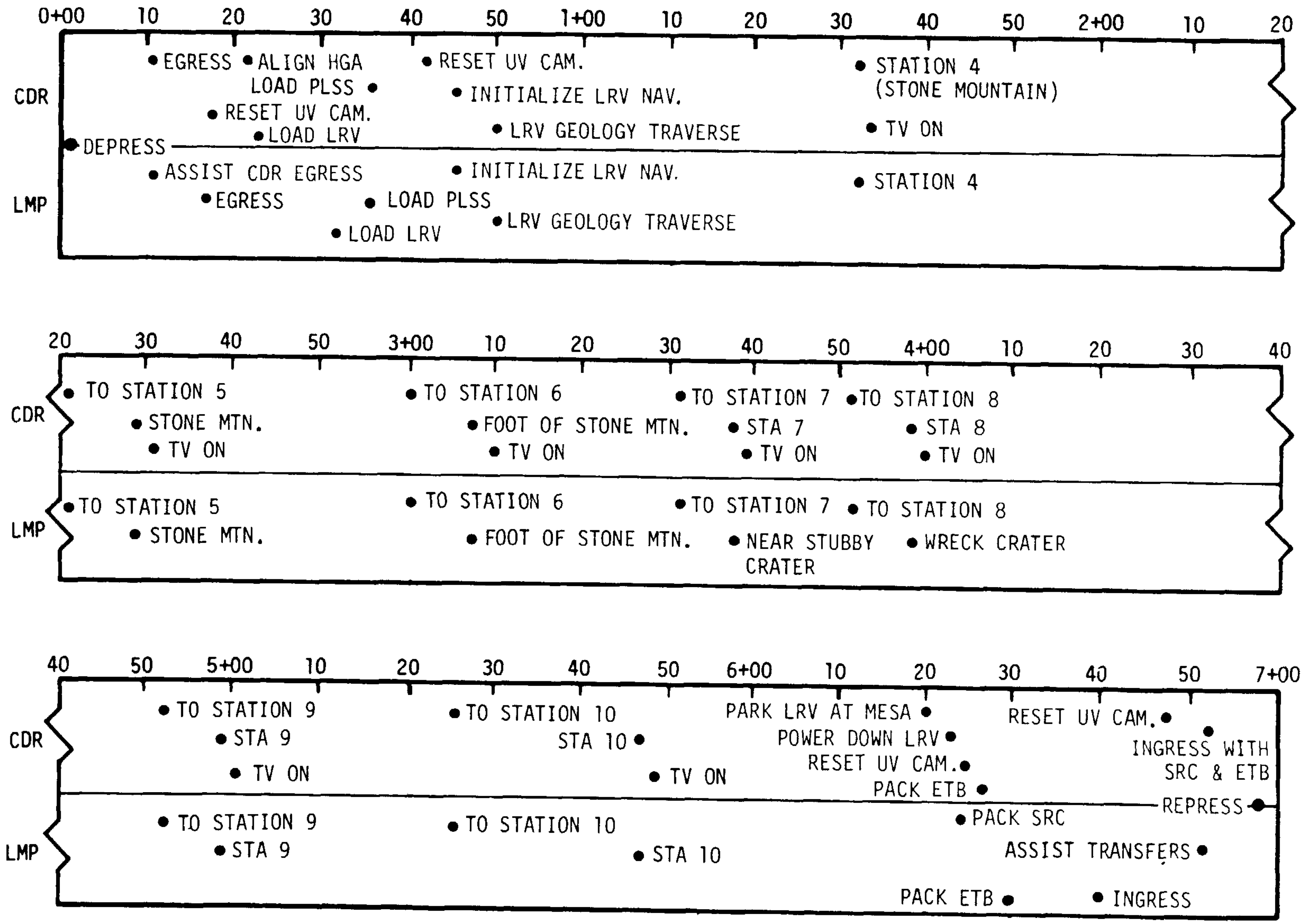
Fig. 8

APOLLO 16 EVA-2 TIMELINE



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APOLLO 16 EVA-3 TIMELINE

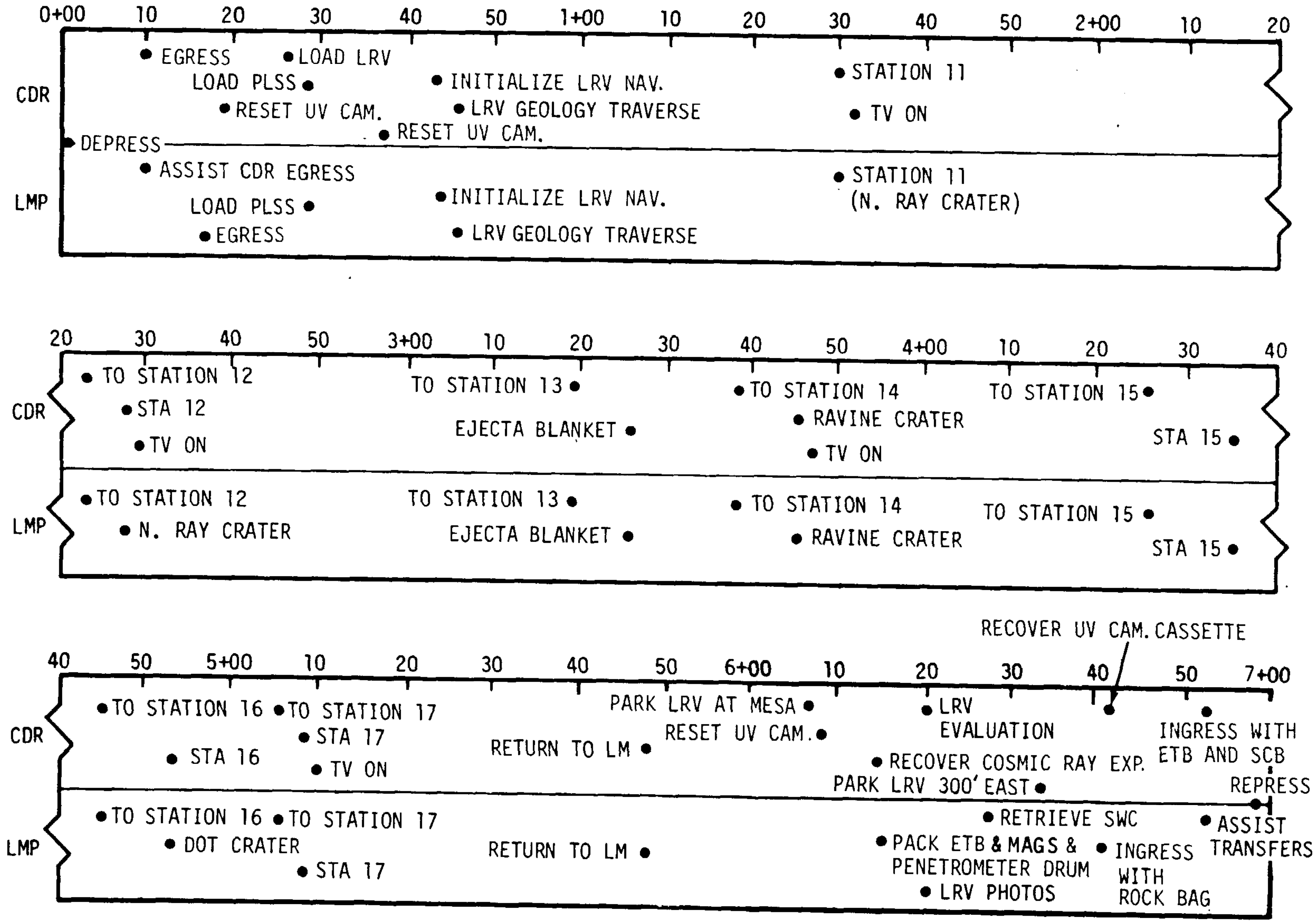

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Fig. 9

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Pre-Rendezvous Lunar Orbit Science

Orbital science operations will be conducted during the 60 x 9-NM orbits after DOI, while in the docked configuration. Orbital science operations will be stopped for the separation and circularization maneuvers performed during the 12th revolution, then restarted after CSM circularization. In the event of a T-24 launch, the additional day in the 60 x 9-NM orbit prior to lunar landing will also be used for orbital science.

The experiments timeline has been developed in conjunction with the surface timeline to provide, as nearly as possible, 16-hour work days and concurrent 8-hour CSM and LM crew sleep periods. Experiment activation cycles are designed to have minimum impact on crew work-rest cycles.

Conduct of orbital experiments and photographic tasks have been planned in consideration of: mass spectrometer and gamma-ray spectrometer boom extend/retract requirements; outgassing, stand-by, and warm-up periods; experiments fields-of-view limitations; and Manned Space Flight Network (MSFN) data collection requirements. Water and urine dumps and fuel cell purges have been planned to avoid conflict with operation cycles. Prior to LM liftoff, the CSM will perform a plane change maneuver to provide the desired coplanar orbit at the time of the LM rendezvous.

LM Ascent, Rendezvous and Jettison

After completion of lunar surface activities and ascent preparations, the LM ascent stage propulsion system (APS) and RCS will be used to launch and rendezvous with the CSM.

The direct ascent rendezvous technique initiated on Apollo 14 and subsequently used on Apollo 15 will be performed. The LM ascent stage liftoff window duration is about 30 seconds and is constrained to keep the perilune above 8 NM. The ascent stage will be inserted into a 48 x 9-NM orbit so that an APS terminal phase initiation (TPI) burn can be performed approximately 47 minutes after insertion. The final braking maneuver will occur about 41 minutes later. The total time from ascent stage liftoff to the final braking maneuver will be about 95 minutes.

Docking will be accomplished by the CSM with RCS maneuvers. Once docked, the two LM crewmen will transfer to the CSM with lunar sample material, exposed films, designated equipment.

The LM ascent stage will be jettisoned and subsequently deorbited to impact on the lunar surface to provide a known stimulus for the emplaced seismic experiment. The impact will be targeted for 9°28'S and 14°58'E, about 23 km from the Apollo 16 ALSEP.

Post-Rendezvous Lunar Orbit Science

A period of orbital science activities will be conducted following LM jettison. If SPS ΔV reserves permit, a plane change maneuver will be performed to increase the orbital inclination by at least 3°. An orbit shaping burn may be performed to insure at least 1 year of orbital lifetime for the subsatellite. The subsatellite will be launched from the SIM in a predetermined orbit.

TRANSEARTH INJECTION THROUGH LANDING

After completion of the post-rendezvous CSM orbital activities, the SPS will perform a posigrade burn to inject the CSM onto the transearth trajectory. The nominal return time will not exceed 110 hours and the return inclination will not exceed 70° with relation to the earth's equator.

During the transearth phase there will be continuous communications coverage from the time the spacecraft appears from behind the moon until shortly prior to entry. MCCs will be made, if required. A 6-hour period, including pre- and post-EVA activities, will be planned to perform an in-flight EVA to retrieve film cassettes from the SIM bay in the SM and to conduct experiment M-191. TV and photographic tasks will be conducted during transearth coast. The CM will separate from the SM 15 minutes before the entry interface. Earth touchdown will be in the mid-Pacific and will nominally occur approximately 12.1 days after launch. Targeted landing coordinates are 5°0'N, 158°40'W.

POST-LANDING OPERATIONS

Flight Crew Recovery

Following splashdown, the recovery helicopter will drop swimmers and life rafts near the CM. The swimmers will install the flotation collar on the CM, attach the life raft, and pass fresh flight suits in through the hatch for the flight crew to don before leaving the CM. The crew will be transferred from the spacecraft to the recovery ship via life raft and helicopter and will return to Houston, Texas, for debriefing.

Quarantine procedures were eliminated prior to Apollo 15; therefore, the mobile quarantine facility will not be used. However, biological isolation garments will be available for use in the event of unexplained crew illness.

CM and Data Retrieval Operations

As a result of the partially collapsed main parachute experienced during the Apollo 15 landing, an attempt will be made to recover the earth landing system main parachutes on this mission. In addition, the CM RCS propellants will not be vented during the Apollo 16 landing in order to preclude possible damage to the parachutes. After flight crew pickup by helicopter, the CM will be retrieved and placed on a dolly aboard the recovery ship, USS TICONDEROGA. The CM RCS helium pressure will be vented and the CM will be stowed near the ship's elevator to insure adequate ventilation. Lunar samples, film, flight logs, etc., will be retrieved for shipment to the Lunar Receiving Laboratory (LRL). The spacecraft will be offloaded from the ship and transported to an area where deactivation of the propellant system will be accomplished. The CM will then be returned to contractor facilities.

ALTERNATE MISSIONS

If an anomaly occurs after liftoff that would prevent the space vehicle from following its nominal flight plan, an abort or an alternate mission will be initiated. An abort will provide for acceptable flight crew and CM recovery in the Atlantic or Pacific Ocean.

An alternate mission is a modified flight plan that results from a launch vehicle, spacecraft, or support equipment anomaly that precludes accomplishment of the primary mission objectives. The purpose of the alternate mission is to provide the flight crew and flight controllers with a plan by which the greatest benefit can be gained from the flight using the remaining systems capabilities.

The two general categories of alternate missions that can be performed during the Apollo 16 Mission are (1) earth orbital and (2) lunar orbital. Both of these categories have several variations which depend upon the nature of the anomaly leading to the alternate mission and the resulting systems status of the LM and CSM. An attempt will be made to launch the subsatellite in all the identified alternate missions. A brief description of these alternate missions is contained in the following paragraphs.

Earth Orbit

In case of no TLI burn, a mission of approximately 6-1/3 days will be conducted to obtain maximum benefit from the scientific equipment aboard. Subsequent to transfer of necessary equipment to the CM, the LM will be deorbited into the Pacific. A photography orbit of 240 x 114 NM will be established with the apogee over the United States to insure optimum SIM bay camera operation. The X-ray fluorescence spectrometer will be operated to investigate galactic X-ray sources. The gamma ray spectrometer will be used to obtain data on the earth's gamma ray albedo and for gamma ray astronomy. The subsatellite will be jettisoned in the highest apogee orbit to insure the longest available lifetime for gathering science data from the particle detectors. Remaining SIM bay experiments will be operated on a non-interference basis to gather engineering data. Film cassettes will be retrieved by EVA on the last day of the mission.

Lunar Orbit

Lunar orbit missions of the following types will be planned if spacecraft systems will enable accomplishment of orbital science objectives in the event a lunar landing is not possible. If the SIM bay cameras are used, film cassettes will be retrieved by EVA during transearth coast. An attempt will be made to optimize orbital ground tracks in order to minimize real time flight planning activities.

CSM/LM (Operable DPS)

The translunar trajectory will be maintained to be within the DPS capability of an acceptable earth return until LOI plus 2 hours in the event LOI is not performed. If it is determined during translunar coast that a lunar landing mission cannot be performed, either the SPS or the LM DPS may be used to perform the LOI-1 maneuver to put the CSM/LM into an appropriate orbit. In the event the SIM bay door is not jettisoned prior to LOI, the LOI-1 maneuver will be performed with the SPS. The LOI-2 maneuver will place the CSM/LM in a 60-NM orbit. The orbital inclination is to be the maximum that is practicable considering total mission ΔV requirements. Orbital science and photographic tasks will be performed for up to approximately 6 days in lunar orbit.

