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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MISSION SCIENCE REQUIREMENTS

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APOLLO MISSION J-1

(APOLLO 16)

VOLUME I
EXPERIMENTS REQUIREMENTS

REVIEW DRAFT

JULY 15, 1970

LUNAR MISSIONS OFFICE
SCIENCE AND APPLICATIONS DIRECTORATE
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

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Prepared by TRW Systems

for

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Contract NAS 9-8166

MISSION SCIENCE REQUIREMENTS

J-1 TYPE MISSION (APOLLO 16)

VOLUME I

EXPERIMENTS REQUIREMENTS

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INTRODUCTION

The Mission Science Requirements Document (MSRD) has been prepared by TRW Systems under the direction of the Lunar Missions Office, Science and Applications Directorate (S&AD). This document contains the science requirements for the Apollo J-1 Mission. It is intended for use by the Manned Spacecraft Center (MSC) and offsite personnel in program and mission planning and in the integration and implementation of mission science requirements.

The MSRD consists of two volumes. Volume I, Experiments Requirements, contains two sections. Section I lists the experiments assigned to the mission, identifies the Principal Investigator and designated MSC Point-of-Contact for each experiment, and prioritizes experiments to facilitate replanning and rescheduling if a contingency arises during the mission. Section II contains detailed experiments (DE's) which include the necessary details for incorporating science requirements into the Flight Plan and other key mission documents. These DE's also present the criteria for data retrieval and evaluation, and for determining if requirements have been met during the missions.

The DE's comply with the requirements of the Apollo Flight Mission Assignments Directive, Office of Manned Space Flight. They are intended for integration with other mission requirements in the Mission Requirements Document (MRD) published by the Systems Engineering Division, Apollo Spacecraft Program Office. Detailed procedures for implementing these DE's are presented in Volume II of the Mission Science Requirements Document and in other documents identified in Volume I, Section II.

Volume II of the MSRD, Mission Science Planning, is divided into the following seven sections: Section I, General Mission Planning; Section II, Science Equipment; Section III, Operational Requirements Plan; Section IV, Photography Plan; Section V, Lunar Traverse Plan; Section VI, Lunar Receiving Laboratory Plan; and Section VII, Contingency Plan. Volume II includes detailed data for use in mission planning and for implementation of the DE's in Volume I. These data are intended as source material for other MSC documents such as the Flight Plan, Lunar Surface Procedures, Flight Mission Rules, Voice Data Plan, and Operational Trajectory.

The publication schedule for Volume I is independent of that for Volume II. Because Volume I supports the MRD, it will be published about one month before the MRD. The normal publication schedule for Volume I is L-13 months (Review Draft), L-11 months (Final Document) and L-9, L-7, and L-5 months (Revisions A, B, and C, respectively). Volume II, which supports other MSC documents, will normally be published at L-9 months (Review Draft), L-5 months (Final Document), and L-2.5 months (Revision).

The MSRD is the primary source for Apollo Mission J-1 science requirements. All proposed changes and requests for additional copies should be submitted in writing to the following representatives of the Lunar Missions Office, MSC, Houston, Texas: Mr. Richard R. Baldwin/TM1, Science Mission Manager, and Mr. Bruce H. Walton/TM1, Technical Assistant.

SECTION I. GENERAL SCIENCE REQUIREMENTS

1.1 GENERAL

This section summarizes the science objectives and experiments for the J-1 Mission (Apollo 16). Included are the mission objectives and listings of the assigned lunar orbital and surface science experiments, the designated Manned Spacecraft Center Point-of-Contact and the Principal Investigator responsible for each experiment, and the priority for conducting the experiments if a contingency occurs during the mission.

1.2 MISSION SCIENCE OBJECTIVES

Mission science objectives are divided into primary and detailed objectives. The primary science objectives are assigned by the Office of Manned Space Flight (OMSF) and appear in the Apollo Flight Mission Assignments Directive (Reference 1). Primary science objectives assigned to the Apollo J-1 mission are as follows:

1. Investigate, survey, and sample representative material in a preselected region of the central peaks and floor of the crater Copernicus.

or

1a. Investigate, survey, and sample representative cones, domes, and ridges in a preselected region of the Marius Hills area.

2. Emplace and activate experiments for the purpose of examining local, regional, and subsurface structures and environmental characteristics.

3. Investigate, survey, and measure the lunar surface and the near-moon environment from lunar orbit.

Primary science objectives are divided into "numbered" science experiments and detailed objectives. The numbered experiments are those which have been approved by the Manned Space Flight Experiment Board (MSFEB) and subsequently assigned to the mission by the OMSF. The detailed objectives are subdivided into operational objectives, engineering tests, and "unnumbered" science experiments. Only the numbered and unnumbered science experiments are contained in this document; the others are presented in the Mission Requirements Document (Reference 2) published by the Systems

Engineering Division (SED), Apollo Spacecraft Program Office (ASPO). Changes in objectives and experiment assignments are governed by Configuration Control Board (CCB) Directives issued by NASA Headquarters.

1.3 MISSION SCIENCE EXPERIMENTS

The numbered and unnumbered science experiments for this mission are divided into lunar orbital and lunar surface groups. Lunar orbital experiments are listed in Table 1-1, lunar surface experiments in Table 1-2. Also listed are the Principal Investigator (PI) or Chairman of the Principal Investigator Team and the Point-of-Contact assigned within the Science and Applications Directorate (S&AD) for the experiment.

Any questions that arise concerning science and operational requirements of a particular experiment should be directed to the designated S&AD Point-of-Contact who represents the interface between the Manned Spacecraft Center (MSC) and the PI. Problems arising relative to the integration of these experiments into mission and program planning should be referred to the assigned S&AD Science Mission Manager, Mr. Richard R. Baldwin/TM1.

1.4 EXPERIMENTS PRIORITIES

The science experiments for the J-1 Mission are listed in Table 1-3 in descending order of priority. Prioritization is based on considerations such as the following: the science value of the experiment and the science benefits expected, results obtained or changes in experiments from previous missions, the science "opportunity" for the mission such as landing site or hardware flown for the first time, and the role of the experiment in integrated science planning for future flights and programs.

Prioritization is of significance only when one or several of the planned experiments cannot be accomplished because some contingency or abnormal condition occurs during the mission which would impact major items such as consumables, crew operations and participation, or the mission timeline. This priority listing is provided to facilitate the assessment of the relative importance of the science experiments which will, in turn, aid in real-time replanning of the science portions of the mission. Such information is intended to maximize the science return from the mission in case of contingency situations when tradeoffs based on crew requirements, spacecraft capabilities, and time available can be made and assessed.

Table 1-1. Lunar Orbit Experiments And Assigned Science Personnel

LUNAR ORBIT EXPERIMENT		PRINCIPAL INVESTIGATOR	S&AD POINT-OF-CONTACT
NO.	TITLE		
S-160	Gamma-Ray Spectrometer	Dr. James R. Arnold Chemistry Department University of California at San Diego La Jolla, California 92037 (714) 453-2000 Ext. 1453	Mr. Leo E. James/TM2 Lunar Orbital Experiments Office Lunar Missions Office NASA Manned Spacecraft Center Houston, Texas 77058 (713) 483-4621
S-161	X-Ray Fluorescence	Dr. Isidore Adler Theoretical Studies Branch, Code 641 NASA Goddard Space Flight Center Greenbelt, Maryland 20771 (301) 982-5759	Mr. Leo E. James/TM2 Lunar Orbital Experiments Office Lunar Missions Office NASA Manned Spacecraft Center Houston, Texas 77058 (713) 483-4621
S-162	Alpha Particle Spectrometer	Dr. Paul Gorenstein American Science and Engineering, Inc. 11 Carleton Street Cambridge, Massachusetts 02142 (617) 868-1600 Ext. 214	Mr. Leo E. James/TM2 Lunar Orbital Experiments Office Lunar Missions Office NASA Manned Spacecraft Center Houston, Texas 77058 (713) 483-4621
S-164	S-Band Transponder (CSM/LM and Sub-satellite)	Mr. William L. Sjogren Organization 156-251 Jet Propulsion Laboratory 4800 Oak Grove Drive Pasadena, California 91103 (213) 354-4868	Mr. Patrick E. Lafferty/TM2 Lunar Orbital Experiments Office Lunar Missions Office NASA Manned Spacecraft Center Houston, Texas 77058 (713) 483-4621

Table 1-1. Lunar Orbit Experiments and Assigned Science Personnel (Continued)

LUNAR ORBIT EXPERIMENT		PRINCIPAL INVESTIGATOR	S&AD POINT-OF-CONTACT
NO.	TITLE		
S-165	Mass Spectrometer	Dr. John H. Hoffman Atmospheric & Space Sciences University of Texas at Dallas P. O. Box 30365 Dallas, Texas 75230 (214) 231-1471 Ext. 347	Mr. Vernon M. Dauphin/TM2 Lunar Orbital Experiments Office Lunar Missions Office NASA Manned Spacecraft Center Houston, Texas 77058 (713) 483-4621
S-173	Particle Shadows/ Boundary Layer (Subsatellite)	Dr. Kinsey A. Anderson Space Sciences Laboratory University of California at Berkeley Berkeley, California 94720 (415) 642-1313	Mr. Patrick E. Lafferty/TM2 Lunar Orbital Experiments Office Lunar Missions Office NASA Manned Spacecraft Center Houston, Texas 77058 (713) 483-4621
S-174	Magnetometer (Subsatellite)	Dr. Paul J. Coleman, Jr. Department of Planetary & Space Sciences University of California at Los Angeles Los Angeles, California 90024 (213) 825-1776	Mr. Patrick E. Lafferty/TM2 Lunar Orbital Experiments Office Lunar Missions Office NASA Manned Spacecraft Center Houston, Texas 77058 (713) 483-4621
S-177	UV Photography - Earth and Moon	Dr. Tobias C. Owen IIT Research Center 10 West 35th Street Chicago, Illinois 60616 (312) 225-9630	Mr. Samuel N. Hardee, Jr./TM2 Lunar Orbital Experiments Office Lunar Missions Office NASA Manned Spacecraft Center Houston, Texas 77058 (713) 483-4621

Table 1-1. Lunar Orbit Experiments And Assigned Science Personnel (Continued)

LUNAR ORBIT EXPERIMENT	PRINCIPAL INVESTIGATOR	S&AD POINT-OF-CONTACT
CM Orbital Science Photography, includes use of: • Hasselblad Electric Camera • Hasselblad Electric Data Camera • Maurer Data Acquisition Camera	<u>CSM Orbital Science Photographic Team</u> Mr. Frederick J. Doyle, Chairman Topographic Division U. S. Geological Survey U. S. Department of Interior Washington, D. C. 20242 (202) 343-9445	Mr. Andrew W. Patteson/TJ Mapping Sciences Laboratory NASA Manned Spacecraft Center Houston, Texas 77058 (713) 483-6287
SM Orbital Science Photography, includes use of: • 3-Inch Mapping Camera • 24-Inch Panoramic Camera • Laser Altimeter	<u>CSM Orbital Science Photographic Team</u> Mr. Frederick J. Doyle, Chairman Topographic Division U. S. Geological Survey U. S. Department of Interior Washington, D. C. 20242 (202) 343-9445 <u>Laser Altimeter Data Analysis</u> Dr. William M. Kaula Institute of Geophysics and Planetary Physics University of California at Los Angeles Los Angeles, California 90024 (203) 825-4363	Mr. Samuel N. Hardee, Jr./TM2 Lunar Orbital Experiments Office Lunar Missions Office NASA Manned Spacecraft Center Houston, Texas 77058 (713) 483-4621

Table 1-2. Lunar Surface Experiments and Assigned Science Personnel

LUNAR SURFACE EXPERIMENT		PRINCIPAL INVESTIGATOR	S&AD POINT-OF-CONTACT
NO.	TITLE		
S-031	Passive Seismic (ALSEP Experiment)	Dr. Gary V. Latham Lamont-Doherty Geological Observatory Columbia University Palisades, New York 10964 (914) 359-2900	Mr. Wilbert E. Eichelman/TM3 Lunar Surface Experiments Office Lunar Missions Office NASA Manned Spacecraft Center Houston, Texas 77058 (713) 483-2666
S-033	Active Seismic (ALSEP Experiment)	Dr. Robert L. Kovach Department of Geophysics Stanford University Palo Alto, California 44300 (415) 286-2525 Ext. 4827	Mr. Wilbert E. Eichelman/TM3 Lunar Surface Experiments Office Lunar Missions Office NASA Manned Spacecraft Center Houston, Texas 77058 (713) 483-2666
S-034	Lunar Surface Magnetometer (ALSEP Experiment)	Dr. Palmer Dyal, Code N204-4 Space Science Division/Electro- dynamics Branch NASA Ames Research Center Moffett Field, California 94035 (415) 961-1111 Ext. 2706	Mr. Timothy T. White/TM3 Lunar Surface Experiments Office Lunar Missions Office NASA Manned Spacecraft Center Houston, Texas 77058 (713) 483-2666
S-037	Heat Flow (ALSEP Experiment)	Dr. Marcus G. Langseth Lamont-Doherty Geological Observatory Columbia University Palisades, New York 10964 (914) 359-2900	Mr. Wilbert F. Eichelman/TM3 Lunar Surface Experiments Office Lunar Missions Office NASA Manned Spacecraft Center Houston, Texas 77058 (713) 483-2666
S-059	Lunar Field Geology	Dr. William R. Muehlberger Geology Department University of Texas at Austin Austin, Texas 78712 (512) 475-5011	Mr. Martin L. Miller/TM3 Lunar Surface Experiments Office Lunar Missions Office NASA Manned Spacecraft Center Houston, Texas 77058 (713) 483-2666

Table 1-2. Lunar Surface Experiments And Assigned Science Personnel (Continued)

LUNAR SURFACE EXPERIMENT NO.	LUNAR SURFACE EXPERIMENT TITLE	PRINCIPAL INVESTIGATOR	S&AD POINT-OF-CONTACT
S-078	Laser Ranging Retro-Reflector	Dr. James E. Faller Scott Laboratory Wesleyan University Middletown, Connecticut 06457 (203) 347-4421 Ext. 291	Mr. Timothy T. White/TM3 Lunar Surface Experiments Office Lunar Missions Office NASA Manned Spacecraft Center Houston, Texas 77058 (713) 483-2666
S-152	Cosmic Ray Detector (Sheets)	Dr. Robert L. Fleischer General Physics Laboratory General Electric R&D Center Schenectady, New York 12305 (518) 346-8771 Ext. 6469	Mr. Manuel D. Lopez/TM3 Lunar Surface Experiments Office Lunar Missions Office NASA Manned Spacecraft Center Houston, Texas 77058 (713) 483-2666
S-198	Portable Magnetometer	Dr. Palmer Dyal, Code N204-4 Space Science Division/Electro-dynamics Branch NASA Ames Research Center Moffett Field, California 94035 (415) 961-1111 Ext. 2706	Mr. Timothy T. White/TM3 Lunar Surface Experiments Office Lunar Missions Office NASA Manned Spacecraft Center Houston, Texas 77058 (713) 483-2666
S-200	Soil Mechanics	Dr. James K. Mitchell Department of Civil Engineering University of California at Berkeley Berkeley, California 94720 (415) 642-1262	Mr. Martin L. Miller/TM3 Lunar Surface Experiments Office Lunar Missions Office NASA Manned Spacecraft Center Houston, Texas 77058 (713) 483-2666

Table 1-2. Lunar Surface Experiments And Assigned Science Personnel (Continued)

LUNAR SURFACE EXPERIMENT	PRINCIPAL INVESTIGATOR	S&AD POINT-OF-CONTACT
Contingency Sample Collection	To Be Supplied.	Mr. Martin L. Miller/TM3 Lunar Surface Experiments Office Lunar Missions Office NASA Manned Spacecraft Center Houston, Texas 77058 (713) 483-2666
Selected Sample Collection	To Be Supplied.	Mr. Martin L. Miller/TM3 Lunar Surface Experiments Office Lunar Missions Office NASA Manned Spacecraft Center Houston, Texas 77058 (713) 483-2666

Table 1-3. J-1 Mission Lunar Science Experiment Priority

EXPERIMENT	PRIORITY
Contingency Sample Collection	1
ALSEP Array D	2
Heat Flow (S-037)	2.1
Passive Seismic (S-031)	2.2
Active Seismic (S-033)	2.3
Lunar Surface Magnetometer (S-034)	2.4
Selected Sample Collection	3
Lunar Field Geology (S-059)	4
SM Orbital Science Photography	5
Gamma-Ray Spectrometer (S-160)	6
X-Ray Fluorescence (S-161)	7
Subsatellite	8
S-Band Transponder (S-164)	
Particle Shadows/Boundary Layer (S-173)	
Subsatellite Magnetometer (S-174)	
Laser Ranging Retro-Reflector (S-078)	9
Alpha Particle Spectrometer (S-162)	10
Mass Spectrometer (S-165)	11
Soil Mechanics (S-200)	12
Portable Magnetometer (S-198)	13
UV Photography-Earth and Moon (S-177)	14
CM Orbital Science Photography	15
Cosmic Ray Detector (Sheets) (S-152)	16
S-Band Transponder (S-164)	17

SECTION II. EXPERIMENTS REQUIREMENTS

2.1 GENERAL

This section contains detailed requirements for the lunar orbital and lunar surface experiments assigned to the mission. The requirements for each experiment are summarized in a Detailed Experiment (DE). Each DE provides the information necessary to support mission planning, integration, and implementation activities.

2.2 EXPERIMENT IMPLEMENTATION

The timeline included in the mission Flight Plan identifies the basic activities which the crew must perform to satisfy the science requirements for each experiment. Details necessary for implementing the science requirements contained in the DE's are presented in other mission documents. These documents include Volume II of the Mission Science Requirements Document, the Mission Requirements document, Lunar Surface Procedures, Photographic and Television Procedures, LM Lunar Surface Checklist, and the CMP Solo Book.

2.3 DEFINITIONS

The following definitions apply to terms appearing in the DE's, and are consistent with the definitions used in the Mission Requirements Document.

2.3.1 DATA REQUIREMENTS PRIORITIES

The priorities assigned to each item in the Data Requirements portion of the DE's are based upon the following definitions:

a) Mandatory (M) - A mandatory item is essential for evaluation of the objective.

b) Highly Desirable (HD) - A highly desirable item furnishes information which aids evaluation of the objective. These items supply information which is available from alternate sources or which is not required for evaluation of the essential parts of the objective.

2.3.2 TELEMETRY DATA MODE

The number appearing in the "Mode" column of the telemetry listings in the DE's indicate the following:

a) "1" - Telemetry available in the high bit rate format only.

b) "2" - Telemetry available in both the high bit rate and low bit rate formats.

Data storage equipment (DSE) recordings are acceptable in lieu of real-time telemetry if playback occurs at the first opportunity on the next orbit when the moon no longer occults earth-spacecraft communications.

2.4 DETAILED EXPERIMENTS

The detailed experiments appearing in this section consist of lunar orbital and lunar surface science experiments. They appear in the order listed in the Contents page.

GAMMA-RAY SPECTROMETER

Conduct the Gamma-Ray Spectrometer Experiment (S-160)

Purpose

The purpose is to obtain data relating to the origin and evolution of the moon by determining the degree of chemical differentiation the moon has undergone during its development.

The functional test objectives are as follows:

FTO 1) While the CSM is in lunar orbit, measure the radiation flux at the CSM from the direction of the lunar surface to determine the degree of chemical differentiation in different regions of the lunar surface.

FTO 2) While the CSM is in transearth coast, measure the radiation flux of cislunar space to obtain background reference data and a spectrum of the cosmological gamma-ray flux.

FTO 3) While the CSM is in transearth coast, measure the CSM/SIM radioactivity background flux to determine the contribution of this flux to the experiment data.

Test Conditions

FTO 1)
FTO 2)
FTO 3) The SIM door will be jettisoned before the Gamma-Ray Spectrometer Experiment is operated. As soon as possible thereafter, the experiment will be set to the "ON" mode of operation to supply power to internal heaters and thus prevent damage to the experiment. The boom on which the experiment is mounted will be deployed within 2 hours after the SIM door has been jettisoned and power is applied to any other experiment to prevent overheating the gamma-ray detector. During experiment operation, the detector will be oriented toward the lunar surface to within ± 10 degrees of the lunar local vertical. Attitude of the CSM about the Z (yaw) axis is not critical.

The crew will actuate the "SHIELD" switch and change the position of the "STEP HIGH VOLTAGE" switch upon request by MCC.

FTO 1) The experiment will be operated in lunar orbit with the boom fully extended for 10 hours minimum (not necessarily continuous). An additional 50 hours of operation is highly desirable. Data will be obtained during as much of each orbit as possible throughout the experiment period. Concurrent operation with the X-Ray Spectrometer Experiment and the Alpha Particle Spectrometer Experiment is highly desirable.

FTO 2) The boom will be deployed and data will be collected for a minimum of 6 hours (not necessarily continuous), as soon as practicable following TEI. An additional 18 hours of operation is highly desirable.

The boom may be in the deployed position while the CSM rolls in the PTC thermal control mode. The final TBD hours of this experiment period will be conducted with the boom extended about 8 feet and then about 15 feet from the SIM. The procedure for obtaining the position is TBD.

FTO 3) While the boom is in the SIM, the experiment will be operated for a minimum of 1 hour after completion of FTO 2) in order to measure the CSM/SIM radioactivity level. An additional 1-hour period of operation is highly desirable.

Success Criteria

FTO 1)
FTO 2)
FTO 3) The experiment data defined under the Test Conditions for FTO 1), FTO 2), and FTO 3) shall be transmitted to earth and provided to the Principal Investigator.

Evaluation

FTO 1)
FTO 2)
FTO 3) The data analysis and evaluation will be conducted postflight by the Principal Investigator. The linearity of the system and the detector response as a function of energy will be determined by inflight calibration of the system using monoenergetic sources. Least squares analysis and statistical correlation techniques will be used to convert the measured pulse height spectra to the photon spectra incident on the detector. Interfering radiation (such as contributed by the CSM/SIM environment) will be considered to enhance data quality.

The characteristic lines of these spectra will be related to the abundance of geochemical sources on the lunar surface through laboratory and field tests. (Astronaut records, photographs, BET, preflight data, concurrent scientific experiments data, CG 0001 V, SL 1085 T, SL 1086 T, SL 1087 K, SL 1208 T, and TBD)

Data Requirements

1) Telemetry Measurements:

Measurement Number	Description	TM	Mode	Priority
CG 0001 V	Computer Digital Data - 40 Bits	PCMD+	2	M*
SL 1085 T	Detector Temperature	PCM	2	M*
SL 1086 T	Electronics Temperature	PCM	2	HD
SL 1087 K	Gamma-Ray Spectrometer Output	FM	TBD	M*
SL 1208 T	Temp. Thermal Envir. - Gamma	PCM	1	HD
TBD	SIM Temperature	TBD	TBD	TBD

*These measurements are M during mandatory experiment operation and HD during highly desirable experiment operation.

2) Astronaut Logs or Voice Records:

a) Description and GET of the following events during mandatory experiment operation: (M)

1) Change of experiment mode ("ON" and "OFF").

2) Deployment and retraction of experiment boom.

3) Operation of "STEP HIGH VOLTAGE" switch.

4) Operation of the "SHIELD" switch.

b) Description and GET of the following events during highly desirable experiment operation: (HD)

1) Change of experiment modes ("ON" and "OFF").

2) Deployment and retraction of experiment boom.

3) Operation of the "STEP HIGH VOLTAGE" switch.

4) Operation of the "SHIELD" switch.

3) Photographs: (HD)

Photographs taken by the 3-Inch Mapping or 24-Inch Panoramic Cameras during operation of the Gamma-Ray Spectrometer Experiment. Requirements for these photographs will be defined in the SM Orbital Photography Experiment.

4) Trajectory Data:

   a) Best estimate of trajectory (BET) during mandatory experiment operation periods. (M)

   b) Best estimate of trajectory (BET) during highly desirable experiment operation periods. (HD)

5) Concurrent Scientific Experiments Data: (HD)

   Reduced data obtained by X-Ray Fluorescence and Alpha Particle Spectrometer Experiments during periods of concurrent operation with the Gamma-Ray Spectrometer Experiment.

6) Preflight Data: (M)

   Preflight checkout and calibration data in accordance with procedure TBD.

GAMMA-RAY SPECTROMETER

Background and Justification

The Gamma-Ray Spectrometer Experiment is intended to obtain evidence relating to the origin and evolution of the moon. This will be accomplished by measuring the radiation flux from the surface of the moon while the CSM is in lunar orbit. This flux has two components. The first is the decay of natural radioactivity mixed in lunar surface material. The principal contributors will be isotopes of potassium, uranium and thorium, plus radioactive "daughters" of the latter two elements. The intensity of these contributors is a sensitive function of the degree of chemical differentiation of the moon. Chemical differentiation is the result of substantial melting within the moon at any time in the past or present, and will be indicated at the lunar surface by concentrations of various elements which are distinctive from the mean values measured in the solar atmosphere and in meteorites. The second is gamma radiation which will be produced by the interaction of cosmic ray particles with the nuclei of chemical elements making up the lunar surface. This experiment will extend our chemical information from a few landing sites to the entire area overflown by the CSM, with spatial resolution limited only by the total time of data collection.

The history of gamma-ray experiments relating to the moon's surface is not extensive. Gamma-ray experiments were flown on Rangers III, IV, and V, but no significant data were obtained from the moon. The USSR included a gamma-ray experiment on Luna 10, and possibly on Luna 11 and 12. The data from Luna 10 are inconclusive, and no data have been published for Luna 11 and 12. The present Gamma-Ray Spectrometer Experiment was originally developed for the Lunar Orbiter.

Previous Mission Objectives

Experiment Number	Title	Mission
None		

X-RAY FLUORESCENCE

Conduct the X-Ray Fluorescence Experiment (S-161).

Purpose

The purpose is to measure the instantaneous fluorescent X-ray flux from the lunar surface, and to monitor both the direct solar X-ray flux which produces this fluorescence and the background galactic X-ray flux in order to obtain a gross analysis of the elemental composition of the lunar surface materials.

The functional test objectives are as follows:

FTO 1) While the CSM is in lunar orbit, measure the lunar fluorescent X-ray flux albedo and monitor the solar X-ray flux incident on the lunar surface.

FTO 2) While the CSM is in transearth coast, monitor the background X-ray flux in deep space.

Test Conditions

FTO 1)
FTO 2) The SIM door will be jettisoned before the X-Ray Fluorescence Experiment is operated. As soon as possible thereafter, the experiment will be set to the "STANDBY" mode to operate internal heaters and thus prevent damage to the instrument. The experiment must be operated in either the "STANDBY" or "ON" mode during the entire experiment period.

The CSM attitude will be changed as necessary to prevent direct sunlight from entering the 60 degree conical field-of-view of the experiment detector. If necessary to prevent damage, the experiment will be switched to "OFF".

Firings of RCS jets (A2, A4, B1, and B4), urine dumps, and waste water dumps, which may contaminate the experiment and degrade scientific data, will be prohibited during the experiment operating period.

FTO 1) The experiment will be operated in lunar orbit and data collected for 10 hours minimum with at least 8.5 hours of continuous operation. Additional operation and data collection during available time periods throughout the 72-hour SIM experiment period will be highly desirable to improve the statistical quality of experiment data. During data collection, the CSM attitude will be controlled so that the fluorescence detector is oriented to within ±5 degrees of the lunar local vertical. Data will be obtained during complete orbits unless interrupted by required operational activities such as DSE operation.

Concurrent operation of this experiment and the Gamma-Ray Spectrometer and the Alpha Particle Spectrometer Experiments (geochemical group) is highly desirable.

Once each activity day during the 72-hour SIM experiment period, the CSM will be maneuvered so that the fluorescence detector is oriented toward deep space at an angle of 135° to 180° with respect to the nadir. This maneuver will be performed on the dark side of the moon and the deep space background X-ray flux data collected for 15 minutes.

FTO 2) The experiment will be operated and data collected for 6 hours minimum (not necessarily continuously) during transearth coast. Collection of data for an additional 18 hours is highly desirable. Data collection will begin after the CSM is approximately 43,000 NM from the moon to minimize occultation of galactic background by the moon. Data collection will end when the CSM is about TBD NM from the earth to minimize occultation of galactic background by the earth.

At the end of this period, it will be highly desirable to determine the degree of sensor degradation caused by the sun's rays impinging on the fluorescence sensor. This may be accomplished while the CSM is in the PTC thermal control mode. However, PTC will be initiated such that data are obtained during a CSM roll of about 300 degrees before the sun's rays impinge on the sensor. Data collection will continue until MCC can determine the degree of sensor degradation.

Success Criteria

FTO 1)
FTO 2) The experiment data defined under the Test Conditions for FTO 1) and FTO 2) shall be transmitted to earth and provided to the Principal Investigator.

Evaluation

FTO 1)
FTO 2) The Principal Investigator and investigation team will study and evaluate the data at the individual investigator's laboratories. Automatic inflight calibration using internal monoenergetic sources will establish the linearity of the system and detector response as function of energy input.

Least squares analysis and statistical correlation techniques will be used to convert the measured pulse height spectra to the photon spectra incident on the detectors. This conversion to the photon spectra will allow information to be more readily distinguished.

The geochemical interpretation will be conducted under a consortium utilizing the results from this analysis and, if available, those of the Gamma-Ray and Alpha Particle Experiments. (Astronaut records, BET, preflight data, concurrent scientific experiments data, CG 0001 V, CH 3546 X through CH 3561 X, SL 1050 K, SL 1051 V through SL 1055 V, and SL 1056 T through SL 1061T).

Data Requirements

1) Telemetry Measurements:

Measurement Number	Description	TM	Mode	Priority
(TBD)	SIM Temperature	(TBD)	(TBD)	HD
CG 0001 V	Computer Digital Data - 40 Bits	PCMD+	2	M*
CH 3546 X	RCS Solenoid Activate C3/13/+X	PCME	2	HD
CH 3547 X	RCS Solenoid Activate A4/14/+X	PCME	2	HD
CH 3548 X	RCS Solenoid Activate A3/23/-X	PCME	2	HD
CH 3549 X	RCS Solenoid Activate C4/24/-X	PCME	2	HD
CH 3550 X	RCS Solenoid Activate D3/25/+X	PCME	2	HD
CH 3551 X	RCS Solenoid Activate B4/26/+X	PCME	2	HD
CH 3552 X	RCS Solenoid Activate B3/15/-X	PCME	2	HD
CH 3553 X	RCS Solenoid Activate D4/16/-X	PCME	2	HD
CH 3554 X	RCS Solenoid Activate B1/11/+Z	PCME	2	HD
CH 3555 X	RCS Solenoid Activate D2/22/+Z	PCME	2	HD
CH 3556 X	RCS Solenoid Activate D1/21/-Z	PCME	2	HD
CH 3557 X	RCS Solenoid Activate B2/12/-Z	PCME	2	HD
CH 3558 X	RCS Solenoid Activate A1/+Y	PCME	2	HD
CH 3559 X	RCS Solenoid Activate C2/+Y	PCME	2	HD
CH 3560 X	RCS Solenoid Activate C1/-Y	PCME	2	HD
CH 3561 X	RCS Solenoid Activate A2/-Y	PCME	2	HD
SL 1050 K	Pulse Height Analyzer	PCMD	2	M*
SL 1051 V	Low Voltage PS Summed Monitor	PCM	2	HD
SL 1053 V	Discriminator Ref. Voltage	PCM	2	HD
SL 1054 V	X-Ray +6.75 Volts Power Supply Monitor	PCM	2	TBD
SL 1055 V	X-Ray +5.00 Volts Digital Power Supply	PCM	2	TBD
SL 1056 T	X-Ray Processor Temperature Monitor	PCM	2	TBD
SL 1057 T	X-Ray Detector Assembly Temperature Monitor	PCM	2	TBD
SL 1059 T	X-Ray Low Voltage Power Supply Temperature Monitor	PCM	2	TBD
SL 1060 T	Lunar X-Ray Detector Temperature Monitor	PCM	2	TBD
SL 1061 T	Solar X-Ray Detector Temperature Monitor	PCM	2	TBD

*These measurements are M during mandatory experiment operation and HD during highly desirable experiment operation.

2) Astronaut Logs or Voice Records:

a) GET of experiment switch operation ("STANDBY", "ON", and "OFF") during mandatory experiment operating periods. (M)

b) GET of experiment switch operation ("STANDBY", "ON", and "OFF") during highly desirable experiment operating periods. (HD)

3) Photography: (HD)

Photographs taken by the 24-Inch Panoramic Camera and 3-Inch Mapping Camera during operation of the X-Ray Fluorescence Experiment Requirements for these photographs will be defined in the SM Orbital Photography Experiment.

4) Trajectory Data:

a) Best estimate of trajectory (BET) during mandatory experiment operation. (M)

b) Best estimate of trajectory (BET) during highly desirable experiment operation. (HD)

5) Concurrent Scientific Experiments Data: (HD)

Data obtained by Gamma-Ray Spectrometer and Alpha Particle Spectrometer Experiments during periods of concurrent operation with the X-Ray Fluorescence Experiment.

6) Preflight Data: (M)

Instrument calibration and checkout data in accordance with procedure (TBD).

Background and Justification

The X-Ray Fluorescence Experiment is one of a group of experiments designed to perform a remote compositional survey of the lunar surface from lunar orbit. The other measurements in this group involve gamma-ray and alpha particle measurements made from lunar orbit. Similar experiments either have been flown on or have been planned for the OGO, OSO, AIMP, and Orbiter spacecraft. The Russians have also attempted such an experiment in their Luna series of spacecraft.

The solar X-rays should interact with the lunar surface to produce characteristic fluorescent X-rays. The measurement of these X-rays would then be expected to yield the following information about the lunar surface:

a. Nature of surface material.

b. A measure of the homogeneity of the lunar surface as the spacecraft orbits the moon.

c. By comparison with the Gamma-Ray Spectrometer Experiment results, some idea of the extent of "gardening"* and whether the composition of the surface is like that of the subsurface.

In particular, the solar X-ray flux incident on the lunar surface will produce a substantial X-ray albedo that will consist primarily of "K" and "L" lines from the more abundant elements. This will enable the detection of the relative abundance of the elements sodium, magnesium, aluminum, silicon, potassium, calcium, and iron as determined from the measured radiation yield of the lunar surface obtained during the quiet, active, and flare periods of the sun that may occur during the experiment period. The simultaneous measurement of the solar X-ray spectrum for background information will determine the excitation conditions for the radiation yield measured. The experiment results should provide the capability to discriminate among regions that are granitic, basaltic, or meteoritic in nature.

*The outer layer of the lunar surface - regolith - is sometimes called the "gardened layer".

Previous Mission Experiments

Objective/Experiment Number	Title	Mission
None		

ALPHA PARTICLE SPECTROMETER

Conduct the Alpha Particle Spectrometer Experiment (S-162).

Purpose

The purpose is to obtain data on the gross rate of lunar surface radon evolution and on localized sources of enhanced radon emission for use in constructing a radiation map showing lunar surface inhomogeneities.

The functional test objective is as follows:

FTO 1) While the CSM is in lunar orbit, obtain alpha particle emission data from Rn^{222}, Rn^{220}, and their daughter products located on the lunar surface.

Test Conditions

FTO 1) The SIM door will be jettisoned before the Alpha Particle Spectrometer is operated. As soon as possible thereafter, the experiment will be set to the "ON" mode to maintain thermal control for the instrument. During data collection, the CSM attitude will be controlled so that the experiment sensor is oriented to within ± 5 degrees of the lunar local vertical. The CSM attitude will be changed as necessary to prevent direct sunlight from entering the ± 45 degree field-of-view of the sensor for more than 5 minutes at any one time or for more than 30 minutes total during experiment operation.

The experiment will be operated in lunar orbit and data collected for 10 hours minimum. Additional operation and data collection during available time periods throughout the 72-hour SIM experiment period will be highly desirable to improve the statistical quality of experiment data. Continuous experiment operation and data collection during complete orbits are desired. Concurrent operation of this experiment and the Gamma-Ray Spectrometer and X-Ray Fluorescence Experiment is highly desirable. Once each activity day during the 72-hour SIM experiment period, the CSM will be maneuvered so that the experiment sensor is oriented toward deep space at an angle of 135° to 180° with respect to the local vertical. This maneuver will be performed on the dark side of the moon and the background alpha particle emission data collected for 15 minutes.

Success Criteria

FTO 1) The experiment data defined under the Test Condition for FTO 1) shall be transmitted to earth and provided to the Principal Investigator.

Evaluation

FTO 1) The Principal Investigator (PI) will study and evaluate the data obtained from the MSFN receiving stations. These investigations will be conducted postflight at the PI's laboratory. Inflight calibrations using internal monoenergetic sources will establish the energy scale and resolution of the detectors. Statistically significant peaks in the energy spectrum will be identified. From these numbers it will be possible to determine the strength of the daughter alpha lines from Rn^{222}, Rn^{220} and their products, and the extent to which radon has evolved. If an important Rn^{220} effect is found, the results of this measurement become strongly coupled with the gamma-ray measurements and the two must be analyzed and interpreted together in terms of uranium content and the radon conduction properties of the lunar surface.

Examination of spatial inhomogeneities will be made in the Rn^{220} data and the results will be correlated with the X-ray and gamma-ray measurements plus topographic maps of the lunar surface. The final result will be an attempt by the entire geochemistry study group to incorporate all measurements obtained to arrive at a consistent picture of the chemical condition of the lunar surface plus the demarcation of the following possible lunar regions: unusual radon transparency such as from crevices or fissures, sites of escaping volatiles, and areas with unusually large thorium concentrations. (Astronaut records, BET, preflight data, scientific experiments data, CG 0001 V, SL 1065 K, SL 1066 K, SL 1067 K, SL 1068 T, SL 1069 V, SL 1070 T, SL 1071 T, SL 1072 V, SL 1073 V, SL 1074 V, SL 1075 V, SL 1076 V, and TBD).

Data Requirements

1) Telemetry Measurements:

Measurement Number	Description	TM	Mode	Priority
CG 0001 V	Computer Digital Data - 40 bits	PCMD+	2	M*
SL 1065 K	Alpha Particle Count	PCMD	2	M*
SL 1066 K	Detector Channel Identification	PCM	2	M*
SL 1067 K	Alpha Particle Count Rate Meter	PCM	2	HD
SL 1068 T	Temperature, Detector Monitor	PCM	2	TBD
SL 1069 V	Voltage, Power Supply/Analog Electronics	PCM	2	TBD
SL 1070 T	Temperature, Detector Monitor	PCM	2	TBD

Measurement Number	Description	TM	Mode	Priority
SL 1071 T	Temperature, Low Voltage Power Supply	TBD	2	TBD
SL 1072 V	Detector Bias Voltage	PCM	2	TBD
SL 1073 V	Voltage, Discriminator Reference	PCM	2	TBD
SL 1074 V	Voltage, Power Supply/Analog to Digital Converter	PCM	2	TBD
SL 1075 V	Voltage, Power Supply/Digital Electronics	PCM	2	TBD
SL 1076 V	Voltage, Power Supply/Summing Electronics	PCM	2	TBD
TBD**	Temperature, High Voltage Power Supply Monitor	TBD	TBD	TBD
TBD**	Voltage, Condition Monitor #2	TBD	TBD	TBD
TBD	Temperature, SIM	TBD	TBD	TBD

*These measurements are M during mandatory experiment operation and HD during highly desirable experiment operation.

**These channels are available with the instrument; however, they have not been formally included in the measurement list.

2) Astronaut Logs or Voice Records:

a) During mandatory experiment operation. (M)

1) GET and description of waste dumps

2) GET of SIM door jettison

3) GET of start and end of experiment operation periods and mode changes.

b) During highly desirable experiment operation: (HD)

1) GET and description of waste dumps

2) GET of start and end of experiment operating periods and mode changes.

3) Photography: (HD)

Photographs taken by the 24-Inch Panoramic Camera and 3-Inch Mapping Camera during operation of the Alpha Particle Spectrometer Experiment. Requirements for these photographs will be defined in the SM Orbital Photography Experiment.

4) Trajectory Data:

a) Best estimate of trajectory (BET) during mandatory experiment operation. (M)

b) Best estimate of trajectory (BET) during highly desirable experiment operation. (HD)

5) Concurrent Scientific Experiment Data: (HD)

Data obtained by Gamma-Ray Spectrometer and X-Ray Fluorescence Experiments during periods of concurrent operation with the Alpha Particle Experiment.

6) Preflight Data: (M)

Preflight calibration and checkout data in accordance with procedure (TBD).

Background and Justification

Terrestrial radon evolution is a well-known phenomenon. Observations of this effect on the earth, carried out mostly by collecting the radon, have indeed shown enhanced local emission from the surface fissures and regions having substantial uranium and thorium concentrations. The terrestrial radon transparency exhibits variations with rock type and the concentration of water. Because of the short range of alpha particles in the earth's atmosphere, it is not possible to detect this radon by the method described for use in this experiment.