If while in lunar orbit (following a nominal translunar coast and LOI trajectory) it is determined that a lunar landing mission cannot be performed, and the DPS is still available, the DPS will be used to perform a plane change to obtain maximum practicable orbital inclination. Orbital science and photographic tasks will be performed for up to approximately 6 days in lunar orbit.

An SPS capability to perform TEI on any revolution will be maintained.

CSM Alone

In the event the LM is not available following a nominal TLI burn, an SPS MCC-1 maneuver will place the CSM on a trajectory such that an acceptable return to earth can be achieved within the CM RCS capability. LOI will not be performed if the SIM bay door cannot be jettisoned. Orbital science and photographic tasks will be performed in a maximum practicable orbital inclination with the CSM remaining in a 60-NM orbit. The duration in lunar orbit will be up to approximately 6 days.

If, following a nominal LOI maneuver it is determined that the DPS is inoperable, the LM will be jettisoned and an SPS circularization maneuver will be performed to obtain a maximum practicable orbital inclination. The CSM will generally remain in a 60-NM orbit. Orbital science and photographic tasks will be performed for up to approximately 6 days in the lunar orbit.

CSM Alone (From Landing Abort)

In the event the lunar landing is aborted, an orbital science mission will be accomplished by the CSM alone after rendezvous, docking, and LM jettison. The total lunar orbit time will be approximately 6 days.

EXPERIMENTS, DETAILED OBJECTIVES, IN-FLIGHT DEMONSTRATIONS, AND OPERATIONAL TESTS

The technical investigations to be performed on the Apollo 16 Mission are classified as experiments, detailed objectives, in-flight demonstrations, or operational tests:

Experiment — A technical investigation that supports science in general or provides engineering, technological, medical or other data and experience for application to Apollo lunar exploration or other programs and is recommended by the Manned Space Flight Experiments Board (MSFEB) and assigned by the Associate Administrator for Manned Space Flight to the Apollo Program for flight.

Detailed Objective — A scientific, engineering, medical or operational investigation that provides important data and experience for use in development of hardware and/or procedures for application to Apollo missions. Orbital photographic tasks, though reviewed by the MSFEB, are not assigned as formal experiments and will be processed as CM and SM detailed objectives.

In-flight Demonstration — A technical demonstration of the capability of an apparatus and/or process to illustrate or utilize the unique conditions of space flight environment. In-flight demonstration will be performed only on a non-interference basis with all other mission and mission-related activities. Utilization performance, or completion of these demonstrations will in no way relate to mission success.

Operational Test — A technical investigation that provides for the acquisition of technical data or evaluates operational techniques, equipment, or facilities but is not required by the objectives of the Apollo flight mission. An operational test does not affect the nominal mission timeline, adds no payload weight, and does not jeopardize the accomplishment of primary objectives, experiments, or detailed objectives.

EXPERIMENTS

The Apollo 16 Mission includes the following experiments:

Lunar Surface Experiments

Lunar surface experiments are deployed and activated or conducted by the Commander and the Lunar Module Pilot during EVA periods. Those experiments which are part of the ALSEP are so noted.

Lunar Passive Seismology (S-031) (ALSEP)

The passive seismic experiment is designed to monitor lunar seismic activity and to detect meteoroid impacts, free oscillations of the moon, surface tilt (tidal deformations), and changes in the vertical component of gravitational acceleration. The experiment sensor assembly is made up of three orthogonal, long-period seismometers and one vertical, short-period seismometer. The instrument and the near-lunar surface are covered by a thermal shroud.

Lunar Active Seismology (S-033) (ALSEP)

The active seismic experiment is designed to generate and monitor artifically stimulated seismic waves (3 Hz - 250 Hz) in the lunar surface and near subsurface. Naturally occurring seismic waves in the same frequency range will also be monitored on the experiment's emplaced geophones when they are active. Seismic waves will be produced by an astronaut-operated thumper device containing explosive initiators, as well as by an earth-commanded mortar package containing rocket-launched high explosive grenades. The grenades are designed to impact at various ranges from the geophones.

Lunar Tri-axis Magnetometer (S-034) (ALSEP)

The lunar surface magnetometer experiment is designed to measure the magnetic field on the lunar surface to differentiate any source producing the induced lunar magnetic field, to measure the permanent magnetic moment, and to determine the moon's bulk magnetic permeability during traverse of the neutral sheet in the geomagnetic tail. The experiment has three sensors, each mounted at the end of a 3-foot long arm, which are first oriented parallel to obtain the field gradient and thereafter orthogonally to obtain total field measurements.

Lunar Heat Flow (S-037) (ALSEP)

The heat flow experiment is designed to determine the net lunar heat flux and the values of thermal parameters in the first 2.5 meters of the moon's crust. The experiment has two sensor probes placed in bore holes drilled with the Apollo lunar surface drill (ALSD).

Lunar Geology Investigation (S-059)

The lunar geology experiment is designed to provide data for use in the interpretation of the geological history of the moon in the vicinity of the landing site. The investigation will be carried out during the planned lunar surface traverses and will utilize astronaut descriptions, camera systems, hand tools, core tubes, the ALSD, and sample containers. The battery-powered ALSD will be used to obtain core samples to a maximum depth of about 3 meters. There are two major aspects of the experiment:

Documented Samples — Rock and soil samples representing different morphological and petrologic features will be described, photographed, and collected in individual pre-numbered bags for return to earth. This includes comprehensive samples of coarse fragments and fine lunar soil to be collected in pre-selected areas. Documented samples are the highest priority tasks in the experiment because they support many sample principal investigators in addition to lunar geology.

Geological Description and Special Samples — Descriptions and photographs of the field relationships of all accessible types of lunar features will be obtained. Special samples, such as core tube samples, will be collected and documented for return to earth.

Solar Wind Composition (S-080)

The solar wind composition experiment is designed to measure the isotopic composition of noble gases in the solar wind, at the lunar surface, by entrapment of particles on an aluminum and platinum foil sheet. A staff and yard arrangement is used to deploy the foil and maintain its plane perpendicular to the sun's rays. After return to earth, a spectrometric analysis of the particles entrapped in the foil allows quantitative determination of the helium, neon, argon, krypton, and xenon composition of the solar wind.

Cosmic Ray Detector (Sheets) (S-152)

The cosmic ray experiment is designed to measure, at the lunar surface, the flux, energy, spectrum, and the isotopic and charge distribution of solar cosmic rays heavier than helium, especially the abundant elements from carbon to iron, in the energy range up to 100 Mev/nucleon.

The instrument package consists of four types of detector material mounted on a panel: lexan polycarbonate plastics, aluminum foil, feldspar and pyroxene crystals, and mica sheets. This panel, which is bolted to the side of the LM, is exposed by the crew during the lunar stay time. At the end of the lunar surface mission the panel is returned to earth for detailed analysis.

Portable Magnetometer (S-198)

The portable magnetometer experiment is designed to measure the magnetic field at several points along a lunar surface traverse. The instrument is a fluxgate magnetometer having two ranges: ±50 gamma and ±100 gamma, with a resolution of 1 gamma. The tripod mounted instrument is connected by a 50-foot cable to a hand-held meter. Values along three orthogonal axes will be read by the astronaut and transmitted to earth over the voice communications link.

Soil Mechanics Experiment (S-200)

The soil mechanics experiment is designed to obtain data on the mechanical properties of the lunar soil from the surface to depths of tens of centimeters.

Data are derived from LM landing, flight crew observations and debriefings, examination of photographs, analysis of lunar samples, and astronaut activities using the Apollo hand tools. Experiment hardware includes an astronaut-operated self-recording penetrometer.

Far UV Camera/Spectroscope (S-201)

The far UV experiment is designed to measure the amount and excitation of hydrogen in nearby and distant regions of the universe (lunar surface, geocorona, solar wind, interstellar wind, and galaxy clusters) by obtaining imagery and spectroscopic data in the 500 to 1555Å range. Of particular interest is the Lyman-alpha line at 1216Å. The experiment will add to understanding the earth's magnetosphere, check the density of interplanetary and interstellar hydrogen clouds, and provide evidence of intergalactic hydrogen, as well as provide information on the suitability of a lunar-based astrophysical observatory.

The instrument is a tripod-mounted electronographic Schmidt camera with a lithium fluoride corrector plate, an objective grating, and Lyman-alpha interference filter. Film will be returned to earth for processing and analysis.

In-Flight Experiments

In-flight experiments may be conducted during all phases of the mission. They are performed within the CM, from the SIM located in sector I of the SM, and by a subsatellite launched in lunar orbit.

Gamma-Ray Spectrometer (S-160) (SIM)

The gamma-ray spectrometer experiment is designed to determine the lunar surface concentration of naturally occuring radioactive elements and rock-forming elements. This will be accomplished by the measurement of the lunar surface natural and induced gamma radiation while in orbit and by the monitoring of galactic gamma-ray flux during transearth coast.

The spactrometer detects gamma rays and discriminates against charged particles in the energy spectrum from 0.1 to 10 Mev. The instrument is encased in a cylindrical thermal shield which is deployed on a boom from the SIM for experiment operation.

X-Ray Fluorescence (S-161) (SIM)

The X-ray spectrometer experiment is designed to determine the concentration of major rock-forming elements in the lunar surface. This is accomplished by monitoring the fluorescent X-ray flux produced by the interaction of solar X-rays with surface material and the lunar surface X-ray albedo. The X-ray spectrometer, which is integrally packaged with the alpha-particle spectrometer, uses three sealed proportional counter detectors with different absorption filters. The direct solar X-ray flux is detected by the solar monitor, which is located 180° from the SIM in the SM sector IV. An X-ray background count is performed on the lunar darkside. Selected galactic sources are sampled during transearth coast.

Alpha-Particle Spectrometer (S-162) (SIM)

The alpha-particle experiment is designed to locate sources and to establish gross radon evolution rates, which are functions of the natural and isotopic radioactive material concentrations in the lunar surface. This will be accomplished by measuring the lunar surface alpha-particle emissions in the energy spectrum from 4.7 to 9.3 Mev.

The instrument employs 10 surface barrier detectors. The spectrometer is mounted in an integral package with the X-ray spectrometer.

S-Band Transponder (S-164) (CSM/LM)

The S-band transponder experiment is designed to detect variations in the lunar gravity field caused by mass concentrations and deficiencies and to establish gravitational profiles of the ground tracks of the spacecraft.

The experiment data are obtained by analysis of the S-band Doppler tracking data for the CSM and LM in lunar orbit. Minute perturbations of the spacecraft motion are correlated to mass anomalies in the lunar structure.

Mass Spectrometer (S-165) (SIM)

The mass spectrometer experiment is designed to obtain data on the composition and distribution of the lunar atmosphere constituents in the mass range from 12 to 66 amu. The experiment will also be operated during transearth coast to obtain background data on spacecraft contamination.

The instrument employs ionization of constituent molecules and subsequent collection and identification by mass unit analysis. The spectrometer is deployed on a boom from the SIM during experiment operation.

Bistatic Radar (S-170) (CSM)

The bistatic radar experiment is designed to obtain data on the lunar bulk electrical properties, surface roughness, and regolith depth to 10-20 meters. This experiment will determine the lunar surface Brewster angle, which is a function of the bulk dielectric constant of the lunar material.

The experiment data are obtained by analysis of bistatic radar echos reflected from the lunar surface and subsurface, in correlation with direct downlink signals. The S-band and VHF communications systems, including the VHF omni and S-band high gain or omni antennas, are utilized for this experiment.

UV Photography — Earth and Moon (S-177) (CM)

This experiment is designed to photograph the moon and the earth in one visual and three UV regions of the spectrum. The earth photographs will define correlations between UV radiation and known planetary conditions. These analyses will form analogs for use with UV photography of other planets. The lunar photographs will provide additional data on lunar surface color boundaries and fluorescent materials.

Photographs will be taken from the CM with a 70mm Hasselblad camera equipped with four interchangeable filters with different spectral response. Photographs will be taken in earth orbit, translunar coast, lunar orbit, and transearth coast.

Subsatellite

The subsatellite is a hexagonal prism which uses a solar cell power system, an S-band communications system, and a storage memory data system. A solar sensor is provided for attitude determination. The subsatellite is launched from the SIM into lunar orbit and is spin-stabilized by three deployable, weighted arms. The following three experiments are performed by the subsatellite:

S-Band Transponder (S-164) (Subsatellite) — Similar to the S-band transponder experiment conducted with the CSM and LM, this experiment will detect variations in the lunar gravity field by analysis of S-band signals. The Doppler effect variations caused by minute perturbations of the subsatellite's orbital motions are indicative of the magnitudes and locations of mass concentrations in the moon.

Particle Shadows/Boundary Layer (S-173) (Subsatellite) — This experiment is designed to monitor the electron and proton flux in three modes: interplanetary, magnetotail, and the boundary layer between the moon and the solar wind.

The particle experiment uses five curved plate particle detectors and two solid state telescopes to measure solar wind plasma (electrons in two ranges, 0-14 kev and 20-320 kev, and protons 0.05-2.0 Mev).

Magnetometer (S-174) (Subsatellite) — The subsatellite magnetometer experiment is designed to determine the magnitude and direction of the interplanetary and earth magnetic fields in the lunar region.

The biaxial magnetometer is located on one of the three subsatellite deployable arms. This instrument is capable of measuring magnetic field intensities in two ranges, 0 ± 25 gammas and 0 ± 100 gammas.

Gegenschein from Lunar Orbit (S-178) (CM)

The gegenschein experiment is designed to photograph the Moulton point region, an analytically defined null gravity point of the earth-sun line behind the earth. These photographs will provide data on the relationship of the Moulton point and the gegenschein (an extended light source located along the earth-sun line behind the earth). These photographs may provide evidence as to whether the gegenschein is attributable to scattered sunlight from trapped dust particles at the Moulton point.

Microbial Response in Space Environment (M-191)

The microbial response experiment is designed to determine the type and degree of alteration produced in selected biological systems when exposed to various types of radiation in a space environment. A self-contained microbial environment exposure device (MEED) will maintain representative types of microorganisms for exposure to space radiation for a specified period of time near the end of the transearth coast EVA. The MEED will be returned to earth for laboratory analysis of the exposed microorganisms.

Other Experiments

Additional experiments assigned to the Apollo 16 Mission which are completely passive are discussed in this section only. Completely passive connotes no crew activities are required during the mission to perform these experiments.

Apollo Window Meteoroid (S-176) (CM)

The objective of the Apollo window meteoroid experiment is to obtain data on the cislunar meteoroid flux of mass range 10^{-12} grams. The returned CM windows will be analyzed for meteoroid impacts by comparison with a preflight photomicroscopic window map.

Bone Mineral Measurement (M-078)

The bone mineral experiment is designed to determine the occurrence and degree of bone mineral changes in the Apollo crewmen, which might result from exposure to the weightless condition; and whether exposure to short periods of 1/6 g alters these changes. At selected pre- and post-flight times, the bone mineral content of the three Apollo crewmen will be determined using X-ray absorption techniques. The radius and ulna (bones of the forearm) and os calcis (heel) are the bones selected for bone mineral content measurements.

Biostack (M-211)

The biostack experiment is designed to study the interaction of biologic systems with the heavy particles of galactic cosmic radiation. Dormant biological systems will be sandwiched or stacked alternately between different physical detectors of heavy particle tracks. Post-flight analyses will correlate individual incident particles with the biological effects.

DETAILED OBJECTIVES

Following is a brief descritpion of each of the launch vehicle and spacecraft detailed objectives planned for this mission.

Launch Vehicle Detailed Objectives

Impact the expended S-IVB/IU in a preselected zone on the lunar surface under nominal flight profile conditions to stimulate the ALSEP passive seismometers.

Post-flight determination of actual S-IVB/IU point of impact within 5 km, and time of impact within 1 second.

Spacecraft Detailed Objectives

Evaluate LRV operational characteristics in the lunar environment.

Obtain SM high resolution panoramic and high quality metric lunar surface photographs and altitude data from lunar orbit to aid in the overall exploration of the moon.

Obtain CM photographs of lunar surface features of scientific interest and of low brightness astronomical and terrestrial sources.

Record visual observations of farside and nearside lunar surface features and processes to complement photographs and other remote-sensed data.

Obtain more definitive information on the characteristics and causes of visual light flashes.

Obtain data concerning exterior contamination induced by and associated with manned spacecraft.

Demonstrate that the improved gas/water separator can deliver gas-free water.

Evaluate the use of the improved fecal collection bag.

Determine the function of the Skylab food packages.

Evaluate the differences, correlation and relative consistency between ground-based and lunar surface task dexterity and locomotion performance.

Obtain data to support an understanding of the degree of body fluid and electrolyte disturbance during weightlessness.

Obtain data from subsatellite tracking for investigating new navigation techniques.

Obtain data via LM voice and data relay to provide a better understanding of the capability to transmit voice and PLSS data from extravehicular communications-1 (EVC-1) to MSFN via the LM in case of a LCRU failure during LRV traverses.

IN-FLIGHT DEMONSTRATION

The in-flight demonstration described below will be performed by the crew on a non-interference basis, during translunar coast.

Electrophoretic Separation

This demonstration will show the feasibility of separating mixtures of biological molecules by electrophoresis in a liquid medium. A comparison will be made of the separation resolution obtained in simple electrophoresis cells under weightless conditions and on earth.

This demonstration will not be flown for the May and June T-24 hour launch opportunities. In the event there is a scrub from a T-24 launch date and a rapid turnaround to a T-0 or T+24 hour launch opportunity, the electrophoretic separation demonstration will be installed.

OPERATIONAL TEST

The following significant operational test will be performed in conjunction with the Apollo 16 Mission.

Acoustic Measurement

The noise levels of the Apollo 16 space vehicle during launch and the CM during entry into the atmosphere will be measured in the Atlantic launch abort area and the Pacific recovery area, respectively. The data will be used to assist in developing high-altitude, high-Mach number, accelerated flight sonic boom prediction techniques. The Manned Spacecraft Center (MSC) will conduct planning, scheduling, test performance, and reporting of the test results. Personnel and equipment supporting this test will be located aboard secondary recovery ships, the primary recovery ship, and at Fanning Island uprange from the prime recovery site.

MISSION CONFIGURATION AND DIFFERENCES

MISSION HARDWARE AND SOFTWARE CONFIGURATION

The Saturn V Launch Vehicle and the Apollo Spacecraft for the Apollo 16 Mission will be operational configurations.

CONFIGURATION	DESIGNATION NUMBERS
Space Vehicle	AS-511
Launch Vehicle	SA-511
First Stage	S-IC-11
Second Stage	S-II-11
Third Stage	S-IVB-511
Instrument Unit	S-IU-511
Spacecraft-LM Adapter	SLA-20
Lunar Module	LM-11
Lunar Roving Vehicle	LRV-2
Service Module	SM-113
Command Module	CM-113
On-board Programs	
Command Module	Colossus 3
Lunar Module	Luminary 1F
Experiments Package	Apollo 16 ALSEP
Launch Complex	LC-39A

CONFIGURATION DIFFERENCES

The following summarizes the significant configuration differences associated with the AS-511 Space Vehicle and the Apollo 16 Mission:

Spacecraft

Command/Service Module

Replaced 42-second timer with 61-second timer in the RCS control box.	Extend Mode 1-A abort sequence to T+61 seconds to reduce possible hazard of land landing with pressurized propellant tanks.
Strengthened meter glass.	Installed transparent Teflon shields to strengthen meter glass and to retain glass particles in case of breakage.

Installed Inconel parachute links in place of nickel plated links.	Reduced probability of parachute riser link failures due to flaws in links.
Replaced selected early series switches with 400 series switches	Reduced the possibility of switch failure by inspection and replacement as required.
Crew Systems	
Modified swage fitting in suit assembly.	Redesigned swage fitting at front termination of crotch and thigh pulling cables to provide greater freedom of movement and reliability.
Lunar Module	
Descent stage batteries modified.	Installation of Teflon separators between cells and battery case to prevent adhesion and cell case cracking. Also, increased thickness of plate tabs. Increased electrical capacity.
Installed battery coolant bypass to maximize capacity	Addition of Glycol shutoff valve to increase battery temperature, if required, to maximize electrical capacity.
Strengthened meter glass.	Added an exterior glass doubler to the range/range rate meter window to reduce stress. Added tape and particle shield as required to other meters.
SLA	
Changed ordnance adhesive in pyro train.	Replaced potting compound (DC30-121) with GE-577 RTV to avoid a lead acetate reaction.
LRV	
Improved seat belts on LRV.	New stiffer seatbelts were installed to eliminate adjustment and latching problems.

Launch Vehicle

S-IC

Added four retro-rocket motors.	Added four retro-rocket motors (previously deleted for Apollo 15) to improve S-IC/S-II separation characteristics.

S-II

Modified S-II structure.	Increased factor of safety from 1.3 to 1.4. Improved POGO stability.
Modified S-II engines start/cutoff circuitry.	Eliminated signle point relay failure modes in start/cutoff circuitry.

S-IVB

Installed 2-ply fuel and LOX feedline bellows.	Vendor change from stainless steel products duct to 2-ply solar duct.

IU

Modified LVDC to distinguish between failures of lower or upper engines.	LVDC modification provides indication of which engine has failed and initiates proper abort guidance program.
Redesigned command decoder.	Added solder joint stress relief to eliminate solder joint cracks for improved reliability.

Support Equipment

Ground/Electrical

Added redundant IU umbilical paths and logic changes for critical functions.	Reduced the possibility of an undesired S-IC/F-1 engine shutdown or failure to shutdown when desired.
Added redundant hardware command line through S-IC umbilical for each F-1 engine start control valve.	Minimized the possibility of an engine failing to start or run due to an open circuit through the umbilical.

TV AND PHOTOGRAPHIC EQUIPMENT

Standard and special-purpose cameras, lenses, and film will be carried to support the objectives, experiments, and operational requirements. Table 2 lists the TV and camera equipments and shows their stowage locations.

Table 2

Nomenclature	CSM at Launch	LM at Launch	CM to LM	LM to CM	CM at Entry
TV, Color, Zoom Lens (Monitor with CM System)	1	1			1
Camera, Data Acquisition, 16mm	1	1			1
Lens - 10mm	1	1			1
- 18mm	1				1
- 75mm	1				1
Film Magazines	13				13
Camera, 35mm Nikon	1				1
Lens - 55mm	1				1
Cassette, 35mm	9				9
Camera, 16mm		1			
Battery Operated (Lunar Surface)					
Lens - 10mm		1			
Film Magazines	8		8	8	8
Camera, Hasselblad, 70mm	1				1
Electric					
Lens - 80mm	1				1
- 250mm	1				1
- 105mm UV (4 band-pass filters)	1				1
Film Magazines	7				7
Film Magazine, 70mm UV	1				1
Camera, Hasselblad Electric Data (Lunar Surface)		2			
Lens - 60mm		2			
Film Magazines	11		11	11	11
Polarizing Filter		1			
Camera, 24-in Panoramic (In SIM)	1				
Film Magazine (EVA Transfer)	1				1
Camera, Lunar Surface Electric		1			
Lens - 500mm		1			
Film Magazines	2		2	2	2
Camera, 3-in Mapping Stellar (SIM)	1				
Film Magazine Containing 5-in Mapping and 35mm Stellar Film (EVA Transfer)	1				1
Camera, Ultraviolet, Lunar Surface		1			
Film Magazine, UV, LS		1		1	1

FLIGHT CREW DATA

PRIME CREW (Figure 10)

Commander: John W. Young (Captain, USN)

Space Flight Experience: Captain Young was selected as an astronaut by NASA in September 1962.

Captain Young was Command Module Pilot for the Apollo 10 Mission, which included all phases of a lunar mission except the final minutes of an actual lunar landing.

He also served as pilot for the Gemini 3 Mission and Commander of the Gemini 10 Mission.

Captain Young has logged more than 267 hours in space.

Command Module Pilot: Thomas K. Mattingly, II (Lieutenant Commander, USN)

Space Flight Experience: Lieutenant Commander Mattingly is one of 19 astronauts selected by NASA in April 1966. He served as a member of the support crews for the Apollo 8 and 11 Missions.

He was selected as the Command Module Pilot for Apollo 13. However, he had been exposed to German measles and was replaced by John L. Swigert, Jr. 72 hours before Apollo 13 liftoff.

Lieutenant Commander Mattingly has been on active duty since 1960.

Lunar Module Pilot: Charles M. Duke, Jr. (Lieutenant Colonel, USAF)

Space Flight Experience: Lieutenant Colonel Duke was selected as an astronaut by NASA in April 1966. He served as backup Lunar Module Pilot for the Apollo 15 Mission.

Lieutenant Colonel Duke has been on active duty since graduating from the U.S. Naval Academy in 1957.

APOLLO 16 PRIME CREW

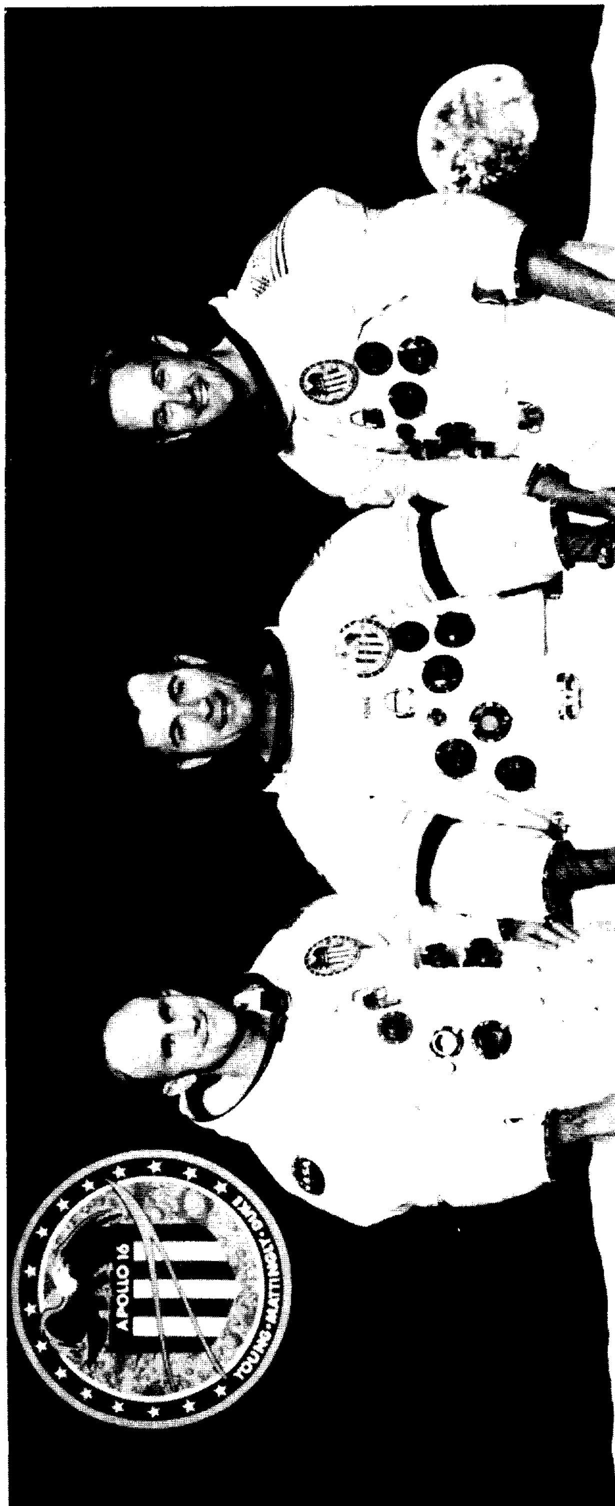


Fig. 10

BACKUP CREW

Commander: Fred W. Haise, Jr. (Mr.)

Space Flight Experience: Mr. Haise was selected as an astronaut by NASA in April 1966. He served as a member of the backup crews for Apollo 8 and 11 Missions.

He was the Lunar Module Pilot for the Apollo 13 Lunar Landing Mission which was modified in flight to a lunar fly-by mission due to SM cryogenic oxygen system anomalies.

He has logged 142 hours 54 minutes in space.

Command Module Pilot: Stuart A. Roosa (Lieutenant Colonel, USAF)

Space Flight Experience: Lieutenant Colonel Roosa was assigned to the astronaut crew by NASA in April 1966. He was a member of the astronaut support crew for the Apollo 9 flight and Command Module Pilot for the Apollo 14 Lunar Landing Mission.

He has spent 216 hours 42 minutes in space.

Lunar Module Pilot: Edgar D. Mitchell (Captain, USN)

Space Flight Experience: Captain Mitchell was in the astronaut group selected in April 1966. He served as a member of the astronaut support crew for Apollo 9, backup Lunar Module Pilot for Apollo 10, and Lunar Module Pilot for Apollo 14.

Captain Mitchell has logged more than 216 hours in space.