A recent analysis of lunar surface data obtained during background measurements of the Surveyor alpha backscattering instruments has revealed a surface deposit of alpha particle activity of the Surveyor 5 landing site. The surface deposit indicated the presence of radon daughter products of the type that would occur as a result of radon diffusion. These recent Surveyor results provide the following favorable indications for the Apollo Alpha Particle Spectrometer Experiment:

1) The existence of a fairly intense radioactive deposit on the lunar surface.

2) The surface deposit is inhomogeneous; it is different for the Surveyor 5, 6, and 7 landing sites.

3) The background alpha particle emission for the experiment is lower than previously thought.

Instrumentation required in this experiment has already been used successfully in space. Similar alpha particle detectors were used in the alpha-scattering measurements at the Surveyor lunar landing sites. There are many other instances in which these detectors have been used successfully in space. Similarly, the principal method of handling data, pulse height analysis, is a well-established technique and should present no difficulty in this application.

There are several reasons for wishing to study radon evolution from the moon. Perhaps the most important is that the concentrations of uranium and thorium in different lunar regions can be directly compared when the alpha particle and gamma-ray results are correlated. With information from a gamma sensor, the concentration of uranium can be determined so that it is possible to determine the diffusion characteristics of the soil. In turn, the diffusion properties are related to the porosity and quantity of absorbed gases in the lunar soil. If there is significant diffusion of radon to the surface, then the active deposit from the radon decay will increase the gamma activity of the surface (for terrestrial rates of radon evolution, the gamma emission would be increased by a factor of three, thus making the surface appear considerably more acidic). Hence, the alpha measurement is needed in order to subtract the effect of surface deposits and give a clearer interpretation to the gamma measurements in terms of uranium concentrations. The location of regions with enhanced radon emission is an indication of one or more of the following interesting features: the occurrence of crevices or fissures on the lunar surface; areas which release volatiles generally; or possibly regions with unusual concentrations of thorium.

The alpha particle measurements should be considered along with the X-ray and gamma-ray measurements as a part of an integrated geochemistry experiment that has as one of its principal objectives the determination of a map of the lunar chemical composition. In addition, it shares much of the same data handling techniques.

Previous Flight Objectives

Experiment Number	Title	Mission
None		

S-BAND TRANSPONDER

Conduct the S-Band Transponder Experiment (S-164).

Purpose

The purpose is to obtain S-band Dopper tracking data to determine the distribution of mass along the lunar surface ground track.

The functional test objectives are as follows:

FTO 1) Obtain S-band Doppler tracking measurements of the docked CSM/LM and the undocked CSM during non-powered flight while in lunar orbit.

FTO 2) Obtain S-band Doppler tracking measurements of the LM during non-powered portions of the lunar descent.

FTO 3) Obtain S-band Doppler tracking measurements of the LM ascent stage during non-powered portions of the descent for lunar surface impact.

Test Conditions

FTO 1)
FTO 2)
FTO 3) MSFN will obtain and record S-band Doppler tracking measurements of the docked CSM/LM and undocked CSM in lunar orbit, of the LM during descent, and of the LM ascent stage during descent for impact on the lunar surface. S-band Doppler tracking data will be obtained for all orbits with altitudes less than 60 NM.

DSN S-band Doppler tracking data will be obtained by the Principal Investigator directly from JPL. Measurements will be taken of the docked CSM/LM during front side passes between LOI and the circularization burn, of the LM during the unpowered portion of lunar descent and of the LM ascent stage during descent toward lunar surface impact.

The following are highly desirable:

a) The S-band Doppler tracking data will be obtained under quiescent conditions, i.e., while the spacecraft is undisturbed by effluent dumps, fuel cell purges, and unbalanced thruster firings.

b) The spacecraft attitude will be controlled by RCS jets operating in balanced couples so as to prevent translational motion.

c) The sources of spacecraft acceleration listed under a) above will be inhibited from 1 revolution before through 1 revolution after each data collection period.

The minimum tracking data sample rate required to obtain the desired spatial resolution of gravitational variations is dependent on the vehicle altitude above the lunar surface. The following table lists the minimum tracking data sample rates for various lunar altitudes.

Lunar Altitude (NM)	Tracking Data Sample Rate
$\geq$ 30	1 per minute
20 to 30	6 per minute
$\leq$ 20	1 per second

S-band Doppler tracking data are required from one ground station operating in the two-way mode. It is highly desirable to obtain tracking data from two additional ground stations operating in the three-way mode. It is also highly desirable that all ground stations supplying data be located within continental boundaries.

FTO 1) The CSM S-band transponder system will be operated during experiment periods while the CSM is in nominal 60 NM circular, 60 x 8 NM elliptical, and 170 x 60 NM elliptical lunar orbits. It is highly desirable that the crew minimize physical activity during data collection periods.

In the 60 NM circular orbit, the MSFN will Doppler track the CSM during a number of quiescent experiment data collection periods. Each data collection period will consist of two consecutive front side passes. The total number of collection periods will be a function of the inclination of the CSM orbit. The following table lists various lunar orbit inclinations and, for each inclination, the number of revolutions which must elapse before new unique gravitational data will be next obtained. This table applies only to a nominal 60 NM circular orbit.

Lunar Orbit Inclination (Degrees)	Revolutions Between Data Periods
0	Only 1 data period required
3	26
5	17
7	12
10	9
15	6
20	4
25	3
35	2
60	1
90	1

MSFN will obtain tracking data for all revolutions in the 60 x 8 NM and 170 x 60 NM elliptical orbits.

FTO 2)
FTO 3) The LM S-band transponder system will be operated during the experiment period.

Success Criteria

FTO 1) CSM and CSM/LM S-band Doppler tracking data collected between LOI and TEI shall be delivered to the Principal Investigator.

FTO 2) LM S-band Doppler tracking data collected during the LM descent shall be delivered to the Principal Investigator.

FTO 3) LM S-band Doppler tracking data collected during the period between the LM deorbit burn and lunar impact shall be delivered to the Principal Investigator.

Evaluation

FTO 1)
FTO 2)
FTO 3) The S-band Doppler tracking data will be reduced postflight to produce Doppler residual plots. These plots will be visually inspected to identify time increments containing non-gravitational disturbances. Depending on the results of this inspection, supplemental tracking data may be processed. The unperturbed raw tracking data will then be reprocessed to compute the gravitational acceleration in a continuous form. Line-of-sight acceleration contour maps will be correlated with lunar surface features to define the locations of gravitational anomalies. In addition, the valid raw data will be processed by a Surface Mass Determination Program to generate an enhanced lunar surface mass distribution. (Astronaut records, MSFN and DSN data, and trajectory data)

Data Requirements

1) MSFN and DSN Data:

   a) S-band Doppler tracking data for docked CSM/LM and CSM alone. (M)

   b) S-band Doppler tracking data for LM during unpowered lunar descent. (M)

   c) S-band Doppler tracking data for LM ascent during unpowered portion of flight after deorbit burn. (M)

   d) Transmitting frequency of each MSFN and DSN station. (M)

   e) Identity of transmitting ground stations and GET of their transmissions at acquisition of signal and loss of signal. (M)

   f) Identity of ground stations which are in three-way mode and GET of their receptions at acquisition of signal and loss of signal. (M)

   g) Geocentric coordinates (radius, latitude, and longitude) for all MSFN and DSN stations. (M)

   h) Station delay time for each ranging pass. (HD)

2) Astronaut Logs and Voice Records:* (M)

   GET of events which induce non-gravitational motion between AOS and LOS during CSM/LM 170 x 60 NM and 60 x 8 NM orbits, LM descent, and between AOS and LOS for the two front side passes immediately preceding and following the 60 NM circular quiescent data collection periods. The events include spacecraft maneuvers, unbalanced RCS firings, SPS burns, effluent dumps, fuel cell purges, and S-band high gain antenna movements.

3) Trajectory Data: (M)

   Estimates of trajectory parameters (position and velocity) during the period of the experiment.

*If these data are available through ground-based sources, that source may be substituted.

Background and Justification

S-band Doppler tracking data have been analyzed from the Lunar Orbiter missions. Definite gravity variations were detected. These results showed the existence of mass concentrations (mascons) in the ringed maria. Confirmation of these results has been obtained with Apollo tracking data.

With appropriate spacecraft orbital geometry, much more scientific information can be gathered on the lunar gravitational field. The CSM and/or LM in low-altitude orbits can provide new detailed information on local gravity anomalies. These data can also be used in conjunction with high-altitude data to possibly provide some description on the size and shape of the perturbing masses. Correlation of these data with photographic and other scientific records will give a more complete picture of the lunar environment and support future lunar activities. Inclusion of these results is pertinent to any theory of the origin of the moon and the study of the lunar subsurface structure. There is also the additional benefit of obtaining better navigational capabilities for future lunar missions in that an improved gravity model will be known.

Previous Mission Experiments

Experiment Number	Title	Mission
S-164	CSM/LM S-band Transponder	H-3
S-164	S-band Transponder	H-4

MASS SPECTROMETER

Conduct the Mass Spectrometer Experiment (S-165).

Purpose

The purpose is to obtain data on the composition of the lunar ambient atmosphere, on areas of lunar volcanism, and on contamination in lunar orbit and cislunar space.

The functional test objectives are as follows:

FTO 1) While the CSM is in lunar orbit, obtain data to determine the natural distribution of gases in the lunar atmosphere.

FTO 2) While the CSM is in lunar orbit, obtain data to locate areas of lunar volcanism.

FTO 3) While the CSM is in lunar orbit, obtain data to determine the amount of lunar atmospheric contamination due to rocket firing near the lunar surface.

FTO 4) While the CSM is in transearth coast, obtain data to determine contamination present in cislunar space.

Test Conditions

FTO 1)
FTO 2)
FTO 3)
FTO 4)
The crew will perform necessary control functions to extend and retract the experiment boom, to energize the ion source heaters, to place the experiment in "STANDBY," "ON," and "OFF" modes, and to control experiment electronics.

FTO 1)
FTO 2)
FTO 3)
The SIM door will be jettisoned before the Mass Spectrometer is operated. The boom will be extended for all Mass Spectrometer data collection, ion source heater operations, and effluent dumps. Before initial data collection, the ion source heaters will be operated for a cumulative period of 6 hours of which the last hour will be continuous. For each interruption, one-half hour of heater operation will be added to the 6 hour total each time heater operation is interrupted. Effluent dumps will be inhibited 1 hour before ion source heater operation; the heater will be set to "OFF" 15 minutes before a dump is initiated. RCS jets A2, A4, B1, B4, C1, and C3 which could contaminate the experiment will be inhibited. CSM attitude will not be critical during ion source heater operation.

Before each data collection period following the initial period, the ion source heaters will be operated continuously for 30 minutes. Effluent dumps will be inhibited 2 hours before and during data collection. RCS jets A2, A4, B1, B4, C1, and C3 will also be inhibited during data collection.

During data collection, the CSM -X axis will be oriented to within ±5 degrees of the velocity vector and the centerline of the SIM pointed toward the lunar surface and to within ±5 degrees of the local vertical. (This CSM orientation will insure that the boom is pointed in the proper direction within the required tolerances of ±10 degrees pitch, ±15 degrees yaw, and ±60 degrees roll.)

The experiment will be operated and data collected for a minimum of 2 complete revolutions, not necessarily continuous, during each of 3 separate periods.* Three additional revolutions during each period will be highly desirable. It will also be highly desirable during each revolution to collect data from a lunar surface area extending ±15 degrees on each side of the sunset and sunrise terminators.

Toward the end of the 72-hour experiment period, data will be collected for 1 complete revolution with the CSM +X axis in the direction of the velocity vector to obtain background data. (The attitude tolerances for the boom during this period are ±30 degrees in pitch, ±60 degrees in yaw, and ±60 degrees in roll.) This period will not compromise the obtaining of the primary data.

FTO 4) The experiment will be operated during transearth coast no sooner than 6 hours after TEI or an MCC burn. Before data collection, the ion heaters will be operated for a cumulative period of 3 hours of which the last hour will be continuous. During this ion source heater activity, the boom may be in the one-half extension position, if required by operational constraints. Effluent dumps will be inhibited 1 hour before and during ion source heater operation and data collection. RCS jets A2, A4, B1, B4, C1, and C3 will be inhibited. Data will be collected for 1 hour minimum with the boom fully extended. The boom will then be retracted in five equal steps with data being collected for 7 minutes after each retraction step, for a total of 35 minutes. The last 7-minute data collection period will occur with the boom in a fully retracted position. CSM attitude is not critical during this transearth coast activity.

*The requirement for 3 separate data collection periods conflicts with current operational planning and is being resolved.

Success Criteria

FTO 1) FTO 2) FTO 3) FTO 4)	The experiment data defined under the Test Conditions for FTO 1), FTO 2), FTO 3), and FTO 4) shall be transmitted to earth and provided to the Principal Investigator.

Evaluation

FTO 1) FTO 2) FTO 3) FTO 4) Data obtained will be studied and evaluated postflight by the Principal Investigator and investigation team in the individual investigator's laboratories. The data obtained from this experiment are in the form of a counting rate for each channel as a function of the step number of the ion accelerating voltage. A direct plot of these parameters will produce an analog representation of the mass spectrum for each channel. Further data reduction will produce the amplitude and position of each peak in the mass spectra, and plot this information as a function of time.

The position of the peak in the spectrum determines the mass number of gas species in the ion source being measured. The amplitude of the peak is a function of the concentration of that species in the source. The data will then be plotted as a function of lunar coordinates and local lunar time in order to be applicable to the flight objectives of this experiment. (Astronaut records, BET, preflight data, CG 0001 V, SL 1081 K through SL 1083 K, and SL 1124 V).

Data Requirements

1) Telemetry Measurements:

Measurement Number	Description	TM	Mode	Priority
CG 0001 V	Computer Digital Data - 40 Bits	PCMD+	2	M*
SL 1081 K	Mass Spectrometer Output 10 Bit Data A	PCMD	2	M*
SL 1082 K	Mass Spectrometer Output 10 Bit Data B	PCMD	2	M*
SL 1083 K	Mass Spectrometer Output Sweep Start Flag Data C	PCME	2	M*
SL 1124 V	Mass Spectrometer Output Combined Data	PCMD	2	HD

*These measurements are M during mandatory experiment operation and HD during highly desirable experiment operation.

2) Astronaut Logs or Voice Records:

a) Description and GET of changes to experiment control settings during mandatory periods of experiment operation. (M)

b) Description and GET of changes to experiment control settings during highly desirable periods of experiment operation. (HD)

3) Trajectory Data:

a) Best estimate of trajectory (BET) for the CSM during mandatory periods of experiment operation. (M)

b) Best estimate of trajectory (BET) for the CSM during highly desirable periods of experiment operation. (HD)

4) Preflight Data: (M)

Preflight calibration and checkout data in accordance with procedure <u>TBD</u>.

Background and Justification

It has recently been shown that light gases with negligible production and loss rates tend to be distributed at the lunar surface as the inverse 5/2 power of temperature, while heavier gases are influenced by rotation of the moon. Neon is a light gas, and its concentration on the dark side should be about 32 times that on the sunlit side and thus, at an assumed satellite altitude of 32 km, the diurnal fluctuation of neon concentration should be about 10. Because argon is heavier than neon and has less diurnal variation, it is expected to be noticeably influenced by the rotation of the moon. As a result, there will be a longitudinal shift of argon's maximum toward sunrise and thus a concentration which is twice that which exists at sunset.

Other atmospheric gases are not as amenable to analytic analysis, but their distributions are nonetheless important. Hydrogen and helium, which are thought to originate mainly through neutralization of solar wind ions on the lunar surface, are produced mainly on the sunlit surface. They escape easily, and thus are not expected to be concentrated excessively on the dark side. The accretion rates can be calculated, assuming a direct impingement of the solar wind on the lunar surface and that the composition of the solar wind is the same as that for the solar surface. Both of these assumptions and the processes of accumulation and escape of these gases can be checked with the mass spectrometer data.

Water vapor, krypton, and xenon probably exist in the lunar atmosphere, but not on the dark side nor near the poles where the surface temperature is below 100°K and absorption must remove every particle that comes in contact with the surface. Gases absorbed in continuously shadowed regions near the poles are unlikely to reenter the atmosphere, but at lower latitudes the rotation of the moon transports absorbed gases into sunlight where they are released into the atmosphere. Since surface heating occurs rapidly, this release probably occurs entirely within a few degrees longitude from the sunrise terminator, creating a pocket of gas. Whether this dawn enhancement can be detected at satellite altitudes is speculative, depending mainly on the abundance of these gases in the lunar atmosphere.

Study of the composition and distribution of gases in the lunar atmosphere is important to two current problems. The first problem is the understanding of the origin of the lunar atmosphere. Light gases, such as hydrogen, helium, and neon, probably originate from neutralization of solar wind ions at the surface of the moon, whereas Ar^{40} is most likely due to radioactive decay of K^{40}; Ar^{36} and Ar^{38} may be expected as spallation products of cosmic ray interactions with surface materials. Molecular gases, such as carbon dioxide, carbon monoxide, hydrogen sulfide, ammonia, sulphur dioxide, and water vapor may be produced by lunar volcanism.

The second problem is related to transport processes in planetary exospheres. The exosphere of the earth, and that of almost any other planet, is bounded by a dense atmosphere in which hydrodynamic wind systems complicate the problem of specifying appropriate boundary conditions for exospheric transport. This contrasts sharply with the situation in the lunar atmosphere, which is entirely a classical exosphere, with its base the surface of the moon. The lunar exosphere should be amenable to accurate, analytical study. Experimental determination of the global distribution of lunar gases can provide a reasonable check on theory, giving confidence to the application of theoretical techniques to transport problems in the terrestrial exosphere.

Previous Flight Objectives

Experiment Number	Title	Mission
None		

SUBSATELLITE

Conduct the Subsatellite Experiment while it is in lunar orbit (S-164, S-173, S-174)

Purpose

The purpose is to obtain data on the lunar gravitational field, charged particles, electric fields, and magnetic fields in the vicinity of the moon. The Subsatellite includes the S-band Transponder Experiment (S-164), the Particle Shadows/Boundary Layer Experiment (S-173), and the Magnetometer Experiment (S-174).

The functional test objectives are as follows:

FTO 1) Obtain S-band Doppler tracking measurements of the Subsatellite. (S-164).

FTO 2) Obtain data on the topology of the magnetotail, the energetic magnetotail plasma, and the d-c electric field. (S-173).

FTO 3) Obtain data on the lunar magnetic field. (S-174).

Test Conditions

FTO 1)
FTO 2)
FTO 3)

The SIM door will be jettisoned before launch of the Subsatellite. All effluent dumps will be inhibited during the period between SIM door jettison and Subsatellite launch to prevent contamination of the solar cells and sensors. Launch must occur within 21 days of Subsatellite servicing in the SIM due to battery degradation.

Prior to launch, the CSM will be maneuvered into a fixed inertial attitude so that the Subsatellite will be launched with its spin axis at a predetermined angle with respect to the normal to the reference plane; that is, the plane which passes through the center of the moon and is parallel to the ecliptic plane. The Subsatellite will be launched northward, and the SIM bay will be oriented to prevent sunlight from entering the field-of-view of the sun-sensitive instruments. This attitude will be maintained within ± 2 degrees. After the Subsatellite launch platform has been extended from the SIM bay, the CSM will be allowed to stabilize (drift rate less than 0.05 degrees per second) prior to Subsatellite launch. Subsatellite launch will occur within ± 10 minutes of the time the CSM crosses the reference plane. The direction of Subsatellite rotation about its spin axis will be opposite to the rotation of the CSM about the moon.

After its launch the Subsatellite will be photographed to check the physical condition of its external surface, to confirm proper deployment of the magnetometer and other booms, and to determine the orientation of the Subsatellite with respect to some well-defined frame of reference. The camera(s) and film type(s) to perform this task are TBD. If maneuvers are required to photograph the Subsatellite, they will be performed in such a way as to avoid contaminating the Subsatellite and/or disturbing its dynamics.

The Subsatellite launch platform will be retracted after launch to remove it from the field-of-view of other experiments.

The Subsatellite will be electrically inert until launch has been completed. At launch, a switch closes to connect the battery to the Subsatellite load and allows the transmitter to be turned on by a MCC command.

FTO 1) S-band Doppler tracking data will be received and recorded by MSFN and DSN stations for a minimum of 1 front side pass per day over a 6-month period. Data recording on one front side pass per day during a second 6-month period will be highly desirable. If power limitations do not prevent, it will be highly desirable to record data for TBD additional front side passes per day. Tracking will be conducted by at least 2 stations. It is desirable that ground stations use resolvers to improve data accuracy. Initial tracking is not required until after the J-1 Mission. The tracking schedule will be updated by the Flight Operations Directorate and the Principal Investigator as required.

FTO 2)
FTO 3) Experiment data will be obtained over a minimum elapsed time period of 6 months. An additional 6-month period will be highly desirable.