MISSION MANAGEMENT RESPONSIBILITY

Title	Name	Organization
Director, Apollo Program	Dr. Rocco A. Petrone	OMSF
Mission Director	Capt. Chester M. Lee, USN (Ret)	OMSF
Saturn Program Manager	Mr. Richard G. Smith	MSFC
Apollo Spacecraft Program Manager	Brig. Gen. James A. McDivitt	MSC
Apollo Program Manager, KSC	Mr. Robert C. Hock	KSC
Director of Launch Operations	Mr. Walter J. Kapryan	KSC
Director of Flight Operations	Mr. Sigurd A. Sjoberg	MSC
Launch Operations Manager	Mr. Paul C. Donnelly	KSC
Flight Directors	Mr. M. P. Frank Mr. Eugene F. Kranz Mr. Gerald Griffin	MSC MSC MSC

ABBREVIATIONS AND ACRONYMS

AGS	Abort Guidance System
ALSEP	Apollo Lunar Surface Experiments Package
AOS	Acquisition of Signal
APS	Ascent Propulsion System (LM)
APS	Auxiliary Propulsion System (S-IVB)
ARIA	Apollo Range Instrumentation Aircraft
AS	Apollo/Saturn
BIG	Biological Isolation Garment
BSLSS	Buddy Secondary Life Support System
CCATS	Communications, Command, and Telemetry System
CCGE	Cold Cathode Gauge Experiment
CDR	Commander
CPLEE	Charged Particle Lunar Environment Experiment
CM	Command Module
CMP	Command Module Pilot
CSI	Concentric Sequence Initiation
CSM	Command/Service Module
DAC	Data Acquisition Camera
DDAS	Digital Data Acquisition System
DOD	Department of Defense
DOI	Descent Orbit Insertion
DPS	Descent Propulsion System
DSKY	Display and Keyboard Assembly
ECS	Environmental Control System
EI	Entry Interface
EMU	Extravehicular Mobility Unit
EPO	Earth Parking Orbit
EST	Eastern Standard Time
ETB	Equipment Transfer Bag
EVA	Extravehicular Activity
FM	Frequency Modulation
fps	Feet Per Second
FDAI	Flight Director Attitude Indicator
FTP	Fixed Throttle Position
GCTA	Ground Commanded Television
GET	Ground Elapsed Time
GNCS	Guidance, Navigation, and Control System (CSM)
GSFC	Goddard Space Flight Center
HBR	High Bit Rate
HFE	Heat Flow Experiment
HTC	Hand Tool Carrier
IMU	Inertial Measurement Unit
IU	Instrument Unit
IVT	Intravehicular Transfer
KSC	Kennedy Space Center
LBR	Low Bit Rate
LCC	Launch Control Center
LCRU	Lunar Communications Relay Unit
LDMK	Landmark
LEC	Lunar Equipment Conveyor
LES	Launch Escape System
LET	Launch Escape Tower
LGC	LM Guidance Computer
LH_2	Liquid Hydrogen
LiOH	Lithium Hydroxide
LM	Lunar Module
LMP	Lunar Module Pilot
LOI	Lunar Orbit Insertion
LOS	Loss of Signal
LOX	Liquid Oxygen
LPO	Lunar Parking Orbit
LR	Landing Radar
LRL	Lunar Receiving Laboratory
LRRR	Laser Ranging Retro-Reflector
LSM	Lunar Surface Magnetometer
LV	Launch Vehicle
MCC	Midcourse Correction
MCC	Mission Control Center
MESA	Modularized Equipment Stowage Assembly
MH_z	Megahertz
MOCR	Mission Operations Control Room
MOR	Mission Operations Report
MPL	Mid-Pacific Line
MSC	Manned Spacecraft Center
MSFC	Marshall Space Flight Center
MSFEB	Manned Space Flight Evaluation Board
MSFN	Manned Space Flight Network
NASCOM	NASA Communications Network
NM	Nautical Mile
OMSF	Office of Manned Space Flight
OPS	Oxygen Purge System
ORDEAL	Orbital Rate Display Earth and Lunar
PCM	Pulse Code Modulation
PDI	Powered Descent Initiation
PGA	Pressure Garment Assembly
PGNCS	Primary Guidance, Navigation, and Control System (LM)
PLSS	Portable Life Support System
PSE	Passive Seismic Experiment
PTC	Passive Thermal Control
QUAD	Quadrant
RCS	Reaction Control System
RR	Rendezvous Radar
RLS	Radius Landing Site
RTCC	Real-Time Computer Complex
RTG	Radioisotope Thermoelectric Generator
S/C	Spacecraft
SEA	Sun Elevation Angle
SEVA	Stand-up EVA
S-IC	Saturn V First Stage
S-II	Saturn V Second Stage
S-IVB	Saturn V Third Stage
SIDE	Suprathermal Ion Detector Experiment
SIM	Scientific Instrument Module
SLA	Spacecraft-LM Adapter
SM	Service Module
SPS	Service Propulsion System
SRC	Sample Return Container
SSB	Single Side Band
SSR	Staff Support Room
SV	Space Vehicle
SWC	Solar Wind Composition Experiment
TD&E	Transposition, Docking and LM Ejection
TEC	Transearth Coast
TEI	Transearth Injection
TFI	Time From Ignition
TLC	Translunar Coast
TLI	Translunar Injection
TLM	Telemetry
TPF	Terminal Phase Finalization
TPI	Terminal Phase Initiation
T-time	Countdown Time (referenced to liftoff time)
TV	Television
USB	Unified S-Band
USN	United States Navy
USAF	United States Air Force
VAN	Vanguard
VHF	Very High Frequency
ΔV	Differential Velocity

GPO 930-168

Post Launch
Mission Operations Report
No. M-933-72-16

April 28, 1972

TO: A/Administrator

FROM: MA/Apollo Program Director

SUBJECT: Apollo 16 Mission (AS-511) Post Mission Operation Report No. 1

The Apollo 16 Mission was successfully launched from the Kennedy Space Center on Sunday, 16 April 1972. The mission was completed successfully, with recovery on 27 April 1972, one day earlier than originally planned. An anomaly in the backup Thrust Vector Control (TVC) system caused a delay in initiation of powered descent. Analysis and duplication of the anomalous condition in ground simulator systems indicated that the cause was loss of rate damping in the backup yaw control system and that the resultant gimbal oscillation was self limiting. The backup TVC system was therefore considered operable and the decision was made to "GO" for powered descent three revolutions later than initially scheduled. To minimize the remaining SPS engine firings, lunar orbit plane change 2 and the subsatellite shaping burn were deleted. Subsequently, it was decided to shorten the mission one day. Initial review of the mission events indicates that all mission objectives were accomplished. However, the Apollo Lunar Surface Experiments Package (ALSEP) Heat Flow Experiment (HFE) was terminated after drilling of the first bore hole, due to the inadvertent separation of the HFE cable from the connector at the central station. Detailed analysis of all data is continuing and appropriate refined results of the mission will be reported in the Manned Space Flight Centers' technical reports.

Attached is the Mission Director's Summary Report for Apollo 16 which is submitted as Post Launch Mission Operations Report No. 1. Also attached are the NASA OMSF Primary Objectives for Apollo 16. The Apollo 16 Mission has achieved all the assigned primary objectives and I judge it to be a success.

Rocco A. Petrone

Approval:

Dale D. Myers
Associate Administrator for
Manned Space Flight

Attachments

NASA OMSF MISSION OBJECTIVES FOR APOLLO 16

PRIMARY OBJECTIVES

- Perform selenological inspection, survey, and sampling of materials and surface features in a preselected area of the Descartes region.
- Emplace and activate surface experiments.
- Conduct in-flight experiments and photographic tasks.

Rocco A. Petrone
Apollo Program Director

Date: 29 March 1972

Dale D. Myers
Associate Administrator for
Manned Space Flight

Date: 31 March 1972

ASSESSMENT OF THE APOLLO 16 MISSION

Based upon a review of the assessed performance of Apollo 16, launched 16 April 1972 and completed 27 April 1972, this mission is adjudged a success in accordance with the objectives stated above.

Rocco A. Petrone
Apollo Program Director

Date: 2 May 1972

Dale D. Myers
Associate Administrator for
Manned Space Flight

Date: MAY 5, 1972

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO
ATTN OF: MAO

April 27, 1972

TO: Distribution

FROM: MA/Apollo Mission Director

SUBJECT: Mission Director's Summary Report, Apollo 16

INTRODUCTION

The Apollo 16 Mission was planned as a lunar landing mission, to accomplish selenological inspection, survey, and sampling of materials and surface features in a preselected area of the Descartes region of the moon; emplace and activate surface experiments; and conduct in-flight experiments and photographic tasks. Flight crew members were Commander (CDR) Captain John W. Young (USN), Command Module Pilot (CMP) Lieutenant Commander Thomas K. Mattingly (USN), and Lunar Module Pilot (LMP) Lieutenant Colonel Charles M. Duke, Jr. (USAF). Significant detailed information is contained in Tables 1 through 14. Initial review indicates that all primary mission objectives were accomplished (reference Table 1). Table 2 lists the Apollo 16 achievements.

PRELAUNCH

The Apollo 16 prelaunch countdown was accomplished with no unscheduled holds; however, at T-5 hrs 51 min there was an abnormal null shift for 2 seconds in the spare yaw rate gyro channel in the Instrument Unit (IU). A failure mode analysis was performed and it was concluded that the shift, should it occur, would not have an adverse effect on the mission. Launch day weather conditions were clear, visibility 10 miles, winds 13 knots, and scattered cloud cover 3,000 feet.

LAUNCH, EARTH PARKING ORBIT, AND TRANSLUNAR INJECTION

The Apollo 16 space vehicle was successfully launched from Kennedy Space Center, Florida, on time at 12:54 p.m. EST, April 16, 1972.

The S-IVB/IU/LM/CSM was inserted into an earth orbit of 95 x 90 nautical miles (NM) at 11:56 GET (Min:Sec).

During earth orbit, the IU temperature control system gaseous nitrogen (GN_2) bottle pressure started to leak at 10 psi/min. It was predicted that the GN_2 would be lost at approximately 5 hours GET. The IU was given another 2 hours before components would reach temperature redlines and start to fail. The S-IVB auxiliary propulsion system (APS) module No. 2 helium regulator also malfunctioned and caused continuous overboard venting. During the first revolution, a leak was also noted in the APS No. 1 helium supply. These problems did not affect the translunar injection (TLI) burn which occurred at 2:33:34 GET (hrs:min:sec). TLI was nominal.

TRANSLUNAR COAST

The Command Service Module (CSM) separated from the S-IVB/IU/LM at 3:05:01 GET (hr:min:sec), transposed, and then docked with the Lunar Module (LM). Color TV was transmitted for approximately 18 minutes during transposition and docking.

Due to expected early APS helium depletion, the liquid oxygen (LOX) dump from the S-IVB was retargeted closer to the desired lunar impact in order to reduce the length of the APS-1 burn required.

The first S-IVB APS burn, aimed for impact of the lunar surface at 2.3°S and 31.7°W was near nominal. Because of the APS Module No. 1 helium depletion and potential trajectory disturbances from stage venting, the APS-2 maneuver was not performed, and lunar impact operations were terminated. Tracking of the S-IVB was lost at 27:09:07 GET due to the loss of signal from the IU command and communications system.

During the CSM/LM docking, light colored particles were noticed coming from the LM area. These particles were unexplained. At 7:18 GET, the crew reported a stream of particles emitting from the LM in the vicinity of aluminum close-out panel 51 which covers the mylar insulation over reaction control system (RCS) system A. This panel is located below the docking target on the +Z face of the ascent stage. To determine systems status, the crew entered the LM at 8:17 GET and powered up. All systems were normal. There had been no appreciable change in consumables since close-out on the pad, and the LM was powered down at 8:52 GET. CM TV was turned on at 8:45 GET in order to give the Mission Control Center (MCC) a view of the particle emission. In order to point the high gain antenna (HGA), panel 51 was rotated out of sunlight and a marked decrease was then noted in the quantity of particles. On the TV picture, the source of the particles appeared to be a growth of grass-like particles at the base of the panel. TV was turned off at 9:06 GET. Results of the investigation determined that the particles were shredded thermal paint. It was further determined that the degraded thermal protection due to the paint shredding would have no effect on subsequent LM operations.

The spacecraft trajectory was such that midcourse correction (MCC-1) was not required.

The electrophoresis in-flight demonstration commenced on schedule at 25:05 GET. The demonstration appeared to be successful, based on the verbal description from the crew.

Ultraviolet (UV) photography of the earth from approximately 58,000 and 117,000 nm was accomplished as planned.

MCC-2 maneuver was performed on time at 30:39 GET and the burn was normal. The service propulsion system (SPS) burn of 1.8 seconds produced a velocity change of 12.5 feet per second (fps). The MCC-2 maneuver was also used to track an SPS tank pressure transducer anomaly which occurred earlier in the mission. The transducer responded to the change in tank pressure, indicating that the transducer reference cavity was leaking. The transducer presented no problem during subsequent SPS maneuvers. However, procedures were uplinked to the crew to account for the transducer reading.

At approximately 38:19:02 GET the command module computer (CMC) received an indication an Inertial Measurement Unit (IMU) gimbal lock had occurred. The computer correctly downmoded the IMU to "coarse align" mode and set the appropriate alarms. Due to the large number of LM panel particles floating near the spacecraft and blocking the CMP's vision of the stars, realignment of the platform was accomplished using the sun and moon. It was suspected that the gimbal lock indication was an electrical transient caused by actuation of the thrust vector control (TVC) enable relay when exiting the IMU alignment program (P-52). An erasable software program was uplinked to the crew and entered in the CMC which caused the CMC to ignore gimbal lock indication during critical periods.

Visual light flash phenomenon was started about 2 hours late at 49:10 GET. Numerous light flashes were reported by the crew prior to terminating the experiment at 50:16 GET. The crew also reported the flashes left no after-glow, were instantaneous, and were white.

MCC-3 was not performed since the CSM/LM combination was nearly on the planned trajectory.

UV photography of the earth at approximately 177,000 nm was completed as planned.

During suiting operations prior to scheduled intravehicular transfer (IVT) to the LM, the CDR commented that it was very difficult to zip up the LMP suit. Also, the LMP expressed concern that his suit felt short and requested that he be allowed to let out his leg lacings. Lengthening the legs is possible during flight, but the adjustment was not recommended since it was felt that under pressurized conditions the length would be correct. No corrective action was recommended for the difficulty with the zipper as this is characteristic of tight fitting suits.

The second IVT/LM housekeeping commenced about 54:30 GET and completed at 55:11 GET. All LM systems checks were nominal.

The Skylab food test was conducted about 6 hours later than planned, mainly for crew convenience.

The spacecraft entered the moon's sphere of influence at 59:19 GET and at approximately 33,000 nm from the moon.

MCC-4 was not performed since the spacecraft trajectory was near nominal.

The Scientific Instrumentation Module (SIM) door was successfully jettisoned at 69:59:00 GET.

LUNAR ORBIT INSERTION AND S-IVB IMPACT

Lunar Orbit Insertion (LOI) was performed at 74:28:27 GET. The 374.3-second maneuver produced a velocity change (ΔV) of -2802 fps and inserted the CSM/LM into a lunar orbit of 170.3 x 58.1 nm. The resultant orbit was very close to the prelaunch predicted orbit of 170.6 x 58.5 nm.

S-IVB impact occurred at 75:08:00 GET about 37 minutes later than the prelaunch prediction. The event was recorded by the Apollo 12, 14, and 15 Apollo Lunar Surface Experiment Package (ALSEP) sites. The best estimate of the impact point location is 1°50'N, 23°18'W. The estimate was based on the last data received at S-IVB loss of signal at 27:09:07 GET.

DESCENT ORBIT

The Descent Orbit Initiation (DOI) maneuver of -209.5 fps for 24.1 seconds resulted in an orbit of 58.5 x 10.9 nm. The prelaunch planned orbit parameters were 58.6 x 10.9 nm.

IVT/LM activation occurred at 93:34 GET, about 11 minutes early. The LM was powered up and all systems were nominal. The LMP did not report any difficulty with his suit before or after the IVT.

A pressure rise was noted at the LM reaction control system (RCS) system A helium pressure regulator. In order to prevent a rupture of the burst disc and ensure sufficient ullage entrapped for expulsion of the propellant, 53.8 pounds of LM RCS fuel and oxidizer were transferred to the LM ascent propulsion system (APS) tanks to reduce the pressure and gain ullage in the RCS tanks. At 93:03 GET the burst disc ruptured. Subsequently the helium source pressure decreased at a rate which varied from about 4 psi/hr initially to about 1.25 psi/hr.

UNDOCKING, POWERED DESCENT, AND LANDING

The CSM and LM performed the undocking and separation maneuver on schedule at 96:13:31 GET.