Sufficient command capability and real time data will be made available so that the performance of the Subsatellite can be assessed as early in the mission as will be practicable. After a thorough assessment of the Subsatellite performance under all operational and environmental conditions, MCC and MSFN support may proceed on a regular schedule except during selected periods of enhanced solar activity. For these periods it will be necessary to control and monitor the Subsatellite on a continuous real time basis. The ground support schedule is in process of development.

Success Criteria

FTO 1) Subsatellite S-band Doppler tracking data, collected in accordance with Test Conditions for FTO 1), shall be recorded and delivered to the Principal Investigator.

FTO 2) FTO 3) The experiment data defined under Test Conditions for FTO 2) and FTO 3) shall be transmitted to earth and provided to the Principal Investigator.

Evaluation

FTO 1) The Principal Investigator will study and evaluate the S-band Doppler tracking data obtained from the MSFN and DSN receiving stations. The data will be reduced to obtain the line-of-sight accelerations. Correlations with visible lunar features can then be made. The surface mass distribution will have been greatly enhanced when a dynamic fit has been made to the data acquired. This information will be incorporated into future Apollo navigational models for more precise trajectory calculations and orbit prediction capability. In addition, the presence of mascons, their properties, and association with lunar features will be investigated. (MSFN and DSN data)

FTO 2) The Principal Investigator and Investigation Team will study and evaluate the data obtained from the MSFN receiving stations. The data will be evaluated for the spatial distribution of low energy electrons and protons near the charged particle terminator. The derived distributions will then yield the desired information on plasma flow and electric fields associated with the solar wind and magnetotail. (Trajectory data, Photographs, Preflight data, and TBD telemetry)

FTO 3) The Principal Investigator and Investigation Team will study and evaluate the data obtained from the MSFN receiving stations.

This experiment should provide data on the magnetic fields at nominal Apollo lunar orbital altitudes. The behavior of the field in this region will, in turn, provide information on physical processes in the solar wind plasma, the macroscopic and microscopic properties of the interaction of the plasma with the moon, and the physical properties of the moon. This lunar magnetic field determination will also be utilized in the analysis supporting the Particle Shadows/Boundary Layer Experiment which is carried on the same Subsatellite as the Magnetometer Experiment. (Trajectory data, photographs, concurrent scientific experiments data, preflight data, and TBD telemetry)

Data Requirements

1) Telemetry Measurements: (M)

Data requirements for the Subsatellite (including experiments S-164, S-173, and S-174) as defined in Volume II of the MSRD.

2) Photographs: (M)

Photographs of launched Subsatellite with booms deployed.

3) MSFN and DSN Data:

a) S-band Doppler tracking data for Subsatellite in lunar orbit. (M)

b) Transmitting frequency of each MSFN and DSN station which supplies data. (M)

c) Identity of transmitting ground stations and GET of their transmissions at acquisition of signal and loss of signal. (M)

d) Identity of ground stations which are in 3-way mode, and GET of their transmissions at acquisition of signal and loss of signal. (M)

e) Geocentric coordinates for all MSFN and DSN stations which supply data. (M)

4) Trajectory Data: (M)

Trajectory data required for S-173 and S-174 will be supplied by either the S-164 Principal Investigator or NASA.

5) Concurrent Scientific Experiment Data: (TBD)

Concurrent data will be required from the Lunar Surface Magnetometer Experiment (S-034) of the ALSEP Array D.

6) Preflight Data:

Preflight checkout and calibration data in accordance with procedure TBD.

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Background and Justification

S-Band Transponder Experiment (S-164)

S-band Doppler tracking data have been analyzed from the Lunar Orbiter missions. Definite gravity variations were detected. These results showed the existence of mass concentrations (mascons) in the ringed maria. Confirmation of these results has been obtained with Apollo tracking data.

With appropriate spacecraft orbital geometry, much more scientific information can be gathered on the lunar gravitational field. These data can also be used in conjunction with high-altitude data to possibly provide some description on the size and shape of the perturbing masses. Correlation of these data with photographic and other scientific records will give a more complete picture of the lunar environment and support future lunar activities. Inclusion of these results is pertinent to any theory of the origin of the moon and the study of the lunar subsurface structure. There is also the additional benefit of obtaining better navigational capabilities for future lunar missions in that an improved gravity model will be known.

Particle Shadows/Boundary Layer (S-173) and Magnetometer (S-174) Experiments

Vector magnetometer surveys have been the primary means of determining magnetic fields in space. Many basic properties of the interplanetary medium, bow shock, and magnetosphere have been determined by this method. Although generally highly successful, the method does have limited ability to detect weak, directed components due to considerable variability of the fields. Thus, it has not been possible to find or to rule out the existence of a field component normal to the magnetopause. Such a component bears directly on the question of openness of the magnetosphere. Also, it has not been possible to identify which field lines surrounding the neutral sheet in the tail connect on both ends to the earth and which go behind the earth and perhaps extend into interplanetary space.

a. Particle Shadows

Recently a new method complementary to vector magnetometers has been described. This method is used to determine the large scale topology of field lines under certain conditions. It is essentially a particle tracing technique which determines where particles have been and where they go on the particular field lines under study. The tracer particles are supplied by the sun. The method also requires the presence of a large absorber such as the moon. As a spacecraft orbits the moon, a pattern of varying solar electron intensity is produced. The characteristics of the field lines are then deduced from the symmetry properties of these patterns. Much has already been learned on the lunar orbiting Explorer XXXV, but the method should now be applied in full measure in order to deal with the most basic problems of magnetospheric structure and dynamics. The improvements that must be incorporated in any new experiment to exploit the method of large absorbers are as follows:

1. The shadow patterns which reveal the field line topology must be obtained much more frequently. This will permit better spatial determinations in a moving spacecraft, and allow better temporal resolution for study of magnetospheric dynamics.

2. Data coverage is needed over the entire lunar orbit. This would require a simple data storage system in the spacecraft. Full data coverage would allow all details of the shadow pattern to be studied.

3. Better time resolution is needed to examine the penumbral regions of the shadows. This is important for setting improved limits on electric fields and diffusion in certain regions of the magnetotail.

b. The Boundary Layer

The empirical study of the boundary layers and discontinuities in naturally occurring plasmas is, in most cases, greatly complicated by the motion of the layers. This problem has arisen, for example, in the studies of the bow shock and magnetopause at the earth.

On the basis of present evidence, the interaction of the solar wind with the moon occurs very close to the lunar surface. The boundary layer for this interaction extends from the lunar surface outward to some distance which is as yet unknown, but which is estimated to be of the order of 100 km. We have, then, a boundary layer that is fixed, since the inner boundary is the lunar surface, and variable in thickness. Thus, in this particular boundary layer, complications due to the motion do not exist.

The goal of this part of the experiment is to obtain data on the physics of this interaction region or boundary layer. The characteristics of the boundary layer are determined by the properties of the plasma as well as those of the moon. Thus, the study of the interaction region will yield information of the external plasma, the interior of the moon, the surface and the lunar ionosphere.

Measurements from a 60 NM lunar orbit should provide information on both microscopic processes in the interaction region and macroscopic features of the flow. This low altitude should also provide a more sensitive mapping of the lunar magnetic field than accomplished during Lunar Orbiter flights from altitudes greater than 400 NM.

At present, very little work has been done on the theory of the microscopic behavior of the plasma in the boundary layer immediately above the lunar surface. On the daylight side the solar wind particles probably reach the surface in their steady state condition but photoelectric fields and ionized particles from the moon may complicate the situation.

Measurements of magnetic fields in the transient and steady state boundary layers should provide indirect information on the lunar ionosphere and transient lunar atmosphere. It is estimated that the altitude of the top of the boundary layer at the surface, or the skin depth of the lunar perturbation in the solar wind plasma, will vary from 5 to 500 km. The dynamical processes, e.g., wave-particle and field-particle interactions are probably very important in this region. Magnetic field measurements at the high data rate should provide exploratory data on such phenomena.

In the cavity directly behind the moon, the properties of the plasma and magnetic field are very different from those of the solar wind flowing in the adjacent regions. At the boundary between this downstream cavity and the solar wind, there are strong gradients in the density and velocity of the plasma. The 60 NM lunar orbit will traverse this layer in two places. Thus, one of the main purposes of this experiment would be to obtain data on the microscopic behavior in this region.

Previous Mission Experiments

Experiment Number	Title	Mission
S-164	CSM/LM S-band Transponder	H-3
S-164	S-band Transponder	H-4

CM ORBITAL SCIENCE PHOTOGRAPHY

Obtain photographs from lunar orbit of areas of high scientific interest.

Purpose

The purpose is to obtain photographs of areas and features of the lunar surface which are of interest to the scientific community and will aid in the total exploration of the moon.

The functional test objectives are as follows:

FTO 1) Obtain photographs of lunar surface areas of prime scientific interest.

FTO 2) Obtain photographs of specific segments of the lunar surface in earthshine and in low light near the terminator.

Test Conditions

FTO 1) Medium resolution photographs of particular regions of the moon's surface will be obtained using the Hasselblad electric camera with the 250 mm lens. The camera will be manually operated to provide approximately 60 percent forward overlap. Low resolution black and white photographs of particular areas of the lunar surface will be obtained using the Hasselblad electric data camera (bracket-mounted) with the 80 mm lens and the 16 mm data acquisition camera with an 18 mm lens. The frame cycle rate for the Hasselblad electric data camera will be set to provide 60 percent forward overlap. The 16 mm camera cycling rate will be set at one frame per second. The photographic sequences will begin as indicated in Table 1. Exposure parameters and the number of frames per sequence will be as defined in the Photographic and Television Procedures. Sensitometric calibration of film and film processing requirements will be as defined in the Mission Science Requirements Document.

FTO 1)
FTO 2) Telemetry data are highly desirable relative to time of opening the shutter of the Hasselblad electric data camera.

FTO 2) Black and white photographs of particular areas in earthshine and in low light near the terminator will be obtained using the 16 mm data acquisition camera with an 18 mm lens and the Hasselblad electric data camera (bracket-mounted) with an 80 mm lens to provide stereo strips with 60 percent forward overlap. The aperture setting of the 16 mm data acquisition camera will be T 1.0 (f.95). The camera frame cycle rate will be 1 frame per second. The sequence will be taken of areas listed in Table 1.

Success Criteria

FTO 1) FTO 2) The photographic data defined under the Test Conditions for FTO 1) and FTO 2) shall be acquired and returned to earth for processing.

Evaluation

FTO 1) FTO 2) The photographic data will be evaluated by the Apollo Orbital Science Photographic Team for general and specific scientific interest. (Astronaut records, photographs, BET, and CK 1043 X)

Data Requirements

1) Telemetry Measurements:

Measurement Number	Description	TM	Mode	Priority
CK 1043 X	70 mm Camera Shutter Open	PCM	1	HD

Data Requirements

2) Astronaut Logs or Voice Records: (HD)

Record of GET, magazine number, frame number, exposure time and any pertinent visual observations.

3) Photographs: (M)

Photographs of all sites in Table 1 in the manner as specified in the Test Conditions.

4) Trajectory Data: (HD)

Best estimate of trajectory (BET) covering periods when photographs were obtained.

Background and Justification

Very little of the moon's surface will be physically explored through manned landings and surface traverses in the foreseeable future. It is, therefore, important to the total exploration of the moon that we utilize every means at our disposal to accumulate data which will add to our overall knowledge of the moon. Manned landings provide the necessary "ground truth" to increase the confidence level in data from photographic and advance sensor systems.

Until the advent of spacecraft photography, all examination of the lunar surface was from earth-based observations. Ranger, Surveyor and the unmanned Lunar Orbiter Programs provided valuable high resolution photography of the surface. However, area coverage was extremely limited. Furthermore, the unmanned spacecraft did not obtain high illumination angle and zero phase photographs, which are of high scientific and operational value. Fortunately, Orbiter IV offered large area coverage of the moon at a lower resolution. This general coverage has provided a basis for site selection for further photography, interpretation of lunar surface features and their evolution, and identification of specific areas and features whose detailed study would likely provide key data to support or deny theories of origin.

The Apollo lunar missions have in the past obtained photographs of these areas as targets-of-opportunity or in support of specific objectives during Apollo Missions 8, 12, H-3, and H-4. Additional photographs are required to answer questions about the moon, generate new questions as new phenomena are revealed, guide future mission planning, and allow for extrapolation of "ground truth" data collected at the landing sites to larger segments of the lunar surface.

Previous Flight Objectives

Objective Number	Title	Mission
20.115	Lunar Mission Photography from the CM	8
G	Photographs of Candidate Exploration Sites	12
-	CSM Orbital Science Photography	H-3
-	CSM Orbital Science Photography	H-4

Table 1. Photographic Targets

Target Number	Start Point Longitude	Start Point Latitude	Description	Lens	Priority
(Details TBD after preliminary lunar orbit timeline and trajectory data becomes available)					

SM ORBITAL SCIENCE PHOTOGRAPHY

Obtain lunar surface photographs and altitude data from lunar orbit.

Purpose

The purpose is to obtain lunar surface photographic and topographic data to support selenodetic/cartographic goals of the lunar mapping program, and to aid in the overall exploration of the moon.

The functional test objectives are as follows:

FTO 1) Obtain high-quality metric photographs of the lunar surface and time-correlated stellar photographs.

FTO 2) Obtain high-resolution photographs along with stereo coverage of the lunar surface.

FTO 3) Obtain data on the altitude of the CSM above the lunar surface to determine variations in lunar topography.

Test Conditions

FTO 1)
FTO 2)
FTO 3) The three functional test objectives will be accomplished using the 3-Inch Mapping Camera, 24-Inch Panoramic Camera, and Laser Altimeter, respectively. The 3-Inch Mapping Camera consists of a terrain camera with a field-of-view (FOV) of 74 x 74 degrees and a Stellar Camera with a 24 x 18 degree FOV. The terrain camera operates at a frame rate designed to achieve 78% forward overlap from an altitude of 60 NM. The camera will be loaded with 1500 feet of Eastman Kodak type 3400 film of 5-inch width. This film will provide 25 hours of mapping photography. The Stellar Camera will use 510 feet of type 3401 35 mm film. The 24-Inch Panoramic Camera has a 108 x 39 degree FOV envelope and a stereoscopic convergence angle of 25 degrees. It will carry 6500 feet of Eastman Kodak type 3404 film (5-inch width), which will provide 165 minutes of panoramic photography. The Laser Altimeter is an altitude ranging device which operates both independently and in support of the mapping camera. In its independent mode the altimeter pulses once each 20 seconds, and while slaved to the mapping camera, pulses at the center of each camera exposure. To avoid contamination, liquid dumps (urine, waste water, etc.) will be prohibited for 1 hour prior to and during equipment operation, and RCS jets A2, A4, B1, and B4 will be disabled during equipment operation.

FTO 1)
FTO 2) To prevent film set in the film cassettes of the 3-Inch Mapping Camera and the 24-Inch Panoramic Camera, the crew will periodically activate an automatic 5-frame advance of these film spools. This "cycling" of the two cameras will be done at intervals of 24±6 hours after the film has been loaded into the SM. The fields-of-view (FOV) of both cameras will be unobstructed during operation, except when camera operation is supporting another experiment. Experiments which are deployed on booms will be retracted, if necessary, so that they will not obstruct the FOV of either camera. During camera operation the CSM attitude will be controlled so that the optical axes of the cameras are aligned within ±2 degrees of the lunar local vertical, with the +X axis of the CSM directed along the velocity vector. CSM attitude deadband will be ±0.5 degrees about all axes, with less than 0.05 degrees per second drift, while the cameras are in operation. It is highly desirable to operate the 3-Inch Mapping Camera and the 24-Inch Panoramic Camera concurrently. Both cameras will be given a warmup period of at least 3 hours prior to initial operation. Depending on temperature conditions at the panoramic camera lens, initial warmup for this camera may require 10 to 20 hours. Following completion of all photography, the crew will perform an EVA and retrieve film cassettes from both cameras and stow them in the CM.

FTO 1) The 3-Inch Mapping Camera will be operated on light side passes (terminator-to-terminator) in accordance with the requirements of Table 1. Concurrent operation of the Laser Altimeter is required. Mapping camera operation on dark side passes is required during the complete lunar orbits of laser altimeter operation specified in FTO 3), for the purpose of providing stellar attitude data. In this latter mode terrain camera film will be exposed. Mapping camera photography will also support the reduction of data from other lunar orbital experiments: Gamma Ray Spectrometer (S-160), X-Ray Fluorescence (S-161), and UV Photography-Earth and Moon (S-177). Support of these experiments will not impact the primary mapping function of the 3-Inch Mapping Camera.

FTO 2) The 24-Inch Panoramic Camera will be operated for nine 20-minute sequences on lunar orbit light side passes, in accordance with the schedule in Table 2. Film quantity may limit the last of these sequences to approximately 5-minutes duration.

FTO 3) The Laser Altimeter is synchronized with (slaved to) the 3-Inch Mapping Camera and will operate when the camera is operating. In addition, the Laser Altimeter will be operated for one complete lunar orbit each ($1/\sin i$) orbits, where i is the selenocentric inclination of the orbit. It is highly desirable that the altimeter be operated continuously for the entire 72-hour experiment period.

Success Criteria

FTO 1) FTO 2) The photographic data defined under the Test Conditions for FTO 1) and FTO 2) shall be acquired and returned to earth for processing.

FTO 3) Laser Altimeter data as defined under Test Conditions for FTO 3) shall be collected and delivered to the CSM Orbital Science Photographic Team.

Evaluation

FTO 1) FTO 2) The photographic and altitude support data will be evaluated by the CSM Orbital Science Photographic Team to help in the development of an improved lunar surface selenodetic/cartographic control network, and to identify lunar surface details of operational and scientific interest. (Astronaut records, photographs, BET, SL 1211 T, SL 1212 T, and SL 1030 V through SL 1181 V)

FTO 3) The altitude data and photographic support data will be evaluated by the CSM Orbital Science Photographic Team to determine broad variations in lunar topography. (Astronaut records, BET, CG 0001 V, SL 1211 T, SL 1212 T, and SL 1030 V through SL 1181 V)

Data Requirements

1) Telemetry Measurements:

Measurement Number	Description	TM	Mode	Priority
CG 0001 V	Computer Digital Data - 40 Bits	PCMD+	1	M
SL 1030 V	Pan Camera V/H Command Voltage	PCM	1	M
SL 1031 X	Pan Camera Air Solenoid	PCME	1	TBD
SL 1032 T	Pan Camera Film Mag Temp	PCM	1	TBD
SL 1033 H	Pan Camera Framing Roll Position	PCM	1	TBD
SL 1034 H	Pan Camera Shuttle Position	PCM	1	TBD
SL 1035 C	Pan Camera Lens Torque Current	PCM	1	TBD
SL 1036 X	Pan Camera Capping Shutter Pos	PCME	1	TBD
SL 1037 V	Pan Camera FMC Tach Voltage	PCM	1	TBD
SL 1038 H	Pan Camera Exposure Command	PCM	1	M
SL 1039 T	Pan Camera Lens Barrel Temp	PCM	1	HD
SL 1040 T	Pan Camera Fwd Lens Temp	PCM	1	HD
SL 1041 T	Pan Camera Aft Lens Temp	PCM	1	HD
SL 1042 T	Pan Camera Mech Temp	PCM	1	TBD
SL 1043 P	Pan Camera N_2 Tank Press	PCM	1	TBD
SL 1091 V	Laser Altimeter Reg - -5.0 Volt	PCM	1	TBD
SL 1092 V	Laser Altimeter Photomult Volt	PCM	1	TBD
SL 1093 V	Laser Altimeter PFN Volt	PCM	1	TBD
SL 1094 T	Laser Altimeter Cavity Temp	PCM	1	TBD
SL 1122 K	Laser Altimeter Output 24 Bit Ser	PCMD	1	M

Measurement Number	Description	TM	Mode	Priority
SL 1160 T	Metric Fwd Lens Temp	PCM	1	TBD
SL 1161 T	Metric Lens Bar Temp	PCM	1	TBD
SL 1162 T	Stellar Fwd Lens Temp	PCM	1	TBD
SL 1163 T	Stellar Lens Bar Temp	PCM	1	TBD
SL 1164 T	Cassette Temp	PCM	1	TBD
SL 1165 X	Image Motion Stat	PCM	1	TBD
SL 1166 R	Shutter Disc Speed	PCM	1	TBD
SL 1168 X	Deploy/Cut	PCM	1	TBD
SL 1173 X	Metric Film Motion	PCM	1	TBD
SL 1176 Q	Film Remaining	PCM	1	TBD
SL 1180 X	Stellar Film Motion	PCM	1	TBD
SL 1181 V	V/H Increment Level	PCM	1	TBD
SL 1211 T	Temp Thrm Envir - Pan N_2 Line In	PCM	1	TBD
SL 1212 T	Temp Thrm Envir - Pan Camera N_2 Tk	PCM	1	TBD

2) Photographs: (M)

Photographs taken by the 3-Inch Mapping and 24-Inch Panoramic Cameras as specified in the Test Conditions.