The CSM was scheduled to perform the circularization maneuver on the 13th lunar revolution at 97:41:44 GET; however, during gimbal checks, a problem was discovered in the SPS yaw gimbal drive servo loop. As a result, the Powered Descent Initiate (PDI) maneuver was delayed. While the flight controllers were evaluating the servo loop problem, the LM and CSM maneuvered into a stationkeeping situation and prepared to either dock or continue the mission. During troubleshooting of the gimbal drive servo loop, checkout of the backup TVC indicated no rate feedback was obtained and the gimbal position indicator showed yaw oscillations. Analysis of this problem resulted in the conclusion that it would not preclude the lunar landing and that backup capabilities still existed for a safe mission. Based on this conclusion, the spacecraft were given a GO for PDI.

The CSM RCS performed a second separation maneuver at 102:30:00 GET. The SPS was then fired for 4.6 seconds and produced a velocity change of 81.6 fps. The circularization maneuver at 103:21:42 GET placed the CSM into a resultant orbit of 68.0 x 53.1 nm.

PDI with the descent propulsion system (DPS) was performed at 104:17:25 GET on the 16th revolution. Landing occurred in the Descartes area at 104:29:35 GET. The estimate of the landing coordinates based on LM guidance and interpretation of crew visual reports are 8°59'S and 15°30'E, about 230 meters northwest of the planned target point. Since the LM had stayed in lunar orbit longer than planned, the LM was powered down to conserve electrical power. Due to the 6-hour delay in landing caused by the SPS gimbal drive servo loop problem, extravehicular activity (EVA) 1 was rescheduled with a sleep period occurring before the EVA. At 118:06:31 the GET clock was advanced 11 minutes 48 seconds.

LUNAR SURFACE

EVA-1 commenced at 119:05:11 GET. Almost all of the scheduled events were accomplished as planned except additional time was used at station 1, some time was deleted at station 2, additional time was required during LM closeout, and the second heat flow experiment (HFE) bore hole was cancelled during Apollo lunar surface experiment (ALSEP) deploy after the LMP drilled the first HFE bore hole. The cancellation was due to the CDR inadvertently tripping over the HFE cable causing the cable to separate at the connector. The remaining ALSEP components were deployed successfully and functioned nominally at central station activation.

After deployment of the lunar roving vehicle (LRV), the volt and ampere readings for battery #2 read off-scale low and the rear steering was inoperative. Approximately 40 minutes later, subsequent to LRV loading operations, all meters and the rear steering were operating properly. There was no explanation for the off-scale meters or the inoperative steering. The LRV performed nominally throughout the remainder of the EVA; terminated at 126:16:22 GET. Total EVA time was 7 hours 11 minutes 11 seconds.

EVA-2 started at 142:51:15 GET. All stations were explored except station 7 which was deleted prior to crew egress to provide more time at station 10. At 146:48 GET while ascending a ridge and traversing very rocky terrain, full throttle was applied to the LRV, but there was no response at the rear wheels. The LRV continued to move, although the front wheels were "digging in." At 147:14 GET at station 8, a rear-drive troubleshooting procedure was commenced. During this procedure, a mismatch of power mode switching was identified as the cause of the problem. After a change in switch configuration, the LRV was reported to be working properly.

Between EVA stations 9 and 10, at GET 148:45, the LRV range, bearing and distance (all derived from odometer inputs) were reported to be inoperative. However, navigation heading was reported to be working. Later in the EVA the crew reset the power switches and the navigation system began operating nominally.

After the crew arrived at station 10 (LM and ALSEP area), the EVA was extended about 20 minutes. The extension was allowed since the crew's portable life support systems (PLSS) consumables usage was lower than predicted. At approximately 149:19 GET the LMP examined the damaged HFE. Visual inspection of the HFE revealed the cable was separated at the connector. Results of troubleshooting a model of the damaged HFE connector and circuit board indicated that a fix could be accomplished with fairly high probability of success. However, the fix was not attempted because the time required in both EVA 2 and 3 and while in the LM could escalate and impact the 3rd EVA. Additionally, there was some risk to the remainder of the ALSEP components involved in the fix.

After completing surface activities, the crew began ingress. During ingress, approximately a 2-inch portion of the CDR's PLSS antenna was broken off. Subsequently, a 15-18 db drop in signal strength was observed. Since the CDR's backpack radio relays the LMP's information to the LM and the lunar communications relay unit (LCRU) for transmission to ground stations, the broken antenna would have limited communications throughout EVA-3 to a maximum range of 1.9 to 2.1 km from the LM or LCRU if the oxygen purge system (OPS) were not interchanged. A decision was made later to have the CDR use the LMP's OPS which supports the PLSS antenna.

Following completion of tasks, EVA-2 was terminated at 150:14:41 GET. The total EVA time was 7 hours 23 minutes 26 seconds.

EVA-3 commenced approximately 30 minutes early at 165:43:15 GET. The additional 30 minutes were spent in the vicinity of North Ray crater. Two additional stations were explored. All planned activities were accomplished during the EVA; however, some difficulty was experienced in configuring the cosmic ray detector for stowage and return to earth. Television coverage was excellent throughout the EVA. LM closeout at 171:23:29 GET was slightly later than planned. Total EVA-3 time was 5 hours 40 minutes 14 seconds. A total of 27.0 km were traversed during the three EVA's (see Figure 1).

The combined EVA's were 20 hours 14 minutes 54 seconds, and is the longest total lunar EVA time recorded.

The CSM lunar orbit plane change (LOPC) 1 was performed on time. The SPS burn of 7 seconds produced a change in velocity of 124.0 fps and placed the CSM in a 64.6 x 55 nm orbit.

ASCENT, RENDEZVOUS, AND DOCKING

Ascent stage liftoff occurred as planned at 175:43:35 GET. Television of the liftoff and ascent was excellent. The ascent stage was inserted into a 40.2 x 7.9 nm orbit. At insertion, the range between the two spacecraft was about 33,000 feet too close and a 10 fps tweak burn was initiated at 175:54:05 GET to attain the proper separation. The terminal phase initiation (TPI) burn of 3.1 seconds was executed on time at 176:37:52 GET with a nominal velocity change of 78 fps and a resultant orbit of 64.2 x 40.1 nm. After CSM/LM docking, the LM crew transferred all the samples, the film, and some nonscientific equipment to the CSM.

After the crew rest period, the LM crew reentered the LM and transferred the remaining nonscientific equipment to the CSM.

LM jettison occurred at 195:12:00 GET about 2 minutes later than the planned time. After jettison the LM lost attitude and began tumbling at a rate of about 3° per second. This may have been due to the attitude and translation controller assembly (ATCA) primary guidance and navigation system circuit breaker inadvertently being left open. The LM ascent stage is currently in lunar orbit, and present predictions are that the ascent stage will impact the lunar surface in about 1 year.

At 195:15:00 GET the CSM executed a burn of 2 fps to provide an additional separation between the CSM and LM.

The LOPC-2 and the shaping maneuvers were not performed in order to not fire the SPS any more than absolutely necessary due to the degraded backup SPS TVC.

Subsatellite launching occurred at 196:13:55 GET. Its expected lifetime is about 6 to 9 months. The shorter lifetime results from not performing the shaping burn which was to be used to optimize the orbit for a 1-year expected lifetime.

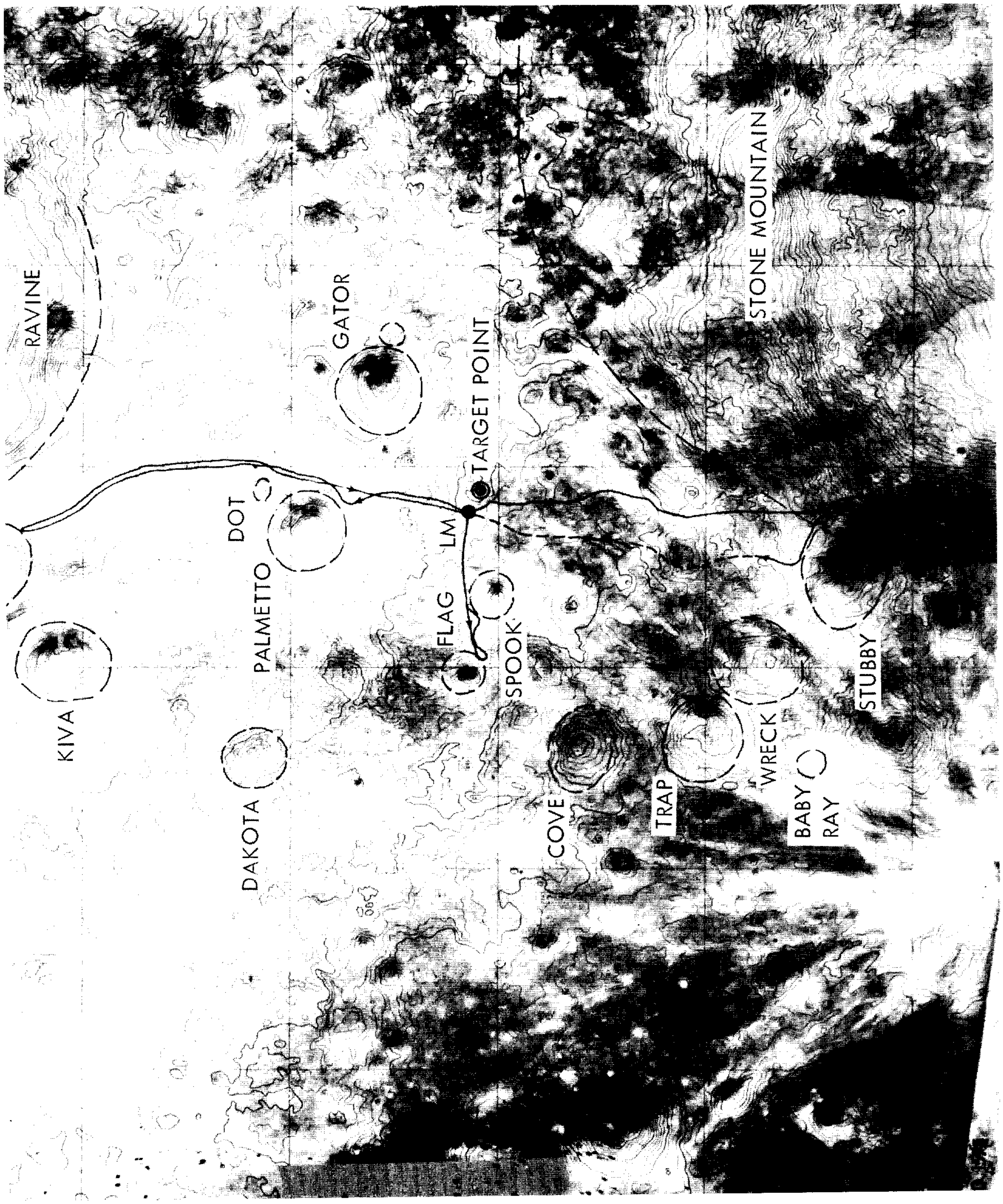

RAVINE
KIVA
DAKOTA
GATOR
DOT
PALMETTO
LM
FLAG
TARGET POINT
SPOOK
COVE
TRAP
WRECK
BABY RAY
STUBBY
STONE MOUNTAIN

Fig. 1

TRANSEARTH INJECTION AND COAST

The transearth injection (TEI) maneuver was performed at the beginning of the 65th revolution at 200:33:20 GET. The SPS 162.4-second burn produced a change in velocity of 3,370.9 fps.

A GET clock update of 24 hours 34 minutes 12 seconds was made at approximately 202:25 GET.

Good quality television pictures inside the CM and from the LRV on the lunar surface were transmitted between 227:53 and 228:08 GET and 228:25 and 229:08 GET, respectively.

The spacecraft entered the earth's sphere of influence at 237:28 GET traveling at 3,751 fps and 187,827 nm from the earth.

The MCC-5 maneuver was performed at 239:21:02 GET with an 8.2-second RCS burn producing a delta velocity of 3.4 fps.

The CMP EVA commenced at 243:24 GET. The CMP retrieved the panoramic and mapping camera film in two trips to the SIM bay. The CMP observed the SIM bay to determine the condition of the instruments (see in-flight science). The microbial environment exposure device (MEED) was deployed and exposed for approximately 10 minutes. After returning the MEED to the CM, the CMP experienced some difficulty in closing the cover. The EVA lasted approximately 1 hour 24 minutes.

A scheduled TV press conference started at 268:13 GET and terminated at 268:31 GET. During the conference the crew gave a brief description of the backside of the moon. An item of particular interest was the crew's description of the crater Guyot which appeared to be full of material. The material seemed to have overflowed and spilled down the side of the crater. The crew compared their observations with similar geological formations in Hawaii.

MCC-6 was not performed since the spacecraft trajectory was near nominal.

The MCC-7 maneuver at 287:23:24 GET with the RCS firing of 3.5 seconds produced a change in velocity of 1.4 fps.

ENTRY AND LANDING

The CM separated from the SM at about 290:08 GET, 15 minutes before entry interface (EI) at 400,000 feet. Drogue and main parachutes deployed normally; landing occurred in the mid-Pacific Ocean at approximately 156°11.4'W longitude and 00°43.2'S latitude. The CM landed in a stable two position, about 2.7 nm from the prime recovery ship, USS Ticonderoga, and about .3 nm from the planned landing point.

Weather in the prime recovery area was as follows: visibility 10 miles, wind 110° at 10 knots, scattered cloud cover 2,000 feet, and wave height of 4 feet.

ASTRONAUT RECOVERY OPERATIONS

Following CM landing, the recovery helicopter dropped swimmers who installed the flotation collar and attached the life raft. Fresh flight suits were passed through the hatch for the flight crew. The post ventilation fan was turned off, the CM was powered down, the crew egressed, and the CM hatch was secured.

The helicopter recovered the astronauts and transferred them to the recovery ship. After landing on the recovery ship, the astronauts proceeded to the Biomed area for a series of examinations. Following the examinations the astronauts departed the USS Ticonderoga the next day, were flown to Hickam Air Force Base, Hawaii, and then to Ellington Air Force Base, Texas.

COMMAND MODULE RETRIEVAL OPERATIONS

After astronaut pickup by the helicopter, the CM was retrieved and placed on a dolly aboard the recovery ship. Since the CM had propellants onboard, it was stowed near the elevator shaft to insure adequate ventilation. All lunar samples, data, equipment will be removed from the CM and subsequently returned to Ellington Air Force Base, Texas. The CM will be offloaded at San Diego, California, where deactivation of the CM propellant system will take place.

SYSTEMS PERFORMANCE

The Saturn V stages performed nominally, with some discrepancies that did not impact the mission.

The spacecraft systems performance was also near nominal throughout the mission with only one notable exception. During the lunar orbit precircularization burn checkout, at approximately 97:40 GET, checkout of the backup TVC indicated no rate feedback was obtained and the SPS engine gimbal position indicator showed yaw oscillations. This delayed the lunar landing some 6 hours until 104:29:35 GET, caused some revision of lunar surface activities, and a 1 day earlier end-of-mission. Other problems were: the HFE cable became entangled in the CDR's legs causing it to break at the connector to the central station, the LM steerable antenna yaw drive was inoperative at 94:35 GET, at 95:03 GET the LM RCS system A helium regulator failed.

A number of "glitches" occurred on the coupling data unit (CDU) circuitry in that the caution and warning (C&W) light and alarms were activated. The exact cause of the anomaly is unknown but it could have been contamination, loose wiring, or some similar condition since the crew could clear the "glitch" by tapping the panel above the display and keyboard assembly (DSKY). It did not appear that the failure was in either the CDU, the inertial measurement unit (IMU) or pulse integrated pendulous accelerometers (PIPA). All indications are that the C&W light indication was faulty and the guidance and navigation (G&N) system would function properly. The glitches did not occur during CM flight.

The stabilization and control system (SCS) was available for backup during the final phase of the mission but was not needed.

All anomalies were rapidly analyzed and either resolved or workaround procedures developed to permit the mission to continue. All anomalies are listed in Tables 9 through 14.

FLIGHT CREW PERFORMANCE

The Apollo 16 flight crew performance was excellent throughout the mission.

All information and data in this report are preliminary and subject to revision by the normal Manned Spaceflight Centers' technical reports.

C. M. Lee

SURFACE SCIENCE

The first Apollo 16 surface science event was the impact of the S-IVB stage at 75:08:00 GET. The best estimate of the impact point location is 1°50'N and 23°18'W. This impact is approximately 155 km north of the Apollo 12 site, 250 km northwest of the Apollo 14 site, and 1100 km southwest of the Apollo 15 site. The seismometers at all three sites recorded the impact. The distance of the impact from the seismometers will facilitate analysis of subsurface structure to depths of 30 to 200 km.

The Apollo 14 cold cathode gauge experiment (CCGE) recorded a brief event approximately 11.5 minutes after predicted S-IVB impact time. A possible gas cloud passage was also recorded by the CCGE at Hadley/Apennine. The charged particle lunar environment experiment (CPLEE) recorded a 1-minute burst of low energy protons about 5 minutes after predicted impact time. Suprathermal ion detectors at Apollo 12, 14, and 15 sites did not record a positive indication of the impact.

The LM touched down on the Descartes plateau at 104:29:35 GET. The crew reported observing expected landmarks during descent. From visual descriptions, the preliminary coordinates of the landing site were 8°59'S and 15°30'E which is about 230 meters northwest of the nominal landing site. The landing site was in a subdued crater lying on a ray from South Ray crater. The surface is densely cratered with 30-40% of the surface covered with blocks up to 1/2 meter in diameter. The rocks and boulders were bright and appeared to be primarily breccias. Detailed verbal descriptions were made of both distant and near field objects. Lineations similar to those observed by the Apollo 15 crew were observed. Stone Mountain appeared to have many terraces. Trafficability for the LRV was considered to be good and an acceptable deployment site for the ALSEP was felt to be to the west of the LM.

The crew commenced the 1st EVA at 119:05:11 GET. The Far UV camera was deployed near the LM and the ALSEP was transported 110 meters WSW for deployment. Deployment of the ALSEP was nominal except for the HFE. The CDR inadvertently tripped over the HFE cable, separating the cable at the connector after the first hole was bored. The second HFE bore hole was cancelled. The remaining ALSEP components deployed nominally. The deep core (8-3/4 feet) was drilled successfully and removed from the regolith by the LMP using the core extractor.

Scheduled traverse events were accomplished as planned with the crew having no difficulty in reaching Flag and Spook craters, although there was some difficulty in the identification of particular craters. Traverse and LRV evaluation test speeds were as high as 11 km per hour. The ground traversed and sampled was characterized by unconsolidated deposits, with or without abundant blocks. Neither bedrock outcrops nor ridge-like thinly mantled bedrock were recognized. Documented and grab samples were obtained. The most common rock type encountered was a breccia with dominantly light-colored clasts in light to dark-colored matrices. The surface layer of dark soil appears to be underlain at a depth of about 1-3 cm by white soil.

A successful lunar portable magnetometer (LPM) site measurement was made at Station 2 (Spook crater). The local magnetic field measured was 180 gamma, approximately straight down. EVA-1 terminated at 126:16:22 GET for a total EVA time of 7 hours 11 minutes 11 seconds.

The crew commenced the 2nd EVA at 142:51:15 GET. All preplanned stations were explored except Station 7, which was deleted from the traverse plan prior to crew egress. The crew proceeded south to Station 4. The surface at Station 4 was largely rocky with rocks having a white clast and glass coating. Documented samples, double core, penetrometer readings, and soil samples were collected. The subsurface soil was found to be white. The crew then proceeded north to Station 5 on a 50-meter wide bench. Blocks were present, but no ledges or bedrock. Blocks were up to 5 cm and almost all angular. No white soil was found. Documented and rake samples were collected. A successful LPM measurement was made. The local magnetic field measured was 125 gamma, nearly vertically up, in contrast to the measurement at Station 2 which was vertically down. Station 6 NNW of Station 5 was on a bench on the lower flank of Stone Mountain. The area was found to have many large, hard rocks. The rocks appeared to be breccias containing needle-like crystals. The samples were definitely different from previous samples. The soil was gray at the surface and to the depth of soil sampled. The crew traveled to the northwest to Station 8. Fields of blocks averaging 10-15 cm, but ranging up to 2 meters were found on the surface. The surface soil was predominantly black, but some white breccia and white crystalline rock fragments were obtained. A double core sample in an area of glass beads as well as rock fillet samples were collected. Documented, grab, and rake samples were obtained. The crew then traveled north to Station 9, an old subdued crater. The crew obtained special soil samples. These samples should provide material from the upper 100-500 micron depth which were probably not exposed to contamination of the LM descent. Rock samples included a breccia with white clasts and a breccia with blue crystals. The crew overturned a boulder and collected samples of the exposed surface. A drive tube sample was also obtained. At Station 10 in the vicinity of the ALSEP, documented samples, a double core, and penetrometer measurements were obtained. Before the crew ingressed the LM, the Far UV camera was retargeted. EVA-2 terminated at 150:14:41 GET after a total EVA time of 7 hours 23 minutes 26 seconds.

EVA-3 commenced at 165:43:15 GET. After loading the LRV and retargeting the Far UV camera, the crew drove directly to North Ray crater. They described this part of the Cayley formation as more subdued and less densely cratered than that covered the previous 2 days. Blocks became less common north of the LM, more common on the flanks of Palmetto crater, and the rim of North Ray crater had many large blocks.

Two main types of rocks were sampled at North Ray: (1) white breccias and (2) dense, dark breccias typified by "House Rock," a 10 x 10 x 30-meter block. The area between Stations 11 and 12 was extensively sampled. Rake, soil samples, documented samples, and grab samples were collected. A shatter cone was also collected from "House Rock." 500mm photos of the interior of the crater were taken, but the crew could not see the bottom.

The crew then drove to Station 13, approximately 1/2 km southeast of Station 11. In addition to sampling and photography, a soil sample was collected from under a 5 meter boulder. This sample is believed to have been in permanent shadow since the rock came to rest on the lunar surface. A LPM reading was taken showing a local field of 313 gammas in a southwesterly direction.

From Station 13 the crew returned to the LM and Station 10; recording, at times, speeds as high as 17 km/hr. At Station 10, a double core, rake/soil sample and other samples were collected. A final LPM measurement was also made after parking the LRV east of the LM, both with and without a locally collected igneous rock placed on the LPM.

EVA-3 terminated at 171:23:29 GET, after a total EVA time of 5 hours 40 minutes 14 seconds.

A brief summary of some of the estimated statistics of the three EVAs follows:

Total EVA man-hours	40 hours 30 minutes
Total stop time at sampling stations	9 hours 7 minutes
Total traverse distance	27.1 km
Sample return	213 pounds

Apollo Lunar Surface Experiments Package

The ALSEP was deployed during the early part of EVA-1. Total deployment time was 2 hours 5 minutes. All experiments were successfully deployed and turned on, with the exception of the HFE. The radioisotope thermoelectric generator (RTG) is now supplying 70.94 watts. The downlink signal strength remains constant at -139 dbm. All central station functions are normal.

Heat Flow Experiment

During deployment of the mortar package the CDR caught his foot in a loop of the HFE cable. He was unaware of the interference and continued to walk away from the central station, severing the cable at the central station connector.

Although the first HFE hole was drilled and a probe emplaced, the experiment could not be activated since the cable was severed.

Passive Seismic Experiment

The passive seismic experiment (PSE) was uncaged and leveled a few hours after activation. Seismic and tidal data channels have functioned normally. The instrument recorded LRV motion and crew activities at all times during the EVAs except on the inbound leg of EVA-3 when the active seismic experiment (ASE) was on, precluding the return of other data. Crew activity to the maximum range of 4.4 km was recorded and LRV range could be estimated to $\pm 1/2$ km. The instrument also recorded equipment jettison, LM venting, and its own settling.

The PSE sensor temperature is not stabilizing to the nominal value which is expected to preclude measuring tidal data during lunar daytime. It is expected to exceed the measurement range shortly before lunar noon. An operating procedure has been devised which should minimize the effect of this anomaly during future lunations.

Lunar Surface Magnetometer

The lunar surface magnetometer (LSM) has been operating normally since turn-on. A field of 230 gamma was observed. Since that time the instrument has recorded the passage of the moon from the solar wind region through the transition region and into the earth's geomagnetic tail (Figure 2).

Two flip calibrations have been performed. A site survey will be performed when the moon is deep in the geomagnetic tail. The LSM is operating with its digital filter in and will remain so for one lunation.

Active Seismic Experiment

The ASE geophones observed the scheduled 19 thumper firings. It was also used to observe the last kilometer of the return of the LRV on EVA-3 to verify its use during Apollo 17 operations. It also was activated during ascent stage liftoff.

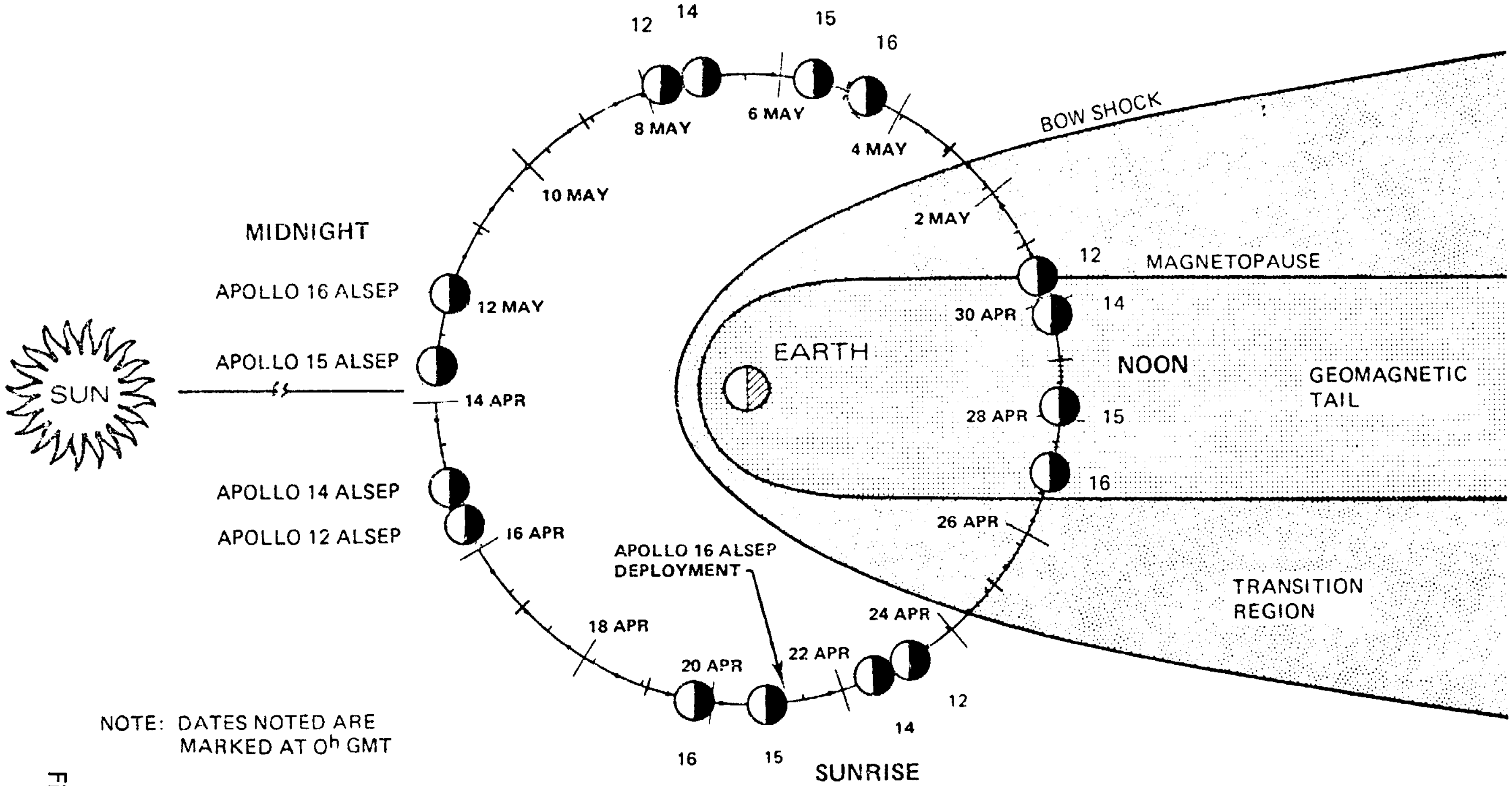
The mortar package roll sensor has shown off-scale high since turn-on. The pitch sensor is normal (-2.3°). Crew observation verified that the mortar is in fact nearly level, indicating failure of the roll sensor.

The ASE will be operating in the listening mode once a week for 30 minutes. Firing of the mortars is currently planned in about 3 months.

Far Ultra-Violet Camera/Spectroscope

The Far UV camera/spectroscope was targeted on the scheduled 11 targets. Film advance was observed to be normal. The camera and battery were repositioned twice to maintain proper temperature. The film cassette was recovered at the end of EVA-3.

MOON POSITIONS RELATIVE TO EARTH-SUN LINE
14 Apr to 13 May 1972



NOTE: DATES NOTED ARE MARKED AT 0^h GMT

Fig. 2

APOLLO (ALSEP)	DAY/HOUR, GMT					
	MIDNIGHT	SUNRISE	NOON		SUNSET	MIDNIGHT
16		19 APR/2032	(1ST)	27 APR/0546	4 MAY/1504	11 MAY/2348
15		20 APR/1950	(10TH)	28 APR/0506	5 MAY/1422	12 MAY/2301
14	15 APR/0430	22 APR/1323	(16TH)	29 APR/2244	7 MAY/0753	
12	15 APR/1607	23 APR/0132	(31ST)	30 APR/1024	7 MAY/1827	

Solar Wind Composition

The solar wind composition (SWC) was deployed for 45 hours 5 minutes. A slight tear made during retrieval will not affect scientific results.

Lunar Portable Magnetometer

Five measurements were made with the LPM; at Spook Crater, Station 5, Station 13, LM site and the LM site with an igneous rock placed on the LPM. Readings ranged from 180 gammas down to 125 gammas up. The rock caused a change of 5 gammas, well within the expected range.

Cosmic Ray Detector

During activation by the crew, a pull lanyard broke, possibly precluding activation of the neutron flux detector, radon emission detector, and solar wind detector. Visual verification by the crew was inconclusive. At the end of EVA-1, temperature indicators showed the cosmic ray detector (CRD) to have exceeded specified values. As planned, it was placed in the LM footpad, in the shadow of the leg. Indicators prior to CRD stowage indicated that the temperatures were not excessive at the Lexan plates which form the bulk of the CRD Experiment.