3) Trajectory Data: (M)

Best estimate of trajectory (BET) during operating periods of the 3-Inch Mapping Camera, the 24-Inch Panoramic Camera, and the Laser Altimeter.

4) Preflight Data: (M)

Preflight checkout and calibration data in accordance with procedures for the 3-Inch Mapping Camera TBD, the 24-Inch Panoramic Camera TBD, and the Laser Altimeter TBD.

Table 1. Photographic Requirements for 3-Inch Mapping Camera - Based on Minimum of 50 Percent Sidelap Between Consecutive Photographic Revolutions

Orbit Inclination	
5°	Rev 1* 35° crosstrack oblique to northeast
	Rev 2 Vertical (sidelap with Rev 1-55%)
5 Photo Revs	Rev 18 Vertical (sidelap with Rev 2-76%)
	Rev 35 Vertical (sidelap with Rev 18-76%)
	Rev 36 35° crosstrack oblique to southwest (sidelap with Rev 35-55%)
10°	Rev 1 35° crosstrack oblique to northeast
	Rev 2 Vertical (sidelap with Rev 1-55%)
5 Photo Revs	Rev 18 Vertical (sidelap with Rev 2-50%)
	Rev 35 Vertical (sidelap with Rev 18-50%)
	Rev 36 35° crosstrack oblique to southwest (sidelap with Rev 35-55%)
15°	Rev 1 same as 5° inclination
	Rev 2 same as 5° inclination
	Rev 12 Vertical (sidelap with Rev 2-53%)
6 Photo Revs	Rev 23 Vertical (sidelap with Rev 12-53%)
	Rev 34 Vertical (sidelap with Rev 23-53%)
	Rev 36 same as 5° inclination (sidelap with Rev 34-50%)

*Referenced to the beginning of the 72-hour lunar orbital experiment period. The actual revolution numbers will be determined following generation of the mission operational trajectory.

Table 2. Photographic Targets for the 24-Inch Panoramic Camera

(Data TBD)

Background and Justification

24-Inch Panoramic Camera:

The scientific productivity and operational certainty of manned landing missions requires further photography to complement and fill gaps in coverage obtained by earlier photography. The sun angle was too high in certain sites covered with the Lunar Orbiter spacecraft to reveal subtle details. Insufficient high-resolution coverage of several scientifically valuable sites prohibits trafficability and landing analysis. Lunar Orbiter IV photography was generally poor in many areas east of about 40°E. No satisfactory sites were photographed in the southern highlands due to the earlier lack of knowledge of the regional relations, knowledge that now has been obtained from other photographs. Also, an insufficient number of near nominal sun incidence photographs were obtained from Orbiter. These photographs are necessary to study albedo variations necessary for geological classification of features.

The need for scientific return from manned landing missions makes the acquisition of additional photography in scientifically valuable sites, particularly in the southern highlands, highly desirable. The following is a partial list of the possible scientific returns from panoramic photography.

a. Much better knowledge of the regional geology in the east, including the crater density and age of mare units.

b. Information on the internal mass distribution of the moon might be obtained. Measurements of the front side lunar radius from Lunar Orbiter photogrammetric reduction and the Lunar Orbiter velocity/height sensor (independent sources of information), plus Apollo 8 data, indicate that the lunar front side radius is approximately 2 kilometers lower than previous determinations based on reduction of earth-based telescopic photographs. Photographs from low orbital altitudes of the lunar far side may aid in determining if similar or opposite conditions exist on the lunar far side. If the results are similar to those found on the near side, the previously accepted mean lunar radius could be in error. If the results indicate a larger radius on the far side, they would tend to confirm theories of a displacement of the moon's center of mass from its geometrical center.

c. Support to scientific interpretation of data obtained with other experiments - such as the geochemistry experiments - from lunar orbit.

3-Inch Mapping Camera:

For many years, positions of lunar features have been derived from earth-based observations. These observations have led to positional accuracies of some features on the near side of the moon on the order of 1000 meters. However, a number of recent reductions of Lunar Orbiter photography have shown inconsistencies of 1-5 kilometers in the positions of some features. Recent grazing occultation experiments with the moon have given rise to the possibility of a fairly large error in lunar declination. On the other hand, Orbiter ranging data seems to have provided strong evidence of the accuracy in range of the correct ephemeris.

The Lunar Orbiter series, plus the Ranger series, have already provided a considerable amount of photographic detail of the moon. Although these photographs were obtained with a variety of resolution limits better than that obtained from earth-based observations, there was no plan for establishing a geodetic network and a cartographic display of the entire lunar surface. Because of limited stereoscopic coverage, and errors introduced in the scanning, transmission and reconstruction of the film, the Orbiter photography does not provide a consistent base for cartographic and geodetic information.

During the short period of time in a lunar landing mission, the need for data on a planetary scale is supplemented by the needs for regional cartographic data and topographic information at relatively large scale. The improvements needed in lunar geodetic and regional cartographic information can only be obtained from lunar photographic satellites.

The lunar geodetic network can only be achieved through use of photogrammetry. If the network is constructed piece by piece through use of strips of photography from a succession of lunar missions, orbital and attitude information becomes increasingly important in the data reduction. Since there is no "ground control" on the moon, control must be derived from the orbit. Attitude information must be derived from either stellar cameras or other auxiliary sensors.

If the network is constructed by the desired method of simultaneous adjustment of the entire sphere, the photogrammetric solution is much stronger and needs less or perhaps no orbital or attitude information to support it. Orbital theory subsequently becomes important, in conjunction with photogrammetry, for determining the gravity potential of the moon. This is accomplished using the established positions of surface features to determine the position of the satellite at the time a picture is taken. Each exposure station then becomes an accurately known point for determining the spacecraft ephemeris.

The mapping camera photographs will provide a means for establishing a lunar geodetic network. The extent of coverage will depend largely on the type mission on which the experiment is flown. The ideal situation is to obtain complete lunar coverage so that a single photogrammetric adjustment of the entire lunar sphere can be performed. This network would fulfill all foreseeable requirements for positional reference on the moon, and would form the basis for subsequent photogrammetric determination of the gravitational field.

The mapping camera photographs will also form the basis of specialized cartographic maps, which will provide additional data on the form, distribution, and relative abundance of major lunar surface features, and provide terrain profile information required to plan subsequent Lunar Exploration Missions.

Laser Altimeter:

The determination of the lunar gravitational field from analysis of the Lunar Orbiter tracking data was of great importance to the study of the moon's structure and evolution. These data, in fact, resulted in the discovery of the mascons. However, the lack of accurate lunar topographic elevations makes it difficult to draw inferences as to the moon's internal structure because the contribution to the lunar gravitational field of the visible topography cannot be subtracted out accurately. Also, the spectrum of the long wave variations in topography is of significance to the study of the lunar structure itself.

Previous determinations of lunar topography from photographs taken by terrestrial telescopes have errors associated with them of several hundred meters in elevation.

The altitudes determined by laser data will be used with earth tracking data to determine the orbits of the Apollo spacecraft more accurately. The topographic variations will then be determined by subtracting the laser measured altitudes from the orbital radial coordinates. This procedure should yield a measure of the topographic variations to within an accuracy approaching that of the instrument, because the wavelengths of topographic variations are much shorter than the wavelengths of variations in the error of the radial coordinates of the orbit.

The laser altitudes will be coordinated with photographs taken with the 3-Inch Mapping Camera and the 24-Inch Panoramic Camera.

Previous Flight Objectives

Objective Number	Title	Mission
None		

UV PHOTOGRAPHY-EARTH AND MOON

Conduct the UV Photography-Earth and Moon Experiment (S-177).

Purpose

The purpose is to obtain ultraviolet (UV) photographs of the earth and moon for use in the study of planetary atmospheres, and for the investigation of short wavelength radiation from the lunar surface.

The functional test objective is as follows:

FTO 1) Obtain photographs of the earth and of the lunar surface in three UV and one visual region of the spectrum.

Test Conditions

FTO 1) Photographs will be obtained from the CM while in earth parking orbit, translunar coast, lunar orbit, and transearth coast, using a Hasselblad camera with a 105 mm UV transmitting lens. The photographs will be taken through the RH CM window. This window will be supplied with quartz panes that pass a large fraction of the incident UV radiation. It should be noted that the UV radiation hazard from this window will therefore be higher than from a standard CM window. The camera will be mounted on a special bracket and will be provided with a ring slide for filters. The following four band-pass filters will be provided:

a) Schott UG-2 centered at 3750 Angstrom units (Å)

b) Schott UV-R-250 centered at 2600 Å

c) Schott UG-11 (treated with a $NiSO_4$ solution) centered at 3250 Å

d) Visible band-pass filter in the range of 4000-6000 Å.

The band-pass ranges for the three UV filters will be at most 400 Å (central wavelength ±200 Å).

The film to be used is Eastman Kodak spectroscopic film type IIa-O. Sensitometric calibration of the film is required for this experiment. The minimum sequence of photographs consists of thirteen sets of four photographs each, for a total of 52. Each set will contain one photograph with each of the four filters. The sequence is as follows:

a)	Earth Parking Orbit:	Clouds	4	(1 set)
		Land and Water	4	
b)	Translunar Coast (TLC) (photographs of the earth disc from these approximate distances):	60,000 NM	4	
		120,000 NM	4	
		180,000 NM	4	
c)	Lunar Orbit:	Earth	4x2	(2 sets)
		Earth and Lunar Horizon	4	
		Lunar Terra	4	
		Lunar Maria	4	
d)	Transearth Coast (TEC) (photographs of the earth disc from these approximate distances):	180,000 NM	4	
		120,000 NM	4	
		60,000 NM	4	
		TOTAL	52	

MCC will transmit to the crew the times at which photographs are to be taken during TLC and TEC. Tolerance on the times of TLC and TEC photography is ±30 minutes from the time of passage through the indicated distances. During earth orbit and lunar orbit, photographs may be taken at any time the indicated subject areas are available. The spacecraft attitude must be such that the photographic subject area is in the field-of-view of the camera, which is mounted with its optical axis normal to the right hand side window. The CSM attitude deadband will be ±5° (all axes) during periods of photography. The crew will be responsible for unstowing and stowing the camera, filter slide, and bracket, for mounting the camera with bracket to the RH window and attaching the filter slide, for taking photographs with each of the four filters, and for recording CSM gimbal angles during periods of photography. Exposure parameters for the photographs are given in the Photographic and Television Procedures for Mission J-1.

Success Criteria

FTO 1) FTO 2) The photographic data defined under Test Conditions shall be acquired and returned to earth for processing.

Evaluation

FTO 1) FTO 2) The Principal Investigator will examine the photographs for correlation with known earth conditions, and to discover evidence of lunar surface fluorescence. (Photographs and BET)

Data Requirements

1) Photographs: (M)

   Fifty-two photographs as described under Test Conditions

2) Astronaut Logs and Voice Records: (M)

   GET of initiation and completion of each set of four photographs.

3) Trajectory Data: (M)

   Best estimate of trajectory (BET) and CSM gimbal angles for the period of each set of photographs.

Background and Justification

This experiment is an investigation of the terrestrial atmosphere by means of photographs of the earth obtained in ultraviolet light at planetary distances in order to aid in the interpretation of similar photographs of Mars and Venus. By photographing the earth in the same manner that is employed for planetary studies, one can use the detailed knowledge about the properties of the terrestrial atmosphere to interpret such planetary observations.

It has been known for many years that photographs of both Mars and Venus obtained in ultraviolet light ($\lambda < 4500$ Å) reveal features not present on visible light photographs. In each case, the anomalous appearance of the planet is attributed to atmospheric effects, but the precise nature of these effects remains unknown.

The appearance of Venus in the ultraviolet is characterized by the presence of dusky markings that are not evident on the customarily featureless visible light photographs of the planet. It has been suggested that the markings may be the result of photochemically produced species, but no convincing identifications of such absorbers have yet been made.

Ultraviolet photographs of Mars appear nearly featureless, with only a few bright clouds on a generally neutral background. The apparent absence of surface detail has led to the hypothesis of a so-called blue haze, which prevents the observer from seeing the planet's surface at the shorter wavelengths. The nature of this haze has remained obscure, although it has been suggested that it might be the result of very fine ice crystals. Several investigators have proposed that the blue haze as such does not exist, and that the absence of apparent surface detail is simply the result of a lack of contrast in the ultraviolet.

It is probable that photographs of the earth taken at the shorter wavelengths will also be dominated by atmospheric features, since it is well known that atmospheric scattering (both molecular and particulate) becomes much more intense as the effective wavelength of observation diminishes.

It is of special interest to be able to identify the various features that are revealed by earth photographs. Do high altitude clouds appear? Do dark areas correspond to clear or cloudy regions of the atmosphere (both hypotheses have been proposed for Venus and Mars)? How much surface detail is visible? How different is its appearance? These questions of interest will have straightforward answers from the data. One can anticipate that such records of the appearance of our own planet will remove much of the mysticism associated with the observations of Mars and Venus, and may also lead to some concrete suggestions for the interpretation of these observations.

Two additional investigations will be carried out with the photographic data. One of these is a study of the terrestrial atmosphere at 2600 Å; the other is a search for lunar color differences and possible fluorescence, also at this effective wavelength. At 2600 Å the lower atmosphere of the earth will be shielded by the ozone layer and one will in effect be observing Rayleigh and Mie scattering from molecules and aerosols in the upper atmosphere. It will be of considerable interest to see whether characteristic global patterns appear on such photographs, particularly in view of the well known latitudinal variation in ozone concentration. Of special interest is the opportunity to observe simultaneously the global distribution of high-altitude aerosols. The most familiar manifestation of these to the ground-based observer is the phenomenon of noctilucent clouds. These clouds are observed most commonly in the latitude range of 45-60°, but there is the possibility that this restriction is imposed by conditions of observation rather than by the process of formation of the clouds. At average heights of 82 km, the noctilucent clouds lie well above the maximum ozone concentration ($\sim$23 km) and should appear in the UV photographs. By photographing only that portion of the atmosphere above the ozone layer, it will be possible to determine which of the features appearing at slightly longer wavelengths are caused by the upper atmosphere.

Photographs of the moon at 2600 Å will be used to extend the wavelength coverage of ground-based colorimetric work and to search for possible fluorescence. Color differences on the moon that can be correlated with topographic features have been known for some time. By extending the wavelength range, it should be possible to improve the definition of features already recorded as well as to detect new colorimetric boundaries.

Lunar fluorescence in this spectral region has been reported by Soviet investigators, but has not been confirmed or properly interpreted. By comparing calibrated photographs obtained at several wavelengths, it will be possible to obtain new data regarding this phenomenon.

In summary, UV photographs of the earth obtained in this experiment will be correlated with known conditions of the terrestrial atmosphere. These correlations will be of significant value in the interpretation of previous UV data on planetary atmospheres, e.g., data obtained from the Mariner flyby missions to Mars.

Previous Mission Experiments	Title	Mission
None		

CONTINGENCY SAMPLE COLLECTION

Collect a contingency sample.

Purpose

The purpose is to collect a small sample of loose material (approximately two pounds) in the immediate vicinity of the LM during the early part of the first EVA period. This will increase the probability of returning a lunar sample to earth in the event of early termination of the EVA period.

The functional test objective is as follows:

FTO 1) Provide a contingency sample for postflight scientific investigations.

Test Conditions

FTO 1) The astronaut will scoop up a loose sample of lunar material during the early part of the first EVA period. Using the Lunar Surface Hasselblad Camera, one photograph will be obtained of the sample while it is on the lunar surface and a second photograph will be obtained of the lunar surface area from which the sample was taken. The sample container will be sealed and stowed in the LM ascent stage during the first EVA period.

Success Criteria

FTO 1) The contingency sample shall be delivered to the Lunar Receiving Laboratory (LRL).

Evaluation

FTO 1) Astronaut records, the sample and the photographs will be studied in the LRL and by the sample Principal Investigators. (Astronaut records, photographs and sample)

Data Requirements

1) Astronaut Logs or Voice Records: (M)

   Character of area where sample was obtained and location of area relative to the LM.

2) Photographs: (HD)

   Photograph of the sample while it is on the lunar surface and photograph of the lunar surface after the sample is collected.

3) Single sample of lunar surface material. (M)

CONTINGENCY SAMPLE COLLECTION

Background and Justification

The contingency sample will be collected as early as practical during the initial EVA period. This will increase the probability of returning at least a minimal lunar sample should a contingency situation arise early during lunar stay which precludes any further EVA operations.

Apollo 11, 12, H-3 and H-4 provided contingency samples and it is planned that Apollo J-1 will also provide a contingency sample. It will be desirable to obtain such a sample at the new landing site for Apollo Mission J-1 in order to assess possible differences in the lunar surface material.

Previous Flight Objectives

Objective Number	Title	Mission
A	Contingency Sample Collection	11
A	Contingency Sample Collection	12
--	Contingency Sample Collection	H-3
--	Contingency Sample Collection	H-4

SELECTED SAMPLE COLLECTION

Collect samples of lunar material.

Purpose

The purpose is to collect selected geologically interesting lunar material during the lunar surface EVA.

The functional test objectives in order of priority are as follows:

FTO 1) Collect rock samples and fine-grained fragmental material.

FTO 2) Collect one large rock.

Test Conditions

FTO 1) Selected samples of rock with varied texture or mineralogy will be collected and the remainder of the sample collection will be comprised of fine-grained fragmental material representative of the landing area. Approximately three-fourths of the quantity will be rock samples with the remaining one-fourth fine-grained material. Upon completion of the sample gathering, samples will be sealed in sample return container number 1 and transferred to the LM.

FTO 2) One large rock of TBD size will be placed in sample return container number 1.

FTO 1)
FTO 2) Photographic requirements are TBD. (It is anticipated that photographic requirements for selected sample collection will be the same as for documented samples). There is no specific requirement for the sample collection area to be at a certain location with respect to the LM.

Success Criteria

FTO 1) Selected rock samples and fine-grained fragmental material shall be collected and delivered to the LRL.

FTO 2) One large rock shall be collected and delivered to the LRL.

Evaluation

FTO 1)
FTO 2) Postflight data evaluation will include evaluation of photographs and analysis of the samples in the LRL and by the individual Principal Investigators in their laboratories. (Astronaut records, photographs and samples)

Data Requirements

1) Astronaut Logs or Voice Records: (M)

Character of area where sample was obtained and location of area relative to the LM.

2) Photographs: (HD)

Photographs of lunar samples and the surrounding lunar surface sample areas.

3) Lunar Surface Samples: (M)

a) Samples of lunar rock and fine-grained fragmental material.

b) One large rock.

SELECTED SAMPLE COLLECTION

Background and Justification

Sample collecting and documenting for the S-059 Lunar Field Geology Experiment, to be done during the second EVA period, will require considerable time and may not be completed. The selected lunar material samples, therefore, should be collected during the first EVA period to assure the return of a reasonable sized sample of selected material should the second EVA period be cancelled. One rock sample will be the largest rock readily available to the crew that can be included with the other samples in sample return container number 1.

The selected sample collection will provide a large amount of lunar material for various scientific investigation techniques not directly related to the Lunar Field Geology Experiment.

Apollo 11 provided a bulk sample of lunar material, Apollo 12, H-3 and H-4 provided selected samples. Samples collected during Apollo Mission J-1 will provide lunar material from a different landing area and with possibly a more diversified composition than was possible during previous Apollo missions. This will permit a more extensive scientific investigation.

Previous Flight Objectives

Objective Number	Title	Mission
F	Bulk Sample Collection	11
F	Selected Sample Collection	12
-	Selected Sample Collection	H-3
-	Selected Sample Collection	H-4

APOLLO LUNAR SURFACE EXPERIMENTS PACKAGE

Deploy the Apollo Lunar Surface Experiments Package (ALSEP) Array D.

Purpose

The purpose is to deploy ALSEP, a package of scientific instruments and supporting subsystems, on the lunar surface to detect geophysical and environmental data for transmission to earth. ALSEP Array D includes Experiments S-031, S-033, S-034 and S-037.

The functional test objectives are as follows:

FTO 1) Deploy the Passive Seismic Experiment (S-031).

FTO 2) Deploy the Active Seismic Experiment (S-033).

FTO 3) Deploy the Lunar Surface Magnetometer Experiment (S-034).

FTO 4) Deploy the Heat Flow Experiment (S-037).

Test Conditions

FTO 1)
FTO 2)
FTO 3)
FTO 4)

The lunar surface deployment task will begin when the astronaut removes the ALSEP from the descent stage of the LM. Two packages will be lowered to the surface via a lanyard-pulley arrangement. The astronaut will then remove the radioisotopic fuel source from its carrying cask on the LM and transfer it to the radioisotope thermoelectric generator (RTG) located on package number two. The RTG will be sealed and packages numbers one and two will be connected by a mast which allows the entire assembly to be carried in barbell fashion to the deployment site.

Upon arrival at the deployment site, the two packages will be separated and set upright. The experiments will be removed from the packages, assembled and power connections made to the central station. The antenna on package number one will then be erected on the central station and aimed at the earth.

The ALSEP telemetry data will be transmitted on an S-band carrier and received and recorded at an appropriate MSFN ground station. Telemetry data will then be routed to the MCC for display and control, and command data generated at the MCC will be transmitted to the ALSEP.

The astronaut will request transmitter turn-on from MCC and MCC will in turn initiate this ground command. MCC will then confirm ALSEP Transmitter ON by observing data display from telemetry. A satisfactory indication will be followed by an Experiment Power ON command after which telemetry data display will indicate whether or not all experiments are operating properly. Failure of Transmitter ON or Experiment Power ON commands will require astronaut coordination for manual execution (via switch) of these commands on the lunar surface. The deployment area, the deployed experiments and the central station will be photographed showing their relative positions and the emplacement on the lunar surface.

Deployment of the ALSEP will be accomplished at a distance of at least 300 feet from the LM in the manner specified in the Mission Science Requirements Document, Volume II.

The ALSEP will be deployed and activated as early as possible in the first EVA to:

a) Obtain maximum data (seismic and pressure) resulting from movements of the astronauts.

b) Provide sufficient time to assess ALSEP performance so that manual repair or adjustment can be performed if required during the lunar stay period.

FTO 2) Following deployment and activation of the ALSEP, the astronaut will activate the Apollo standard initiator explosive charges of the Active Seismic Experiment thumper device along the emplaced geophone line.

Success Criteria

FTO 1)
FTO 2)
FTO 3)
FTO 4) Telemetry data shall be received from the ALSEP central station and from each of the four experiments upon activation on the lunar surface and shall continue for a minimum of one lunar day.

FTO 2) The high explosive grenades shall be mortar fired upon transmission of the ground command which shall be issued shortly before one year has elapsed since emplacement of the Active Seismic Experiment. Data on the resulting seismic waves shall be obtained.

Evaluation

FTO 1)
FTO 2)
FTO 3)
FTO 4) Postflight evaluation will consist of telemetry data analysis on each experiment, and a determination of proper experiment operation. Tapes will be formatted in Houston for processing by each Principal Investigator. Data processing of the individual experiment tapes will be accomplished by the Principal Investigators utilizing their own computer systems and programs. Astronaut records and photographs will provide additional data for the evaluation.

Data Requirements

1) Telemetry Measurements: (M)

   Data requirements for ALSEP are specified in Bendix document ALSEP-SE-03, Measurements Requirements Document.

2) Astronaut Logs or Voice Records: (M)

   Comments on deployment and activation.

3) Photographs: (HD)

   TBD photographs of deployment area, the deployed experiments and the central station as defined in the Mission Science Requirements Document, Volume II.

Background and Justification

The Passive Seismic Experiment (PSE) is designed to monitor seismic activity and affords the opportunity to detect meteoroid impacts and free oscillations of the moon. It may also detect surface tidal deformations resulting in part from periodic variations in the strength and direction of external gravitational fields acting upon the moon.

Analysis of the velocity, frequency, amplitude and attenuation characteristics of the seismic waves should provide data on the number and character of lunar seismic events, the approximate azimuth and distance to their epicenters, the physical properties of subsurface materials and the general structure of the lunar interior.

In the lower frequency end (approximately 0.004 to 3 Hertz) of the PSE seismic signal spectrum, motion of the lunar surface caused by seismic activity will be detected by tri-axial, orthogonal displacement, amplitude-type sensors. These sensors and associated electronics comprise the long period (LP) seismometer. In the higher frequency end (approximately 0.05 to 20 Hertz) of the PSE seismic signal spectrum, vertical motion of the lunar surface caused by seismic activity will be detected by a one-axis sensor. This sensor and associated electronics comprise the short period (SP) seismometer.

The Active Seismic Experiment (ASE) is designed to generate and monitor artificial seismic waves in the 3 to 250 Hertz range, in the lunar surface and near subsurface. The ASE can also be used to monitor natural seismic waves in the same frequency range. Seismic waves will be artificially produced by explosive devices, and detected by geophones. Two energy sources will be employed. The thumper will be used to fire an initiator at each 15-foot interval as the astronaut returns to the central station along the geophone cable (310 feet in length). The thumper device contains 21 explosive initiators. The astronaut will also emplace a mortar package containing four high-explosive grenades. The grenades will be rocket-launched by earth command (no later than 1 year after LM lift-off from the lunar surface) and are designed to impact at four different ranges:

approximately 500, 1000, 3000 and 5000 feet, with individual high-explosive charges proportional to their range.

By varying the location and magnitude of the explosions with respect to the geophones, penetration of the seismic waves to depths of approximately 500 feet can be achieved, and wave velocities through several layers of subsurface materials investigated. Interpretation of the velocities of these compression waves, their frequency spectra, and rate of attenuation permits the type and character of the lunar material to be inferred, as well as the degree of hardness and bearing strength of these materials.

The Lunar Surface Magnetometer Experiment (LSM) is designed to measure the magnitude and temporal variations of the lunar surface equatorial field vector. Data from this experiment will also be used to derive information on the electrical properties of the deep interior of the moon and on the interplanetary magnetic field that diffuses through the moon.

The LSM consists of three magnetic sensors, each mounted in a sensor head and located at the ends of 3-foot-long support arms. The magnetic sensors, in conjunction with the sensor electronics, provide signal outputs proportional to the incident magnetic field components parallel to the respective sensor axes.

The Heat Flow Experiment (HFE) is designed to measure the net outward flux of heat from the moon's interior. Measurements of lunar heat flux will provide:

a) A comparison of the radioactive content of the moon's interior and the earth's mantle.

b) A thermal history of the moon.

c) A lunar temperature versus depth profile.

d) The value of thermal parameters in the first 3 meters of the moon's crust.

When compared with other science measurements, data from the HFE will provide information on the composition and physical properties of the moon's crust.

Two 2-section probes with heat sensors and a heater at each end of each section will be used in conjunction with the HFE electronics package to measure absolute and differential temperatures and thermal conductivity of lunar material. The probes will be inserted into holes bored 3 meters deep into the lunar surface by the astronaut using the Apollo lunar surface drill (ALSD). A core sample approximately 8 feet long will be obtained. Six core stems featuring an open bit will be used to obtain the core sample. Two core stems will be initially inserted into the ALSD and driven into the surface. Additional core stems will be added until the string of six are driven into the surface.

The success criteria of these experiments are associated with satisfactory ALSEP deployment and the receipt of specified telemetry data from the experiment package. The ALSEP mission begins after the experiments are deployed. The ALSEP has a design goal to transmit experiment data for a period of two years; these data will be recorded continuously by MSFN ground stations. MCC monitoring and command controls of ALSEP will be exercised at periodic intervals during the ALSEP lifetime. All data for the entire operating period of ALSEP will be processed and the results of the data will be published in a formal report submitted by each Principal Investigator to NASA.

The Passive Seismic Experiment (S-031) was deployed during Apollo 11, 12, H-3 and H-4 missions. It is planned to deploy additional passive seismic experiments on future lunar missions, consistent with a planned seismic net.

Previous Mission Experiments

Experiment Number	Title	Mission
S-031	Lunar Passive Seismology	11
S-031	Passive Seismic Experiment	12
S-034	Lunar Surface Magnetometer Experiment	12
S-031	Passive Seismic Experiment	H-3
S-033	Active Seismic Experiment	H-3
S-031	Passive Seismic Experiment	H-4
S-034	Lunar Surface Magnetometer Experiment	H-4

LUNAR FIELD GEOLOGY

Conduct those portions of the Apollo Lunar Field Geology Experiment (S-059) assigned to Apollo Mission J-1.

Purpose

The purpose is to increase knowledge and obtain a better understanding of the nature and origin of the moon, and the processes which have modified it, through the study of lunar topographic features and the collection of documented lunar material samples.

The functional test objectives are as follows:

FTO 1) Obtain nine core tube samples of lunar material.

FTO 2) Collect a special environmental sample of lunar material.

FTO 3) Collect samples of lunar surface material for study of residual magnetism.

FTO 4) Examine, describe, photograph, and collect lunar geologic samples for return to earth.

FTO 5) Study and describe field relationships (such as shape, size, range, patterns of alignment or distribution) of all accessible types of lunar topographic features.

FTO 6) Collect lunar surface rock chips using a TBD technique (sieve and rake techniques are under consideration).

Test Conditions

FTO 1) Nine core tube samples will be collected from areas of geological interest. Criteria for selecting sampling locations and obtaining single/multiple core tube samples are TBD. TBD photographs will be obtained.

FTO 2) A special environmental sample will be collected from the bottom of the trench dug in support of the S-200 Soil Mechanics Experiment. The sample will be sealed in the special environmental sample container and placed in sample return container number TBD. Photographic procedures will be the same as for a documented sample except that a horizon photograph is not required.

FTO 3) One micro-breccia and one crystalline rock will be collected at least 300 feet from the LM, placed in the magnetic sample container and stored in a tote bag. These rocks should fill the container as nearly as possible. Photographic procedures will be the same as for a documented sample except that a horizon photograph is not required.

FTO 4) Samples will be collected using the tools carried on the LRV and will be documented by normal documented sample photographs. A limited number of specially selected samples will be placed individually in prenumbered bags and the bags placed in the sample return container weigh bag. These rocks and lunar material will be obtained from each of the major geological sites on the traverse. At lease four documented samples will be obtained at each geologic stop. In addition, the following samples are highly desirable:

a) One or more chips taken from a rock too large to be collected in its entirety. The number of chips to be taken will be determined by the rock texture, mineralogy and structure.

b) Three samples from a rock trail to include a lunar sample from the center of the trail, a lunar surface sample beside and adjacent to the trail, and a rock chip from the rock which made the trail.

c) Radial sampling of a crater to include two samples taken on the rim of the crater and outward from the rim into the field of ejecta.

The above highly desirable samples will be placed individually in prenumbered bags and the bags placed in the sample return container weigh bags.

Additional samples judged by the crew to be of particular interest will be stowed loose in the weigh bag. If the weigh bag is filled with samples, then at the discretion of the crew and within the timeline constraints, additional loose samples may be placed in the remaining volume of the SRC available for samples or in another weigh bag. The priority of additional samples in descending order is as follows:

a) Small rocks (similar in size to documented rocks).

b) A large rock that could not be put in an SRC.

c) Rock chips (up to approximately one inch in diameter).

Near-field and far-field photographic polarimetric measurements will be obtained to provide local calibration data. The procedures to be used are TBD. It is anticipated that both the

Lunar Surface Hasselblad Camera and the Lunar Geological Exploration Camera (LGEC) will be used.

Near-field and far-field photographic colorimetric measurements will be obtained. The procedures to be used are TBD. It is anticipated that both the Lunar Surface Hasselblad Camera and the LGEC will be used.

FTO 5) Lunar surface features and field relationships will be described and photographed. Several sets of panoramic photographs will be taken. Each set will consist of at least 12 photographs, overlapped to provide 360-degree coverage. The far-field detent will be used for all panoramic photographs. The astronaut will aim the Lunar Surface Hasselblad Camera so that the horizon will appear near the top of each photograph.

Three sets of panoramic photographs will be taken in the immediate proximity of the LM (i.e., at locations approximately 20 feet from LM quad 2, from LM quad 3, and from the LM +Z strut). Up to nine additional panoramic photographs of areas of interest and prominent distant features will be taken during each traverse. It is anticipated that the Lunar Surface Hasselblad Camera will be used for panoramic photographs and to photograph other features TBD. The LGEC will be used to document samples, to photograph specific local features and to photograph other items TBD.

These photographs will be based on the following criteria and as defined in the Mission Science Requirements Document (MSRD), Volume II, and in the Photographic and Television Procedures:

a) Geologic features of scientific interest along the planned traverse.

b) From high elevation points along the traverse from which the unobstructed horizon can be seen.

c) Items of crew interest.

d) Upon change of direction or start of advance on a new leg of the traverse.

FTO 6) The test conditions to collect rock chips are TBD.

FTO 1)
FTO 2)
FTO 3)
FTO 4)
FTO 5)
FTO 6)

The position of the landed LM will be determined in real time by the following techniques:

a) LM position as indicated with the LM RR locked onto the CSM, and with the CSM tracking the control landmark.

b) LM position as determined by use of the LM alignment optical telescope and the direction portion of the gravity vector.

c) LM position as determined by the CMP using the sextant or the scanning telescope.

d) The LM position as indicated by PGNCS.

e) The LM position as indicated by AGS.

f) Crew observations during the descent phase and after landing are highly desirable. Lunar features will be related to area maps carried in the LM.

FTO 1)
FTO 2)
FTO 3)
FTO 4)
FTO 5)
FTO 6) The position of the LRV will be determined in real time by techniques TBD.

Success Criteria

FTO 1) Nine core tube samples shall be collected and delivered to the LRL.

FTO 2) The special environmental sample shall be collected and delivered to the LRL.

FTO 3) The lunar rock samples for magnetic analysis shall be collected and delivered to the LRL.

FTO 4) The collection of at least four documented samples at each geologic stop, the placing of samples in the proper containers, and return of the containers and film data to the LRL shall be accomplished.

FTO 5) Lunar surface features shall be observed, described and photographed and the film data shall be returned to the LRL.

FTO 6) Lunar surface rock chips shall be collected and delivered to the LRL.

Evaluation

FTO 1)
FTO 2)
FTO 3)
FTO 4)
FTO 5) The Principal Investigator and Investigation Team will study the samples and data returned to earth. The investigations will be conducted in the LRL and in individual investigator's laboratories. The Investigation Team will debrief the astronauts on the basis of the results of examination of the data

FTO 6) returned. The location of the landed LM and LRV positions during traverses shall be determined. (Astronaut records, astronaut debriefing, lunar surface samples, photographs, video tapes, MSFN tapes, photomaps, RTCC data, CG 0001 V, GG 0001 X, GI 0001 X, and LRV telemetry data).

Data Requirements

1) Telemetry Measurements:

Measurement Number	Description	TM	Mode	Priority
CG 0001 V	Computer Digital Data - 40 bits	PCMD+	2	M*
GG 0001 X	PGNS Downlink Data (to TM)	PCM	1	M**
GI 0001 X	AGS Downlink Data (to TM)	PCM	1	HD***

*Required for periods when the CSM tracks the control landmark after LM landing and when the CSM tracks the LM at the landing site.

**Required from initiation of PDI through touchdown, during the first IMU fine alignment after touchdown, during the period when the Lunar Surface Navigation Program (P22) is accomplished, and during the period when the PGNCS Lunar Surface Align Program (P57) is performed.

***Required from initiation of PDI through touchdown until the AGS Lunar Surface Gyro calibration is performed.

LRV telemetry data requirements are TBD.

2) Astronaut Logs or Voice Records: (M)

a) Comments and identification of samples and photographs.

b) Records of where samples were obtained (location and depth) and reason for selection.

c) Geologic observations of lunar surface.

3) Photographs:

Photographs will be taken as defined in the Test Conditions for FTO 1) through FTO 6) and as detailed in the MSRD, Volume II. Photographs are to include:

a) Photographs of the individual lunar surface sample areas. (M)

b) Photographs of the individual geologic samples. (M)

c) Near-field and far-field photographic polarimetric measurements. (M)

d) Near-field and far-field photographic colorimetric measurements. (M)

e) Three sets of panoramic photographs near the LM. (M)

f) Up to nine sets of panoramic photographs taken during each traverse. (At least one panorama per major site or change of traverse direction greater than 45° is mandatory. Remainder of panoramas are highly desirable).

g) Photographs of the rock chip collection area. (M)

4) Lunar Surface Samples:

a) Nine core tube samples. (M)

b) Special environmental sample. (M)

c) Mangetic rock samples (M)

d) Lunar geologic samples. (M)

e) Lunar rock chips. (M)

f) Rock chip samples from a rock too large to be collected in its entirety. (HD)

g) Samples from a rock trail. (HD)

h) Samples obtained by radial sampling of a crater. (HD)

5) Lunar surface TV; real-time and video tapes. (HD)

6) Postflight evaluation of landed LM position on lunar surface. (M)

7) Astronaut debriefing data. (M)

8) MSFN tape recordings of all MSFN/EVA voice conferences. (M)

9) Annotated photomaps. (HD)

10) RTCC Data:

Location of the landed LM as determined in real time from the following:

a) Rendezvous radar and CSM SXT tracking data. (M)

b) LM alignment optical telescope and the direction portion of the gravity vector. (M)

c) CMP using the CSM SXT. (M)

d) As indicated by PGNCS. (M)

e) As indicated by AGS. (HD)

11) LRV positions during traverses as determined in real time by techniques TBD.

Background and Justification

The fundamental objective of the Lunar Field Geology Experiment is to provide data for use in the interpretation of the geologic history of the moon in the vicinity of the landing site. Apollo lunar landing missions offer the opportunity to correlate carefully collected samples with a variety of observational data on at least the upper portions of the mare basin filling and the lunar highlands, the two major geologic subdivisions of the moon. The nature and origin of the maria and highlands will bear directely on the history of lunar differentiation and differentiation processes. From the lunar bedrock, structure, land forms and special materials, information will be gained about the internal processes of the moon. The nature and origin of the debris layer, or regolith, and land superimposed on the maria and highland regions are a record of lunar history subsequent to their formation. This later history predominately reflects the history of the extra-lunar environment. Within and on the regolith, there will also be materials that will aid in the understanding of geologic units elsewhere on the moon and the broader aspects of lunar history.

The polarizing filters, built into the LGEC stereo camera, will permit the measurement of the degree of polarization and orientation of the plane of polarization contained in light reflected from the lunar surface. Different lunar materials, i.e., fine-grained glass and/or fragments, strongly shocked rocks, slightly shocked rocks and shock-lithified fragmental material, have different polarimetric functions. Comparison of the polarimetric function of known material, such as returned samples and close-up lunar surface measurements, to materials photographed beyond the traverse of the astronaut will allow the classification and correlation of these materials even though their textures are not resolvable. The polarimetric properties of lunar materials and rock types are a useful tool for correlation and geologic mapping of each landing site, and for extrapolation of geologic data from site to site across the lunar surface.

The photometric chart carried on the tool carrier will be used to establish more accurate photometric and colorimetric constants than is possible with the gnomon. The "in situ" photometric properties of both fine-grained materials and coarse rock fragments will serve as a basis for describing, recognizing, delineating, and classifying lunar materials. The photometric chart will be placed in a picture at least once, and, if feasible, whenever different appearing lunar materials are encountered. Thus, the photometric chart will be photographed beside a representative rock, and if practical, beside any rock or fine-grained material with unusual features.

The background information relating to the J-1 mission landing site is TBD.

Previous Mission Experiments

Experiment Number	Title	Mission
S-059	Lunar Field Geology	11
S-059	Lunar Field Geology	12
S-059	Lunar Field Geology	H-3
S-059	Lunar Field Geology	H-4

LASER RANGING RETRO-REFLECTOR

Deploy the Laser Ranging Retro-Reflector Experiment (S-078)

Purpose

The purpose is to deploy the Laser Ranging Retro-Reflector Experiment package on the lunar surface to provide a corner reflector for laser ranging from earth.

The functional test objective is as follows:

FTO 1) Deploy the Laser Ranging Retro-Reflector (LRRR) Experiment.

Test Conditions

FTO 1) The astronaut will remove the experiment from the descent stage of the LM and carry it to the deployment site. The LRRR Experiment will be emplaced, leveled and oriented to the alignment marks corresponding to the landing site.

Deployment Requirements:

a) The LRRR will be deployed a minimum of 300 feet from the LM; a deployment of greater than 500 feet from the LM is highly desirable.

b) The LRRR will face away from the LM to minimize contamination of the reflector surfaces during firing of the ascent engine.

c) The deployment direction will be such that the ascent engine plume does not impinge on the array face.

d) The experiment will be deployed a minimum of 500 feet from the grenade impact area of the Active Seismic Experiment (S-033).

e) TBD photographs will be obtained of the deployment area showing the deployed experiment.

Success Criteria

FTO 1) Successful ranging data shall be obtained at the earth by use of the passive corner reflector system of the LRRR on the moon.