IN-FLIGHT SCIENCE

X-ray and gamma-ray astronomical data and alpha particle cislunar and instrument background data were acquired during transearth coast (TEC). The X-ray sources Scorpius X-1 was observed for a total of 6 hours during three observation periods, Cygnus X-1 was observed for 5 hours during two observation periods, the Super Galactic Plane was scanned for 10 hours, and the Galactic Anti-Center Point was observed for 1 hour. Gamma-ray astronomical data was also acquired with the boom extended (the CSM in the passive thermal control (PTC) mode) and scanning the Super Galactic Auxiliary Plane, the Ecliptic Auxiliary Plane, and the Super Galactic Plane in addition to observations of Scorpius X-1 and Cygnus X-1.

The X-ray, gamma-ray, and alpha-particle spectrometers operated nominally throughout the lunar orbit phase of the mission. A preliminary X-ray fluorescence map has been plotted and shows regions of high aluminum concentration over the highlands, including the Descartes region, with low concentrations of aluminum over the maria. A map of the gamma-ray activity in the range 0.54-2.75 Mev indicates that the only significant region of high radioactivity is the western maria, from 10°E to 60°W and falls off rapidly outside this band. The highest level of radioactivity (10 ppm Thorium) is at 15°W near the Fra Mauro formation, and the lowest over the backside highlands. On the basis of the gamma-ray spectrometer data the radioactivity of the returned samples is predicted to be 1-2 ppm Thorium. No intense regions of radon emission were observed by the alpha-particle spectrometer. However, a significant variation of ^{210}Po was observed over the lunar surface, indicating that radon emissions have occurred in the last tens of years.

Mapping camera operation was nominal throughout the mission, except for longer than nominal extension/retraction times. This has been attributed to the glare shield for the stellar camera being jammed against the handrail paralleling the SIM bay (as reported by the CMP during the inflight EVA). Therefore, glare may be present on the stellar frames and complicate the star field data reduction. Approximately 2900 mapping camera frames were acquired in lunar orbit and approximately 60 of the post-TEI photographs will be useful scientifically. Approximately 5.6% of the lunar surface was covered by the vertical mapping camera photography with about 4.0% being areas not covered by Apollo 15. The mapping camera obliques covered approximately 20% of the surface with about 7% being of areas not similarly photographed on Apollo 15.

The laser altimeter was operated on all vertical mapping camera passes in lunar orbit. A total of 2395 laser altimeter measurements were made with an overall reliability of 63.5%. The percentage of valid measurements gradually deteoriated during the mission, decreasing to about 50% by Rev 60 and decreasing abruptly to about 5% on Rev 63, the last photographic pass. Except for the Rev 63 data, the number of valid altitude measurements is sufficient to provide the necessary cartographic control for the photography.

The mechanical operation of the panoramic camera was nominal throughout the mission. An undervoltage in the power supplied to the camera necessitated termination of the photopass on Rev 3 after only four frames were taken. Operation was nominal on the remaining passes. However, the automatic exposure control indicated consistently low light levels, resulting in overexposure of the film for all areas away from the terminator. It is expected that this overexposure will be largely compensated during film processing. Approximately 1,425 panoramic frames were acquired in lunar orbit and about 175 frames post-TEI. The total area photographed by the panoramic camera was about 10% less than would have been obtained on the nominal mission.

The mass spectrometer operated successfully in lunar orbit acquiring about 85 hours of data during water dumps, fuel cell purges, and during nominal experiment operating periods; however, the attempt to retract the mass spectrometer boom just prior to TEI was unsuccessful. Subsequent attempts at troubleshooting the retraction problem were also unsuccessful and the boom was jettisoned prior to the SPS burn for TEI. The data acquired in lunar orbit should be adequate to overcome the major problem of determination of constituents of the lunar atmosphere. The main purpose of mass spectrometer operation during TEC was to obtain additional data which would help unravel the more puzzling aspects of the contamination problem. Because data was obtained in TEC with the Apollo 15 mass spectrometer, the present loss of data is not of overwhelming importance.

The dual frequency bistatic radar experiment (BRE) was performed on Rev 40. The S-band signal received at Goldstone was quite strong and properly polarized, and signal lock was maintained throughout the experiment. The S-band data are of good quality and all pre- and post-calibrations were good. The reflected VHF signal received at the Stanford 85-foot antenna was of poor quality and the usefulness of the data is questionable.

The VHF only bistatic radar test was initiated on Rev 42. As in the case of the dual frequency BRE, the reflected VHF signal received at Goldstone was of poor quality. The CSM omniantenna was switched off and then back on and the VHF signal problem cleared up. Three and a half frontside passes of good quality VHF bistatic radar data were acquired. The VHF only data can be used in lieu of the poor quality VHF data obtained during the dual frequency portion of the experiment on Rev 40.

S-band transponder (Doppler tracking) data from the CSM, LM, and subsatellite have been processed over short time intervals. The quality of the data is excellent and many new features can be resolved. The amplitudes are not as large as recorded from Apollo 15 since the trajectory path was not over any mascon areas. However, craters and highland features >40 km were evaluated. A preliminary gravity profile acquired on Rev 10 (CSM/LM) from 60°E to 50°W indicates a positive anomaly over Fecunditatis, a positive anomaly over the highlands east of Descartes with a small negative anomaly over the Descartes region, and positive anomalies over the rims of Albategnius and Ptolemaeus, with Ptolemaeus itself a negative anomaly.

The Apollo 16 subsatellite was launched at 196:13:55 GET into a 66.6 x 52.8 nm orbit with a longitude of the descending node on the initial rev of 117°W. Power was applied to the experiments on Rev 26 at 241:18 GET. Preliminary analysis of the data indicates that the magnetometer and solid state telescopes are working normally. The high voltage for the electrostatic analyzers was turned on at 271:11 GET after allowing sufficient time for outgassing. The subsatellite lifetime is estimated between 195-222 days based on the Jet Propulsion Laboratory (JPL) 15-8 gravity model.

The Apollo 15 subsatellite was reactivated at 261:46 GET, Rev 3200 after being inactive for 1 month. No degradation was noted.

The low light level astronomy photographic tasks were performed and 75% of the planned tasks were completed in spite of early termination of the experiment. The CM photography of 22 of 26 planned lunar surface targets were also successfully completed. Visual observations of 10 surface areas were made by the CMP, using the unaided eye as well as the 10X binoculars flown for the first time on Apollo 16, and significant details not otherwise available were noted. The Skylab Contamination Study was conducted on the TEC phase of the mission.

Total SIM data acquired in lunar orbit:

Mass spectrometer	72.5 hr (-X) 12.5 hr (+X)
X-ray/alpha particle spectrometers	63 hr prime data 11.5 hr slightly degraded (LM attached) 13.8 hr non-SIM attitude
Gamma-ray spectrometer	56.3 hr prime data 7.7 hr slightly degraded (boom partially retracted) 11.5 hr seriously degraded (RTG attached) 13.8 hr non-SIM attitude (boom extended) 26.5 hr background dueing TEC
Mapping camera	5 term-to-term obliques 9.3 term-to-term vertical passes 6 darkside passes with concurrent laser altimeter operation
Panoramic camera	1425 frames of stereo photography
Bistatic radar	1 dual frequency pass 4 VHF only passes

Astronomical data acquired during TEC:

X-ray spectrometer	23 hr
Gamma-ray spectrometer	33 hr

TABLE 1

APOLLO 16 OBJECTIVES AND EXPERIMENTS

PRIMARY OBJECTIVES

The following were the NASA OMSF Apollo 16 Primary Objectives:

- Perform selenological inspection, survey, and sampling of materials and surface features in a preselected area of the Descartes region.
- Emplace and activate surface experiments.
- Conduct in-flight experiments and photographic tasks.

APPROVED EXPERIMENTS

The following experiments were performed:

Apollo Lunar Surface Experiments Package (ALSEP)

S-031	Lunar Passive Seismology
S-033	Lunar Active Seismology
S-034	Lunar Tri-Axis Magnetometer
S-037	Lunar Heat Flow (incomplete)*

Lunar Surface

S-059	Lunar Geology Investigation
S-080	Solar Wind Composition
S-152	Cosmic Ray Detector (Sheets)
S-198	Portable Magnetometer
S-200	Soil Mechanics
S-201	Far UV Camera/Spectroscope

In-Flight

S-160	Gamma-ray Spectrometer (SIM)
S-161	X-ray Fluorescence (SIM)
S-162	Alpha-particle spectrometer (SIM)

* The Lunar Heat Flow second bore hole was not accomplished because of the inadvertent breakage of the HFE cable to the central station connector. This experiment is not active (see page 7 - Lunar Surface Section).

In-Flight (Continued)

S-164	S-band Transponder (CSM/LM) (Subsatellite)
S-165	Mass Spectrometer (SIM)
S-170	Bistatic Radar (CSM)
S-173	Particle Shadows/Boundary Layer (Subsatellite)
S-174	Magnetometer (Subsatellite)
S-177	UV Photography — Earth and Moon (CM)
S-178	Gegenschein from Lunar Orbit (CM)
M-191	Microbial Response in Space Environment
--	Visual Observations from Lunar Orbit
--	Visual Light Flash Phenomena

Other

M-078	Bone Mineral Measurement
M-211	Biostack
S-176	Apollo Window Meteoroid

DETAILED OBJECTIVES

The following detailed objectives were assigned to and accomplished on the Apollo 16 Mission:

- Subsatellite Tracking for New Navigation Techniques
- LRV Evaluation
- Gas/Water Separation Delivery of Gas-free Water
- Fecal Collection Bag Evaluation
- Skylab Food Package Function
- SM Photographic Tasks
- CM Photographic Tasks
- Apollo Time and Motion Study
- LM Voice and Data Relay Evaluation
- Visual Observations from Lunar Orbit
- Visual Light Flash Phenomena
- Impact S-IVB on Lunar Surface
- Postflight Determination of S-IVB Impact Point
- Body Fluid and Electrolyte Disturbances Understanding
- Skylab Contamination Study

SUMMARY

Fulfillment of the primary objectives qualifies Apollo 16 as a successful mission. The experiments and detailed objectives which supported and expanded the scientific and technological return of this mission were successfully accomplished.

TABLE 2

APOLLO 16 ACHIEVEMENTS

- Fifth Manned Lunar Landing
- Largest Payload Placed in Lunar Orbit (76,100 pounds)
- First Cosmic Ray Detector Deployed on Lunar Surface
- First Use of Far UV Camera on Lunar Surface
- Longest Lunar Surface Stay Time (71 hours 14 minutes)
- Longest Lunar Surface EVA (20 hours 15 minutes)
- First Landing In and Exploration of Lunar Highlands
- Largest Amount of Lunar Samples Returned to Earth (approximately 213 pounds)

TABLE 3

APOLLO 16 POWERED FLIGHT SEQUENCE OF EVENTS
END OF MISSION

EVENT	PRELAUNCH PLANNED (GET) HR:MIN:SEC	ACTUAL (GET) HR:MIN:SEC
Guidance Reference Release	-17.6	-17.6
Liftoff Signal (TB-1)	0	0
Pitch and Roll Start	11.8	11.8
Roll Complete	29.8	29.8
S-IC Center Engine Cutoff (TB-2)	2:17.4	2:17.2
Begin Tilt Arrest	2:38.7	2:38.5
S-IC Outboard Engine Cutoff (TB-3)	2:41.4	2:41.2
S-IC/S-II Separation	2:43.2	2:43.0
S-II Ignition (Command)	2:43.8	2:43.6
S-II Second Plane Separation	3:13.1	3:12.9
S-II Center Engine Cutoff	7:41.4	7:41.2
S-II Outboard Engine Cutoff (TB-4)	9:18.6	9:19.0
S-II/S-IVB Separation	9:19.6	9:20.0
S-IVB Ignition	9:19.7	9:20.1
S-IVB Cutoff (TB-5)	11:45.0	11:45.8
Insertion	11:54.8	11:55.6
Begin Restart Preps (TB-6)	2:23:57.2	2:23:58.0
Second S-IVB Ignition	2:33:35.2	2:33:36.0
Second S-IVB Cutoff (TB-7)	2:39:19.7	2:39:18.1
Translunar Injection	2:39:29.5	2:39:27.9

Prelaunch planned times are based on MSFC Launch Vehicle Operational Trajectory.

TABLE 4

APOLLO 16 MISSION SEQUENCE OF EVENTS
END OF MISSION

EVENT	PLANNED (GET) HR:MIN:SEC	ACTUAL (GET)* HR:MIN:SEC
Liftoff 12:54.6 April 16	00:00:00	00:00:00.6
Earth Parking Orbit Insertion	00:11:54	00:11:56
Second S-IVB Ignition	02:33:35	02:33:36
Translunar Injection	02:39:29	02:39:29
CSM/S-IVB Separation, SLA Panel Jettison	03:03:50	03:05:01
CSM/LM Docking	03:13:50	03:22:10
Spacecraft Ejection From S-IVB	03:58:50	03:59:20
S-IVB APS Evasive Maneuver	04:23:01	04:18:35
Midcourse Correction-1	11:38:50	Not Performed
Midcourse Correction-2	30:38:50	30:39:00
Midcourse Correction-3	52:28:39	Not Performed
Midcourse Correction-4	69:28:39	Not Performed
SIM Door Jettison	69:58:39	69:59:00
Lunar Orbit Insertion (Ignition)	74:28:39	74:28:27
S-IVB Impact	74:30:08	75:08:00
Descent Orbit Insertion (Ignition)	78:35:30	78:33:44
CSM/LM Undocking	96:13:31	96:13:31
CSM Separation	96:13:31	96:13:31
CSM Separation No. 2	Not Planned	102:30:00
CSM Circularization	97:41:44	103:21:42
Powered Descent Initiate	98:34:41	104:17:25
LM Lunar Landing	98:46:42	104:29:35*
Begin EVA-1 Cabin Depress	102:25:00	119:05:11*
Terminate EVA-1 Cabin Repress	109:25:00	126:16:22
Begin EVA-2 Cabin Depress	124:50:00	142:51:15
Terminate EVA-2 Cabin Repress	131:50:00	150:14:41
Begin EVA-3 Cabin Depress	148:25:00	165:43:15
CSM Plane Change (LOPC)	152:28:48	169:17:40
Terminate EVA-3 Cabin Repress	155:25:00	171:23:29
LM Liftoff	171:45:09	175:43:35

*11 min 48 sec GET clock update at 118:06:31 GET and an additional 24 hr 34 min 12 sec GET clock update at approximately 202:25:00 GET.