Evaluation

FTO 1) Ranging data obtained by use of the LRRR Experiment will be studied by the Principal Investigator and by other scientists who obtain ranging data from the LRRR. (Astronaut records, photographs and LRRR ranging data).

Data Requirements

1) Astronaut Logs or Voice Records: (HD)

   Comments on orientation and elevation setting used for deployment.

2) Photographs: (HD)

   Photographs of the deployment area with the deployed experiment.

3) LRRR ranging data received at appropriate stations (M)

LASER RANGING RETRO-REFLECTOR

Background and Justification

Apollo 11 and Apollo Mission H-3 included the emplacement of a Laser Ranging Retro-Reflector Experiment package on the lunar surface. Various factors affect laser ranging such as lunar motion, lunar librations and earth rotation. Data on the nature of the irregular variations in the earth's rotation, and hence its cause, are determined from the laser ranging data. Data are also obtained on factors affecting earth rotation such as material imperfections, ocean loading and energy interchanges between atmosphere and crust or core and mantle.

Apollo Mission J-1 will provide further knowledge of gravity and relativity, selenophysics, geophysics, and the motion of the moon. These data will supplement the Apollo 11 and Apollo Mission H-3 data. This should result in a refined definition of lunar motion and libration.

Previous Mission Experiments

Experiment Number	Title	Mission
S-078	Laser Ranging Retro-Reflector	11
S-078	Laser Ranging Retro-Reflector	H-3

COSMIC RAY DETECTOR (SHEETS)

Conduct the Cosmic Ray Detector Experiment (S-152)

Purpose

The purpose is to measure the charge, mass and energy spectrum of heavy cosmic ray particles in the energy ranges from 0.5 to 10 Kev/nucleon and from 0.2 to 200 Mev/nucleon.

The functional test objective is as follows:

FTO 1) Obtain data on cosmic ray particles.

*Test Conditions

FTO 1) Solid particle detectors held within a 4-panel folding array will be mounted on the outside of the descent stage of the LM during the flight to the moon. Just prior to termination of the final EVA on the moon, the 4-panel array will be folded and stowed for return to earth for processing and analysis.

At the time the array is folded, half of the plastic sheets making up the panels will be shifted relative to the other half to allow the identification of particles encountered during return from the moon.

The requirement for shifting the plastic sheets at a time other than at the end of the final EVA, the astronaut activities required to perform the shifting, and the mechanism to do the shifting are TBD.

Success Criteria

FTO 1) The folded detector array shall be brought to the LRL and provided to the scientific coordinator of the experiment team.

Evaluation

FTO 1) The scientific coordinator will distribute portions of the array to the three Principal Investigators for evaluation of the particle tracks in the detector material.

Data Requirements

1) Detector panel array which has been exposed to cosmic ray particles. (M)

*These test conditions are tentative and will be finalized when the hardware is designed.

COSMIC RAY DETECTOR (SHEETS)

Background and Justification

The Cosmic Ray Detector Experiment incorporates three different, partially overlapping, but separate investigations. The detector panel array will be shared by the three experimenters to achieve their separate, but complementary, aims. The primary objectives of these experiments are to measure the charge, mass, and energy spectrum of heavy cosmic ray particles, solar wind particles, etc. Subsidiary objectives are to provide calibration of new detectors for the future, more extended missions, to assess whether the problem of the origin of tektites can be solved by a search for cosmic ray tracks, to understand the Ar^{40} anomaly in lunar surface materials, and to measure the flux of neutrons on the lunar surface.

The goal of the University of California (Berkeley) experiment is to determine the abundances of individual nuclei above He in the energy range from 0.2 to 100 Mev/nucleon and to resolve, where possible, isotopes of elements such as Be, Ne, Al, Si, S, Ar, Ca, and Fe. These will be determined with dielectric track detectors, consisting of a large stack of plastic sheets.

The General Electric R & DC experiment plans: (1) to use plastic track detectors to measure the energy spectra, elemental abundances and, where possible, isotopic abundances of solar and galactic cosmic ray nuclei of $Z \geq 3$ in the energy range from 1 to 200 Mev/nucleon; (2) to calibrate glass detectors for use in future space missions by identifying the tracks of iron group nuclei; and (3) to establish from the characteristics of the iron tracks (if possible) the space exposure and hence the place or origin of tektites.

The purpose of the Washington University experiment is to measure the composition and distribution of nuclear particles in the solar wind. Particles in the energy ranges from 0.5 to 10 Kev/nucleon and from 1 to 100 Mev/nucleon are to be detected. A separate goal is to measure the flux of neutrons on the lunar surface. The experiment will lead to a better understanding of the contemporary flux of solar and galactic particles and will greatly aid in the interpretation of results obtained on the returned lunar samples.

The S-151 Cosmic Ray Detector (Helmets) Experiment performed on Apollo 11 provided preliminary data on the dose of highly charged cosmic rays received by the astronauts. The S-152 Cosmic Ray Detector (Sheets) Experiment is an extension and refinement of S-151 and will provide charge, mass, and energy data on heavy cosmic ray particles.

Previous Mission Experiments

Experiment Number	Title	Mission
S-151	Cosmic Ray Detector (Helmets)	11

PORTABLE MAGNETOMETER

Conduct the Portable Magnetometer Experiment (S-198).

Purpose

The purpose is to obtain data on the lunar magnetic field in the vicinity of the landing site and to obtain a map of the surface magnetic field over an area large in comparison with local surface features.

The functional test objectives are as follows:

FTO 1) Measure the vector magnetic field in the vicinity of the landing site.

FTO 2) Measure the gradient of the magnetic field along the geological traverse.

Test Conditions

FTO 1)
FTO 2) To reduce magnetic interference, the sensor assembly will be deployed 50 feet from the LRV, PLSS and any other deployed equipment, and at least 250 feet from the LM.

The following magnetic field measurements will be made during at least one geological traverse. Additional measurements during other traverses will be highly desirable.

FTO 1) Site Point Measurements:

After the magnetic components have been moved at least 250 feet from the LM, the astronaut will carry the sensor assembly, mounted on the tripod, away from the electronics box until the 50-foot cable is unreeled. The tripod will be leveled and aligned using the bubble level and shadowgraph, and the sensor assembly rotated to the Number 1 position. The astronaut will return to the electronics box and relay the readings of the three meters over the voice communications link to the MCC.

The astronaut will return to the sensor and rotate the sensor assembly 180 degrees from top to bottom to the Number 2 position. The meter readings will be made and relayed to MCC as before. The final site measurement will be taken after rotating the sensor assembly 180 degrees in the horizontal plane to the Number 3 position. The meter readings will be made and relayed to MCC as before.

FTO 2) Traverse Measurements:

Following the site measurements, readings during the traverse will be made as follows:

a) One reading at the most distant point from the LM.

b) One reading at a point approximately midway between the LM and the most distant point.

c) An additional reading at a point opposite the midway reading to provide the largest areal coverage for a particular traverse is highly desirable.

The position of the sensor head for the traverse measurements will be the same as for the final site measurement (the Number 3 position). A reading of the three meters will be voiced to the MCC from each site. These data will give an indication of the change with distance of magnetic flux.

The LRV will be used to carry the portable magnetometer to the traverse measurement locations. The electronics box will remain mounted on the LRV while the astronaut deploys the sensor assembly and tripod 50 feet from the LRV. The astronaut will then return to the LRV and read the three meters on the panel of the electronics box. The readings will be relayed over the voice communications link to the MCC. The sensors assembly, tripod and reeled cable will be returned to the LRV and stowed.

Real-time support will be provided by MCC in order to assess the magnitude and gradient of the magnetic field and to suggest possible sample selections and traverse magnetic field measurements.

FTO 1)
FTO 2) TBD photographs using TBD cameras will be obtained of the deployment areas showing the deployed experiment.

Success Criteria

FTO 1)
FTO 2) The measurement data shall be transmitted by voice to the MCC and provided to the Principal Investigator.

Photographs of the sensor deployment at each measurement site shall be provided to the Principal Investigator.

Evaluation

FTO 1)
FTO 2) The Principal Investigator will evaluate the data. (Astronaut records, photographs)

Data Requirements

1) Astronaut Logs or Voice Records: (M)

   a) Record of meter readings for each of the measurement locations.

   b) Estimate of position of the sensor head relative to the LM for each of the measurements taken during the geological traverse.

2) Photograph of sensor location at each measurement site. (M)

   The photographs are to contain a distinguishable surface feature within the field-of-view to assist in the physical location of the measurement site.

PORTABLE MAGNETOMETER

Background and Justification

The value of the permanent magnetic field at the Apollo 12 landing site was greater than that anticipated as a result of data from Explorer XXXV. Thus, several important scientific questions have been raised:

a) Does a field of comparable strength exist elsewhere on the moon?

b) What is its areal strength?

c) What are the possible dimensions and location?

d) What are the spatial variations of the field?

e) Can they be used to determine geologic structure?

The data from Explorer XXXV indicated that the lunar magnetic field at the surface should not exceed 2 to 8γ. The lunar surface magnetometer from Apollo 12 indicated a local magnetic field of 36γ in the vicinity of the landing site. One gamma is defined as 1×10^{-5} oersteds.

The use of a portable magnetometer will allow measurement of the lunar magnetic field at different locations along a traverse.

The data obtained from this experiment on the J-1 mission will supplement the results from the Lunar Surface Magnetometer Experiment conducted on the Apollo 12 and H-4 missions and the Portable Magnetometer Experiment conducted on the H-3 mission.

Previous Mission Experiments

Experiment Number	Title	Mission
S-034	Lunar Surface Magnetometer	12
S-198	Portable Magnetometer Experiment	H-3
S-034	Lunar Surface Magnetometer	H-4

SOIL MECHANICS

Conduct the Soil Mechanics Experiment (S-200).

Purpose

The purpose is to provide additional data on the characteristics and mechanical behavior of the lunar soil at the surface and subsurface and the variations of these properties in a lateral direction.

The functional test objectives are as follows:

FTO 1) Obtain data on the lunar surface and subsurface characteristics relative to the origin and nature of the lunar soil and on the effort required to excavate the lunar soil.

FTO 2) Obtain data on lunar soil mechanical behavior.

FTO 3) Obtain penetrometer data to depths of at least 50 centimeters and plate load-shrinkage data at the surface.

FTO 4) Obtain a representative sample of fine-grained fragmental material and TBD core tube samples.

FTO 5) Obtain data on the lunar soil-LRV interaction.

Test Conditions

FTO 1) Lunar surface activities will include excavating a trench, recording crew observations and biomedical data, and obtaining photographs. At the trench excavation site a penetrometer and plate load test will be performed on a level surface. Immediately adjacent to these test locations, a narrow trench aligned 10 degrees off the sunline will be excavated to a depth of 6 to 8 inches and the penetrometer and plate load tests will be repeated at the bottom of the trench. Thereafter, the narrow trench excavation will proceed until one of the following first occurs:

a) A wall failure

b) Excavation becomes difficult or dangerous in the opinion of the astronaut

c) 10 minutes have elapsed.

If a wall failure does not occur during excavation, a plate load test will be performed at the top of the wall in an effort to induce a wall failure. The excavated material will be piled in one heap to determine the natural slope of the material. The location where the excavation will be performed is TBD.

FTO 2) Information on lunar soil mechanical behavior will be obtained by evaluating astronaut activities during EVA's. These activities will include inspecting the LM, deploying surface experiments and obtaining the lunar samples defined in the Selected Sample Collection and Lunar Field Geology Experiment.

FTO 3) Lunar surface activities will include probing the surface with the hand penetrometer, acquiring plate load-shrinkage data at locations of differing soil consistency, texture or type and obtaining photographs. Penetrometer operations will be performed as indicated in FTO 1) and will include at least one test at each site where core tube samples (Lunar Field Geology Experiment) are taken. The number of penetrations and penetrometer test conditions are TBD.

FTO 4) Approximately 3 kilograms of fine-grained fragmental material will be obtained at least 50 feet from the LM in an area that has not been disturbed by the descent engine plume. The sample will be taken at one location and will include both surface and subsurface material. The sample should exclude, if possible, rocks larger than approximately 2 centimeters in diameter. The material will be placed in a separate sample bag and stowed in the equipment transfer bag for transfer to the LM. Core tube sample test conditions are TBD.

FTO 5) Test conditions for obtaining data on the lunar soil-LRV interaction are TBD.

Success Criteria

FTO 1) Data shall be obtained on lunar surface and subsurface characteristics relative to the origin and nature of the lunar soil. This shall include data on the ability of an astronaut to excavate the lunar surface, the natural slope of the excavated material, the integrity of the sidewalls of the excavation, and the resistance of the soil at the bottom of the trench and in the sidewalls to penetration and plate loads.

FTO 2) Data shall be obtained on the mechanical behavior of lunar surface material including texture, consistency, compressibility, cohesion, adhesion, density, and color.

FTO 3) Data from penetrometer and plate load tests.

FTO 4) Approximately 3 kilograms of fine-grained fragmental material and TBD core tube samples shall be returned to the LRL.

FTO 5) Success criteria for the lunar soil-LRV interaction objective are TBD.

Evaluation

FTO 1) Lunar surface and subsurface characteristics will be evaluated through analysis of the crew comments and photographs of the excavation and material excavated. The excavation and excavated material will provide data on subsurface strata, sidewall crumbling, density and natural slope of the subsurface material. An estimation of the work required to excavate the lunar surface will be made through analysis of the astronaut metabolic rates while the excavation is in progress. Penetrometer and plate load data (force versus penetration or shrinkage) will yield quantitative data on strength, density, and stress-deformation characteristics. These data will be used for scientific analysis of the origin and nature of lunar surface material. (Astronaut records, photographs and GT 9991 U)

FTO 2) The mechanical behavior of the lunar surface material will be assessed through analyses of the LM footpad-lunar soil interactions, soil accumulation on the LM vertical surfaces, soil mechanics data obtained during EVA, and the returned lunar surface samples. The footpad-soil interaction will be determined from photographs and from analysis of the landing gear stroking and touchdown conditions as determined from lunar trajectory data, descent engine thrust and vehicle mass properties. The Soil Mechanics Team will analyze the soil samples returned to the LRL and will debrief the astronauts on the basis of the results of examination of the returned data. (Astronaut records, photographs, LM mass, center of gravity and mass moment of inertia, GG 0001 X, GG 2112 V, GG 2113 V, GG 2142 V, GG 2143 V, GG 2172 V, GG 2173 V, GH 1313 V, GH 1314 V, GH 1461 V through GH 1463 V, GQ 6510 P and GQ 6806 H.)

FTO 3) Lunar soil strength and deformation characteristics and the existence of any hard stratum or subsurface boulders will be evaluated by comparing the effort required to push the penetrometer and bearing plate into lunar soil with that required to probe terrestrial soil analogs. (Astronaut records, photographs, and penetrometer recording drum.)

FTO 4) Approximately 3 kilograms of the fine-grained fragmental material and TBD core tube samples will be used by the Soil Mechanics Team for determination of texture, density, strength and deformation characteristics, abrasive effects, adhesive properties, grain size and shape and other representative characteristics. (Fine-grained fragmental material and core tube samples)

FTO 5) The analyses required to evaluate the lunar soil-LRV interaction objective are TBD.

Data Requirements

1) Telemetry Measurements:

Measurement Number	Description	TM	Mode	Priority
GG 0001 X	PGNS Down Link Data (To TM)	PCM	1	HD
GG 2112 V	Volt, IG 1X Res Output, Sin	PCM	2	HD
GG 2113 V	Volt, IG 1X Res Output, Cos	PCM	2	HD
GG 2142 V	Volt, MG 1X Res Output, Sin	PCM	2	HD
GG 2143 V	Volt, MG 1X Res Output, Cos	PCM	2	HD
GG 2172 V	Volt, OG 1X Res Output, Sin	PCM	2	HD
GG 2173 V	Volt, OG 1X Res Output, Cos	PCM	2	HD
GH 1313 V	Volt, Pitch GDA Position (Ret/Ext)	PCM	2	HD
GH 1314 V	Volt, Roll GDA Position (Ext/Ret)	PCM	2	HD
GH 1461 V	Volt, Yaw RG Signal (.8 KC)	PCM	2	HD
GH 1462 V	Volt, Pitch RG Signal (.8 KC)	PCM	2	HD
GH 1463 V	Volt, Roll RG Signal (.8 KC)	PCM	2	HD
GQ 6510 P	Press, Thrust Chamber	PCM	2	HD
GQ 6806 H	Position, Variable Inj Actuator	PCM	2	HD
GT 8124 J	Electrocardiogram No 1	FM/FM*	N/A	M
GT 8154 T	Temp LCG H_2O Inlet No 1	FM/FM*	N/A	M
GT 8170 T	Temp PLSS No 1 Subl O_2 Outlet	FM/FM*	N/A	M
GT 8182 P	Press PLSS O_2 Supply No 1	FM/FM*	N/A	M
GT 8196 T	Delta T, LCG H_2O In/Out No 1	FM/FM*	N/A	M
GT 8224 J	Volt, PLSS No 2 EKG	FM/FM*	N/A	M
GT 8254 T	Temp, LCG No 2 H_2O Inlet	FM/FM*	N/A	M
GT 8270 T	Temp, PLSS No 2 Subl O_2 Outlet	FM/FM*	N/A	M
GT 8282 P	Press, PLSS No 2 O_2	FM/FM*	N/A	M
GT 8296 T	Delta T, LCG No 2 H_2O In/Out	FM/FM*	N/A	M
GT 9991 U	EMU TM Outputs	FM/FM*	N/A	M

*Measurements GT 8124 J through GT 8296 T are part of measurement GT 9991 U.

Telemetry data from GG 0001 X through GQ 6806 H are desired from the period immediately prior to touchdown until the LM motion ceases. GG 0001 X is also desired during the period of the first IMU fine alignment after touchdown.

LRV telemetry data requirements are TBD.

2) Astronaut Logs or Voice Records:

a) Comments on visibility effects due to any lunar dust erosion during the final approach, on the severity of the landing and on the vehicle stability during touchdown. (M)

b) Comments on LM footpad-lunar soil interactions to include estimates of the amount of penetration, soil displacement and footpad skidding. (HD)**

c) Comments on slope and roughness of the terrain. (HD)

d) Comments describing the descent engine skirt ground clearance. (M)

e) Comments on lunar soil erosion caused by the DPS exhaust impingement during landing to include depth, diameter and shape of any erosion crater. (HD)**

f) Estimate of walking distance, weight carried, time required, and description of terrain traversed during traverses for ALSEP deployment or lunar geology sampling. (HD)

g) Comments describing the variations in depth of boot prints in the lunar surface. (M)

h) Comments on the color and texture of both undisturbed areas of the lunar surface and areas disturbed by LM landing and by the astronauts. (M)

i) Comments on the ability to dig in lunar soil and estimates of depths of any layers (or strata) detected. (M)

j) Estimate of the depth, description of the excavation, and time required to complete the excavation. (M)

k) Estimate of the natural slope of the pile of excavated lunar soil if photographs are not obtained by use of the Lunar Geological Exploration Camera (LGEC). (HD)

l) Comments on the effort required to push the penetrometer and bearing plate into the lunar surface and on the depth and firmness of any subsurface obstructions. (M)

m) Comments on soil behavior (i.e., texture, consistency and adhesiveness) during collection of samples or other surface activities, including LRV operations. (HD)

n) Estimate of the amount of stroking of each primary and secondary strut assembly if the landing gear strut assembly photographs cannot be obtained. (HD)***

o) Comments on tendency of surface adjacent to penetrometer and bearing plate test locations to sink, bulge, or crack.

**Comments on footpad-lunar soil interactions and lunar soil erosion are mandatory only if the inspection of the landed LM and the crater reveals a significantly different set of conditions than existed on Apollo 11, 12, H-3 and H-4.

***Data on landing gear stroking are mandatory only if the inspection of the landed LM reveals that any strut stroked 4 inches or more.