TABLE 4 (Continued)

EVENT	PLANNED (GET) HR:MIN:SEC	ACTUAL (GET)* HR:MIN:SEC
LM Tweak Burn	Not Planned	175:54:05
Terminal Phase Initiate Maneuver	172:39:23	176:37:52
LM/CSM Docking	173:50:00	177:53:13
LM Jettison	177:31:15	195:12:00
CSM Separation	177:36:15	195:15:00
Ascent Stage Deorbit	179:16:29	Not Performed
Ascent Stage Lunar Impact	179:39:29	Not Performed
LOPC-2	193:13:46	Not Performed
Shaping	216:49:12	Not Performed
Subsatellite Launch	218:02:08	196:13:55
Transearth Injection	222:20:33	200:33:20*
Midcourse Correction-5	239:23:03	239:21:02*
CMP EVA Depress	242:00:00	243:24:55
CMP EVA Repress	243:10:00	244:38:05
Midcourse Correction-6	268:22:45	Not Performed
Midcourse Correction-7	287:22:45	287:23:24
CM/LM Separation	290:07:45	290:08:31
Entry Interface (400,000 ft)	290:22:45	290:23:31
Landing	290:36:03	290:37:01**

** Mission duration was approximately 265 hours 51 minutes.

TABLE 5

APOLLO 16 TRANSLUNAR AND MANEUVER SUMMARY
END OF MISSION

Maneuver	GROUND ELAPSED TIME (GET) AT IGNITION (HR:MIN:SEC)			BURN TIME (SECONDS)			VELOCITY CHANGE (FEET PER SECOND-FPS)			GET OF CLOSEST APPROACH / HT (NM) CLOSEST APPROACH		
	Pre-Launch Plan	Real-Time Plan	Actual	Pre-Launch Plan	Real-Time Plan	Actual	Pre-Launch Plan	Real-Time Plan	Actual	Pre-Launch Plan	Real-Time Plan	Actual
TLI (S-IVB)	02:33:15	02:33:34	02:33:34	335	342.7	342.7	10386	10389.6	10389.6	74:32:13.4 / 71.4	74:30:07 / 71.4	74:32:22 / 146.7
CSM Sep	03:03:50	03:04:20	03:05:01	3	3		0.5	0.3		74:32:13.4 / 71.4	----	----
CSM Dock	03:13:50	03:14:20	03:22:10	NA	-	-	NA	-	-	74:32:13.4 / 71.4	----	----
SM EJT	03:58:50	03:59:00	03:59:20	3	3	4.6	0.3	0.3	0.5	74:32:13.4 / 71.4	74:32:22 / 146.7	74:32:21 / 136.2
S-IVB Evasive	04:23:01	04:18:33	04:18:35	80.2	16.0	17.1	9.8	10.2	10.9	74:30:08 / 0	74:22:53 / 0	74:23:07 / 0
MCC-1 (SPS)	11:38:50	NP		0		NP	0	NP		74:32:13.4 / 71.4	----	----
MCC-2 (SPS)	30:38:50	30:39:00	30:39:00	0	1.9	1.8	0	12.6	12.5	74:32:13.4 / 71.4	74:32:12 / 71.5	74:32:07 / 71.7
MCC-3	52:28:39	NP		0		NP	0	NP		74:32:13.4 / 71.4	NP	----
MCC-4	69:28:39	NP		0		NP	0	NP		74:32:13.4 / 71.4	NP	----
SIM Door Jettison	69:58:39	69:59:00	69:59:00	NA			NA			NA	----	----

NA - Not Applicable NP - Not Performed

TABLE 6

APOLLO 16 LUNAR ORBIT SUMMARY
END OF MISSION

Maneuver	GROUND ELAPSED TIME (GET) AT IGNITION (HR:MIN:SEC) Pre-Launch Plan	Real-Time Plan	Actual	BURN TIME (SECONDS) Pre-Launch Plan	Real-Time Plan	Actual	VELOCITY CHANGE (FEET PER SECOND-FPS) Pre-Launch Plan	Real-Time Plan	Actual	RESULTING APOLUNE/PERILUNE (NM) Pre-Launch Plan	Real-Time Plan	Actual
LOI	74:28:39	74:28:27	74:28:27	375	374.3	374.3	2807	2802	2802	170.6/58.5	170/58.3	170.3/58.1
S-IVB Impact	74:30:08	75:07:03	75:08:00	NA			NA			NA		
DOI	78:35:30	78:33:44	78:33:44	24.1	24.2	24.2	206	210.3	209.5	58.6/10.9	58.5/10.3	58.5/10.9
DOI Trim	NA			NA			NA			NA		
Undock	96:13:31	96:13:31	96:13:31	NA			NA			NA		
CSM Sep	96:13:31	96:13:31	96:13:31	1.4	6.8	6.8	1.0	1.0	1.0	60.5/8.9	59.2/10.2	59.2/10.4
CSM 2nd Sep		102:30:00	102:30:00	NA	6.8	6.8	NA	1.0	1.0	NA	59.7/11.2	59.7/11.2
CSM Circ	97:41:44	103:21:42	103:21:42	5.9	4.6	4.6	99.6	81.6	81.0	68.2/51.8	68.0/53.1	68.0/53.1
PDI	98:34:41	104:17:25	104:17:25	721.5	720.5	730	6696.3	6703.9	6703	0/0	0/0	0/0
Landing	98:46:42	104:29:25	104:29:35	NA			NA			NA		

NA - Not Applicable

TABLE 7

APOLLO 16 LUNAR ORBIT SUMMARY
END OF MISSION

Maneuver	GROUND ELAPSED TIME (GET) AT IGNITION (HR:MIN:SEC) Pre-Launch Plan	Real-Time Plan	Actual	BURN TIME (SECONDS) Pre-Launch Plan	Real-Time Plan	Actual	VELOCITY CHANGE (FEET PER SECOND-FPS) Pre-Launch Plan	Real-Time Plan	Actual	RESULTING APOLUNE/PERILUNE (NM) Pre-Launch Plan	Real-Time Plan	Actual
CSM LOPC	152:28:48	169:17:40	169:17:40	9.1	7.1	7.0	158.7	124.7	124	62 / 57.3	64.5 / 55.3	65.6 / 55
ASCENT	171:45:09	175:43:35	175:43:35	434.3	436.8	3.1	6047.9	6054.9		45.4 / 9	41.1 / 8.9	40.2 / 7.9
TWEAK		175:54:05	175:54:05	-	-	-	-	10	10			
TPI*	172:39:23	176:37:52	176:37:52	2.5	3.1	3.1	50.3	77.7	78	61.9 / 44	63.9 / 40.1	64.2 / 40.1
Docking	173:50:00	177:48:26	177:53:13	NA			NA			NA		
LM JETT	177:31:15	195:10:00	195:12:00	NA			NA			NA	68.0 / 53.7	67.8 / 53.8
CSM SEP	177:36:15	195:15:00	195:15:00	13.2	6.8	6.8	2.0	2.0	2.0	61.7 / 59.5	66.4 / 52.7	66.3 / 52.6
ASC Deorb	179:16:29	203:08:09	NP	95.5	150.9	NP	229.6	364.0	NP	NA	68.0 / -130.9	NP
ASC Impact	179:39:29	203:25:16	NP	NA			NA			NA		
LOPC-2	193:13:46	NP	NP	15.8			282.5			62.9 / 57.9		
Shaping	216:49:12	NP	NP	2.2			38			85 / 55		
SAT JETT	218:02:08	196:13:55	196:13:55	NA			NA			85 / 55	66.6 / 52.8	66.6 / 52.8

*APS only, does not include the nominal 10-sec RCS ullage (21.8 fps)

NA - Not Applicable NP - Not Performed

TABLE 8

APOLLO 16 TRANSEARTH MANEUVER SUMMARY
END OF MISSION

Maneuver	GROUND ELAPSED TIME (GET) AT IGNITION (HR:MIN:SEC)			BURN TIME (SECONDS)			VELOCITY CHANGE (FEET PER SECOND-FPS)			GET ENTRY INTERFACE (EI) VELOCITY (FPS) AT EI FLIGHT PATH ANGLE AT EI		
	Pre-Launch Plan	Real-Time Plan	Actual	Pre-Launch Plan	Real-Time Plan	Actual	Pre-Launch Plan	Real-Time Plan	Actual	Pre-Launch Plan	Real-Time Plan	Actual
TEI (SPS)	222:20:33	200:33:20	200:33:20	150.5	162.1	162.4	3212.2	3370.9	3370.0	290:22:45 36,175.8 -6.5	265:48:44 36,196.3 -6.51	265:48:40 36,196.9 -7.44
MCC-5	239:23:03	239:20:55	239:21:02	0.0	8.3	8.3	0.0	3.4	3.4	290:22:45 36,175.8 -6.5	290:23:36 36,196.4 -6.5	290:23:34 36,196.4 -6.5
MCC-6	268:22:45		NP	0.0		NP	0.0		NP	290:22:45 36,175.8 -6.5		NP NP NP
MCC-7	287:22:45	287:23:00	287:23:24	0.0	3.5	3.5	0.0	1.4	1.4	290:22:45 36,175.8 -6.5	290:23:32 36,196.1 -6.5	290:23:32 36,196.4 -6.5
CM/SM SEP	290:07:45	290:09:31	290:08:31	NA			NA			NA NA NA		
ENTRY	290:22:45	290:23:31	290:23:31	NA			NA			290:22:45 36,175.8 -6.5		290:23:31 36,196.2 -6.55
SPLASH	290:36:03	290:36:55	290:37:01	NA			NA			NA NA NA		

NA - Not Applicable NP - Not Performed

TABLE 9

APOLLO 16 CONSUMABLES SUMMARY*
END OF MISSION

CONSUMABLE (TOTAL QUANTITY	FLIGHT LOAD	FLIGHT PLANNED REMAINING	ACTUAL REMAINING
CM RCS PROP (POUNDS)	233.2	173.9	181.7
SM RCS PROP (POUNDS)	1,342.4	580.8	570.0
SPS PROP (POUNDS	40,544.2	1,681.6	2,399.0
SM HYDROGEN (POUNDS)	79.0	20.9	24.0
SM OXYGEN (POUNDS)	961.0	356.4	424.0
LM RCS PROP (POUNDS)	631.2	0.0	345.0**
LM DPS PROP (POUNDS)	19,482.9	757.6	1,155.0
LM APS PROP (POUNDS)	5,288.3	244.7	426.0**
LM A/S OXYGEN (POUNDS)	4.8	4.2	4.6
LM D/S OXYGEN (POUNDS)	93.4	47.0	50.8***
LM A/S WATER (POUNDS)	85.0	52.4	46.2***
LM D/S WATER (POUNDS)	393.2	67.5	RESIDUALS 7.8
LM A/S BATTERIES (AMP-HOURS)	592.0	NOT AVAILABLE	
LM D/S BATTERIES (AMP-HOURS)	2,075.0	NOT AVAILABLE	
LRV BATTERIES (AMP-HOURS)	121.0/121.0	64.5/64.5	158 TOTAL****

* All values adjusted to be compatible with quantities carried in Real-Time Computer Complex (tanked values)

** 53.8 pounds of LM RCS propellant transferred inflight to LM APS tanks.

*** LM Jettison

**** 158 total based on real-time analysis of power consumed during EVAs.

TABLE 10

SA-511 LAUNCH VEHICLE DISCREPANCY SUMMARY

- S-II/J-2 engine No. 4 helium tank decay at ESC. Open
- S-IVB APS-1 helium leak. Open
- S-IVB APS-2 helium leak. Open
- S-IVB Battery No. 2 depletion time. Open
- IU thermal conditioning system GN_2 leak. Open
- IU CCS lost at 27 hours. Open
- IU EMR Bits 13 and 14 at 6:46 to 7:01 hours. Open
- ST-124 cross range velocity shift at F +0.8 hours. Open
- IU EDS spare yaw rate gyro ramp for a 2-second period during prelaunch checks. Open

TABLE 11

COMMAND/SERVICE MODULE 113 DISCREPANCY SUMMARY

- ECS mixing valve fluctuation in auto mode. Open
- Onboard TV monitor horizontal lines. Open
- SPS oxidizer tank pressure reference lost. Open
- Hydrogen tank No. 3 heat leakage excessive. Open
- False gimbal lock at GET 38:18:55. Open
- Unable to uplink commands at GET 44:00. Open
- First Mapping Camera retract cycle time twice normal. Open
- Mass Spectrometer boom talkback barberpole. Open
- SPS secondary engine yaw actuator oscillations. Open
- Twenty percent of laser altimeter data erroneous. Open
- Pan camera film overexposure. Open
- LiOH cannisters sticking. Open
- Gamma ray cover open approximately 30°. Open
- Event timer erratic at 244:20 GET. Open
- CM cabin fan made unusual noise at 202:17 GET. Open
- Master alarm at 195:06 GET. Open
- Battery vent manifold pressure went to 14 psi during battery charging. Open
- Mapping camera stellar lens glare shield crushed against EVA handrail. Open
- Intermittent loss of signal. HGA would not acquire at 260:00 GET. Open
- Inertial subsystem coupling data unit fail alarms. Open

TABLE 12

LUNAR MODULE 11 DISCREPANCY SUMMARY

- Strips of paint peeling off panels at 7:18 GET. Closed
- Steerable antenna locked in yaw at 94:35 GET. Open
- RCS System A helium regulator failure at 95:05 GET. Open
- Landing Radar indicated bad data at 96:37 GET. Open
- Apparent blockage in ECS suit loop. Open
- Panels 186, 187, 188, and 189 tore loose at ascent stage liftoff. Open
- LM ascent stage tumbling after jettison at 195:17 GET. Open
- Ascent engine chamber pressure measurement fluctuated during ascent at 175:32 GET. Open
- Rendezvous radar drifting prior to lunar liftoff. Open
- MESA deployment abnormal. Open

TABLE 13

LUNAR ROVING VEHICLE DISCREPANCY SUMMARY

- Rear wheel steering inoperative at 119:34 GET. Open
- Battery 2 read off scale low at 119:34 GET. Open
- Battery temperature meters read off scale low at 119:34 GET. Open
- Attitude indicator broken at 144:12 GET. Open
- Right rear fender knocked off. Open
- Battery 2 "ampere-hour remaining" meter failure during EVA-3. Open
- Battery 1 "temperature" meter failure during EVA-3. Open
- Batteries 1 and 2 failure to cool down between EVAs. Open
- Battery 1 amp-hours remaining meter readings decreased excessively. Open

TABLE 14

APOLLO 16 CREW/EXPERIMENT DISCREPANCY SUMMARY

- LMP reported PGA suit legs too short at 55:49 GET. Open
- ALSEP subpackage 2 fell off carrier bar at 120:40 GET. Open
- ALSEP Heat Flow Experiment cable broken by crew member. Open
- ALSEP No. 3 spike on mortar package pallet did not deploy. Open
- ALSEP Thumper arm and fire knob required 2 actuations to fire at position No. 2. Closed
- Cosmic ray detector panel 4 curtain raising cable broke. Open
- Purge valve pull pin came off CDR's suit during EVA. Open
- CDR broke 2 inches off OPS antenna during ingress after EVA-2. Open
- During Thumper deployment at 121:19 GET taut cables pulled central station out of alignment. Open
- Vertical staff gnomon separated from leg assembly at 146:22 GET. Open
- Dispensor of documented sample bags fell off several times during EVAs. Open
- Velcro came off sample bags. Open
- TV camera sun shade came loose at 107:40 GET. Open
- Mortar box pitch angle data erratic. Open
- Pan camera lens torque current erratic on Rev 47. Open
- Unexplained MESA temperature response during lunar stay. Open
- Gas separator inoperative. Open
- CDR and LMP suit wrist disconnects hard to lock before SIM EVA. Open
- LMP biomedical readouts bad. Open

TABLE 14 (Continued)

- Suitloop pressure readout 0.5 psi high during CMP EVA at 243:50 GET. Open
- ALSEP Passive Seismic Experiment temperature rise at 261:00 GET. Open
- Vacuum cleaner became inoperative at 192:52 GET. Open

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