3) Photographs:

a) Photographs of the landing gear to show the stroking of the primary and secondary strut assemblies. One photograph is required for each of the eight secondary strut assemblies and the adjoining primary strut assembly. The line of sight from the camera should be approximately perpendicular to the plane containing the strut assembly. Each field-of-view should be as small as possible but should include all of the secondary strut assembly and all of the primary strut assembly at and below the attachment of the secondary assembly. In addition, these members must be photographed prior to the mission. (HD)***

b) Photographs of the LM exterior showing any soil accumulation on the vertical surfaces. (HD)

c) Photographs of the lunar surface showing DPS exhaust impingement erosion crater. (M)

d) Photographs of each LM footpad and surrounding lunar soil exhibiting evidence of LM footpad-lunar soil interaction. (M)

e) Photographs of the course traversed before and after traverses for ALSEP deployment, including photographs of an astronaut footprint showing interaction between astronaut boots and lunar surface. (M)

f) Photographs using the LGEC of the excavation area before, during and after the excavation. (M)

g) Photographs using the LGEC of the pile of excavated material after completion of the excavation. The line of sight of the camera should be approximately perpendicular to the sun direction. (M)

h) Photographs at each penetrometer test to show depth to any impenetrable stratum or the maximum depth to which the astronaut was able to statically push the penetrometer. (M)

i) Photographs of the area where each penetrometer and plate load test was conducted to show the location with respect to LM or a prominent terrain feature. (M)

j) Photographs of natural slopes, boulders, ridges, rills, crater walls and embankments in the vicinity of the landing site. (HD)

k) Lunar Surface Data Acquisition Camera photographs of the trenching operations. (HD)

l) Close-up photographs of undisturbed lunar surface, LRV tracks, bottom of excavated trench, surface of pile of excavated material, boot print and surface under LM descent stage. (HD)

m) Photographs using the LGEC of the lunar soil-LRV interactions. (M)

n) Lunar Surface Data Acquisition Camera photographs of the LRV in motion. (M)

o) Photographs to show detail of soil surface adjacent to penetrometer and plate load tests. Photographs to be taken of the surface both before and after the tests are performed.

4) LM mass, position, velocities and accelerations with respect to the LM landing point during the last 2 minutes before touchdown. (M)

5) Soil mechanics data derived from the returned lunar surface samples obtained in support of Experiment S-059 Lunar Field Geology. (M)

6) Approximately 3 kilograms of fine-grained fragmental material and TBD core tube samples. (M)

7) Penetrometer recording drum. (M)

SOIL MECHANICS

Background and Justification

In order to conduct extensive lunar explorations, surface and subsurface characteristics must be known. It is also important that terrain features be correlated with the soil mechanical properties.

Data obtained from Apollo 11 and 12 and from Apollo Mission H-3 and H-4 will be used to predict the soil mechanical properties at the J-1 mission landing site, based on a correlation betwen the terrain features and soil conditions.

The J-1 mission will provide additional data on lunar soil mechanical properties and terrain features to include penetrometer and plate load test data and lunar soil-LRV interaction data. These data are essential for improving methods of selecting future landing sites, evaluating design criteria for roving vehicles and developing construction techniques for lunar stations.

The fine-grained fragmental material will be used for baseline studies and further evaluation of the mechanical behavior of the lunar soil.

Previous Flight Objectives/Experiments

Objective/Experiment Number	Title	Mission
B	Lunar Surface EVA Operations	11
D	Landing Effects on LM	11
E	Lunar Surface Characteristics	11
B	Lunar Surface EVA Operations	12
H	Lunar Surface Characteristics	12
S-200	Soil Mechanics	H-3
S-200	Soil Mechanics	H-4

APPENDIX A

ACRONYMS AND ABBREVIATIONS

Å	Angstrom Unit (One Ten-Billionth of a Meter)
AFMAD	Apollo Flight Mission Assignments Directive
AGS	Abort Guidance System
AIMP	Advanced Interplanetary Monitoring Platform
Al	Chemical Symbol for Aluminum
ALSD	Apollo Lunar Surface Drill
ALSEP	Apollo Lunar Surface Experiments Package
AOS	Acquisition of Signal
Ar	Chemical Symbol of Argon
Ar^{36}	Isotope of Argon
Ar^{38}	Isotope of Argon
Ar^{40}	Isotope of Argon
APO	Apollo Program Office
ASE	Active Seismic Experiment
ASPO	Apollo Spacecraft Program Office
Be	Chemical Symbol for Beryllium
Ca	Chemical Symbol for Calcium
CCB	Configuration Control Board
CCBD	Configuration Control Board Directive
CM	Command Module
CMP	Command Module Pilot
CSM	Command and Service Module
d-c	Direct Current
DE	Detailed Experiment

DOI	Descent Orbit Insertion
DPS	Descent Propulsion System
DSE	Data Storage Equipment
DSN	Deep Space Network
E	East
EKG	Electrocardiogram
EMU	Extravehicular Mobility Unit
EVA	Extravehicular Activity
Fe	Chemical Symbol for Iron
FM	Frequency Modulation
FM/FM	Frequency Modulated Subcarrier
FMC	Forward Motion Control
FOV	Field-of-View
FTO	Functional Test Objective
GDA	Gimbal Drive Actuator
GET	Ground Elapsed Time
HD	Highly Desirable
HFE	Heat Flow Experiment
IMU	Inertial Measurement Unit
JPL	Jet Propulsion Laboratory
K^{40}	Isotope of Potassium
KC	Kilocycle
Kev	One Thousand Electron Volts
km	Kilometer
Laser	Light Amplification Through Stimulated Emission of Radiation

LCG	Liquid Cooled Garment
LGEC	Lunar Geological Exploration Camera
LM	Lunar Module
LOI	Lunar Orbit Insertion
LOS	Loss of Signal
LP	Long Period
LRL	Lunar Receiving Laboratory
LRRR	Laser Ranging Retro-Reflector
LRV	Lunar Roving Vehicle
LSM	Lunar Surface Magnetometer
M	Mandatory
MCC	Mission Control Center, Mid-Course Correction
Mev	One Million Electron Volts
mm	Millimeter
MRD	Mission Requirements Document
MSC	Manned Spacecraft Center
MSFN	Manned Space Flight Network
MSRD	Mission Science Requirements Document
N_2	Chemical Symbol for Nitrogen
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
Ne	Chemical Symbol for Neon
$NiSO_4$	Nickel Sulfate
NM	Nautical Mile
OGO	Orbiting Geophysical Observatory

ACRONYMS AND ABBREVIATIONS (Continued)

OMSF	Office of Manned Space Flight
OSO	Orbiting Solar Observatory
PCM	Pulse Code Modulation
PCMD	Pulse Code Modulation, Digital
PCMD+	PCMD Channel Available in Both High Bit Rate and Low Bit Rate
PCME	Pulse Code Modulation, Event
PDI	Powered Descent Initiation
PFN	Pulse Forming Network
PGNCS	Primary Guidance and Navigation Control Subsystem
PI	Principal Investigator
PLSS	Portable Life Support Subsystem
PS	Power Supply
PSE	Passive Seismic Experiment
PTC	Passive Thermal Control
R&D	Research and Development
RCS	Reaction Control Subsystem
RG	Rate Gyroscope
RH	Right Hand
Rn^{220}	Isotope of Radon
Rn^{222}	Isotope of Radon
RR	Rendezvous Radar
RTCC	Real Time Computing Complex
RTG	Radioisotope Thermoelectric Generator
S	Chemical Symbol for Sulfur
S&AD	Science and Applications Directorate

SED	Systems Engineering Division
Si	Chemical Symbol for Silicon
SIM	Scientific Instrument Module
SM	Service Module
SP	Short Period
SPS	Service Propulsion System
SRC	Sample Return Container
SXT	Sextant
Tach	Tachometer
TBD	To Be Determined
TEC	Transearth Coast
TEI	Transearth Injection
TLC	Translunar Coast
TM	Telemetry
USSR	Union of Soviet Socialist Republics
U	Unclassified
UV	Ultraviolet
V/H	Velocity/Height
Z	Atomic Number of an Element
γ	Gamma (Measurement of Magnetic Field Strength: $1\ \gamma = 1 \times 10^{-5}$ oersteads)
λ	Lambda (Frequency Wavelength)

APPENDIX B

GLOSSARY

AEROSOL	A suspension of fine solid or liquid particles such as smoke or fog in the earth's atmosphere.
ALBEDO	The amount of electromagnetic radiation reflected by a body expressed as a percentage of the radiation incident on the body.
ALPHA PARTICLE	A nuclear particle of atomic mass 4 made up of 2 protons and 2 neutrons.
ANGSTROM UNIT	A unit of length equal to 10^{-10} meters or 10^{-4} microns commonly used in specifying wavelengths of electromagnetic radiation.
APERTURE	The opening of a camera through which light rays pass when the film shutter is open.
AREAL	Pertaining to coverage of area as maximum areal coverage of a lunar traverse.
ATTENUATION	Decrease in intensity usually of wave phenomena such as light or sound.
BASALTIC	A type of dark gray rock formed by solidification of molten material (previously found on the lunar surface).
BIT	Binary digit of telemetered information.
BOUNDARY LAYER	Interaction layer between the surface of the moon and the undisturbed portion of the solar wind.
BOW SHOCK	The shock wave produced by the interaction of the solar wind with the earth's magnetosphere.
CARTOGRAPHIC	Related to the production of accurately scaled maps as of the moon's surface.
CASSETTE	Container of photographic film for the 24-Inch Panoramic Camera or 3-Inch Mapping Camera.
CISLUNAR	Pertaining to the space between the earth and moon or the moon's orbit.
COLORIMETRIC	Pertaining to the measurement of the intensities of different colors as of lunar surface materials.

COSMIC RAYS	Very high energy nuclear particles, commonly protons, that bombard the earth from all directions.
COSMOLOGICAL	Concerned with the investigation of the character and origin of the universe.
CROSSTRACK	In a plane perpendicular to the instantaneous direction of a spacecraft's ground track.
DEADBAND	The limits of an allowable spacecraft attitude excursion in a particular attitude-hold mode.
DIELECTRIC	A material with few conduction electrons, i.e. an electrical insulator such as the cosmic ray detector sheets.
DIURNAL	Recurring daily.
DOPPLER TRACKING	A continuous-wave, trajectory-measuring system using the Doppler effect caused by a target moving relative to a ground transmitter and receiving stations.
EARTHSHINE	Illumination of the moon's surface by sunlight reflected from the earth.
ECLIPTIC PLANE	The plane defined by the earth's orbit about the sun.
EFFLUENT	Any substance discharged from a spacecraft such as waste water, urine, fuel cell purge products, etc.
ELECTRON	The extranuclear constituent of all atoms carrying a negative charge and a mass of 1/1836 that of a proton.
EPHEMERIS	A tabulation of the predicted positions of a celestial body - such as the moon - at regular intervals.
EPICENTER	The lunar surface point directly above the source of a seismic disturbance.
EXOSPHERE	The outermost portion of the earth's or moon's atmosphere from which gases can escape into outer space.
FIELD	A spatial region in which each point has a definite value of a scalar or vector quantity such as a magnetic field.
FIELD-OF-VIEW	The area from which light is admitted into an optical instrument, usually expressed in terms of angles.
FINE-GRAINED	Broad description of lunar geological material to be gathered that is characterized by a structural composition of fine-grained matrices evident upon microscopic examination.

FLUORESCENCE	Emission of radiant energy in response to the absorption of radiant energy at a different wavelength.
FLUX	The rate of flow (per unit area, as well, for some applications) of some quantity such as the flux of cosmic rays or the flux of plasma particles in the solar wind.
FRAGMENTAL	Broad description of lunar geological material to be gathered representing fragmented material such as small rock chips.
GALACTIC	Pertaining to a galaxy in the universe such as the Milky Way.
GAMMA-RAY	A quantum of electromagnetic radiation emitted by an atomic nucleus as a result of a quantum transition between two energy levels of the nucleus.
GEOCHEMICAL GROUP	A group of three experiments especially designed to study the chemical differentiation and constituents of the lunar surface remotely from lunar orbit; viz. S-160, S-161, and S-162.
GEOPHONE	A small detection device implanted in the lunar surface during the deployment of the ASE (S-033) to record subsurface transmissions of seismic energy from artificial or natural sources.
GEOPHYSICAL	Pertaining to the physics of the earth, or moon, and the surrounding environment.
GNOMON	A rod pivoted about a free bearing used on the lunar surface to indicate the local vertical, to give sun position, and to serve as a distance scale.
GRADIENT	The space rate of change of a function. For example, the local lunar surface magnetic field.
GRANITIC	Pertaining to very hard igneous rock.
GROUND TRUTH	Lunar surface data used as a calibration or check on data taken from lunar orbit.
HERTZ	A unit of frequency used to describe electromagnetic radiation and equal to 1 cycle per second.

INERTIAL COORDINATE SYSTEM	A system in which the (vector) momentum of a particle is conserved in the absence of external forces and whose axes are not undergoing acceleration or rotation.
IGNEOUS ROCK	Rock formed by solidification of molten material.
IN SITU	"In its original position." For example, taking photographs of a lunar surface rock sample "in situ" (as it lays on the surface).
J-1 TYPE MISSION	The first of a class of Apollo missions in the Apollo Lunar Exploration Program providing the capability for extended lunar surface staytimes, longer mission duration, improved surface mobility and communications, more extensive surface science experiments and exploration, and an orbital science payload package (SIM).
K LINES	Band spectra lines characteristic of the innermost atom electron shell containing 2 electrons; this shell is called the K-shell.
L - "X" MONTHS	The number of months before launch; e.g. L-5 months.
L LINES	Band spectra lines characteristic of the next to innermost atom electron shell containing electrons; this shell is called the L-shell.
LIBRATION	Apparent motion of the geometric center of the moon due primarily to the elipticity of the lunar orbit coupled with the fact that its rotation and orbital frequencies are equal.
LITHIFIED	Evidence of having been changed into stone.
MACROSCOPIC	Large enough to be seen with the naked eye or under low magnification.
MAGNETOPAUSE	The transition region between the earth's magnetosphere and the solar wind bow shock.
MAGNETOSPHERE	The region of the earth's atmosphere where ionized gases contribute to the determination of the dynamics of the atmosphere and where the forces of the earth's magnetic field are predominant.
MAGNETOTAIL	The elongated region behind the earth (or moon) in which the solar wind recombines after being deflected around the body.
MANTLE	An intermediate layer of the moon between the lithosphere (outer layer) and the central core.

MARE	A large dark flat area on the lunar surface (Lunar Sea).
MARIA	Plural form of mare.
MASCONS	Large mass concentrations beneath the surface of the moon. They are believed to contain large bodies or masses that have impacted the lunar surface from outer space.
MASS SPECTROMETER	An instrument which differentiates chemical species in terms of their different isotopic masses.
METEORITIC	Pertaining to material apparently originating from meteoroids.
METRIC PHOTOGRAPHY	Recording of events by means of photography, together with an appropriate network of coordinates, to form the basis of accurate measurements and reference points for precise photo mapping.
MICRO-BRECCIA	A rock consisting of sharp fragments embedded in a fine-grained matrix.
MICROSCOPIC	Of such a size as to be viewable, if at all, only under optical magnification.
MIE	Name associated with the theory of scattering of electromagnetic radiation from spherical particles without regard to comparative size of radiation wavelength and particle diameter.
MINERALOGY	The science of minerals that deals with the study of their crystallography and their general physical and chemical properties.
MONOENERGETIC SOURCE	A source of electromagnetic radiation, confined to a very narrow frequency range used, for example, as a calibration source for spectrometers.
NADIR	That point on the earth (or moon) vertically below the observer.
NOCTILUCENT	Shining at night. For example, noctilucent clouds or collections of high-altitude aerosols which scatter light.
NUCLEON	A consituent particle of an atomic nucleus. For example, a proton or a neutron which falls in terms of mass between a meson and a hyperon.

OCCULTATION	The disappearance of a body behind another body of larger apparent size. For example, the occultation of the sun by the moon as viewed by an earth observer to create a solar eclipse.
OZONE	Triatomic oxygen (O_3) found in significant quantities in the earth's upper atmosphere.
PENUMBRAL	Referring to the part of a shadow in which the light (or other ray-type material such as the solar wind) is only partially masked in contrast to the umbra in which light is completely masked by the intervening object.
PHOTON	The electromagnetic quantum, regarded as a zero rest mass particle with no electric charge and possessing an energy of $H\nu$ where H is Planck's constant and ν is the radiation frequency.
PLASMA	An electrically conductive gas comprised of neutral particles, ionized particles and free electrons but which,when taken as a whole, is electrically neutral.
POLARIMETRIC	Referring to the measurement of the intensity of polarized light in a partially polarized light beam or the measurement of the extent of polarization.
PROTON	The positively charged constituent of atomic nuclei. For example, the entire nucleus of a hydrogen atom having a mass of 1.67252×10^{-27} kilograms.
RADON	A radioactive gaseous element with atomic number 86 and atomic mass 222 formed by the radioactive decay of radium.
RAYLEIGH	Name associated with atmospheric scattering of electromagnetic radiation from spherical particles of radii smaller than about one-tenth the wavelength of the radiation.
REGOLITH	The unconsolidated residual material that resides on the solid surface of the moon (or earth).
S-BAND	A frequency band used in radar and communications extending from 1.55 to 5.2 kilomegahertz.
SEISMIC	Related to mechanical vibrations within the surface of the earth or moon resulting from, for example, impact of projectiles on the surface.

SELENOCENTRIC	Referring to an inertial coordinate system whose origin is referenced at the center of the moon.
SELENODETIC	Relating to the accurate determination of positions of points on the moon, measurement of areas on the lunar surface, and the determination of lunar gravitational variations.
SENSITOMETRIC	Pertaining to the measurement of the light response characteristics of photographic film under controlled conditions of exposure and development.
SIDELAP	Overlap of one aerial photographic strip with another in a direction perpendicular to the length of the strips.
SLAVED	The condition of a controlled device or mechanism which operates whenever another device is operating, usually in synchronization.
SOLAR WIND	Streams of plasma emanating from and flowing approximately radially outward from the sun.
SPATIAL	Pertaining to the location of points referenced to three-dimensional space as contrasted with temporal (pertaining to time) locations.
SPECTROMETER	An instrument which disperses radiation into energy bands (or, in a mass spectrometer, particles into mass groups) and indicates the flux in each band or group.
SPECTROSCOPIC	Referring to measurements made with a spectrometer.
SPECTRUM	The totality of wavelengths (or frequencies) of electromagnetic radiation.
STANDBY	An operating mode of certain scientific equipment and sensors in the SIM Bay indicating that thermal control heaters are "ON" or that the electronics are in the process of being "warmed-up" in readiness for the operational period to follow.
STELLAR	Of or pertaining to stars. The stellar camera composing a part of the 3-Inch Mapping Camera is used to photograph star fields.
STEREO	A type of photography in which photographs taken of the same subject area from different angles are combined to produce visible features in three-dimensional relief.

SUBSATELLITE	A small unmanned satellite, deployed from the spacecraft while it is in orbit, designed to obtain various types of solar wind and lunar magnetic data over an extended period of time.
TEKTITES	Small glassy bodies containing no crystals, composed of at least 65 percent silicon dioxide, bearing no relation to the geological formation in which they occur, and believed to be of extra-lunar origin.
TEMPORAL	Referring to the passage or measurement of time.
TERMINATOR	The line separating the illuminated and the darkened areas of a body such as the earth or moon which is not self-luminous.
TERRA	Those portions of the lunar surface other than the maria.
THORIUM	A heavy metallic element with an atomic number 90 and an atomic mass of 232.
THREE-WAY MODE	A Doppler radar method involving a primary station which both sends and receives signals, a transponder on the spacecraft, and a secondary station which receives signals only.
TIDAL	Referring to the seismic movement of layers forming the outer portion of the lunar surface or within the lunar mantle as a result of the earth's gravitational attraction. Similar in nature to the tidal movements of the earth's oceans.
TIMELINE	A detailed schedule of astronaut or mission activities indicating the activity and time at which it is to occur within the mission.
TOPOGRAPHIC	Pertaining to the accurate graphical description, usually on maps or charts, of the physical features of an area on the earth or moon.
TOPOLOGY OF THE MAGNETOTAIL	Pertaining to the study of the composition, structure, and time tracing of solar wind particles appearing in the magnetotail.
TRANSEARTH	During transit from the moon to the earth.
TRANSIENT	An initial, short-lived effect preceding the obtainment of operating equilibrium of a system. For example, the initial current surge that occurs when an electrical system is energized.

TRANSLUNAR	During transit from the earth to the moon.
TRANSPONDER	A combined receiver and transmitter whose function is to transmit signals automatically when triggered by an interrogator.
TWO-WAY MODE	The Doppler radar tracking method which employs a single sending and receiving station and the spacecraft transponder.
URANIUM	A heavy metallic element of atomic number 92 and principal atomic weight 238.
VECTOR	A physical quantity requiring both magnitude and direction for its specification as magnetic force field and gravitational acceleration vectors.
WAVELENGTH	The distance between maxima (or minima) of a periodic phenomenum such as an electromagnetic wave.
X-RAY	An electromagnetic radiation of nonnuclear origin within the wavelength interval of 0.1 to 100 angstroms (between gamma-ray and ultraviolet radiation).
ZERO PHASE	A photographic orientation in which the camera, subject, and sun are coplanar with the camera between the sun and the subject.

APPENDIX C

REFERENCES

1. Apollo Flight Mission Assignments (U), OMSF Document M-D MA 500-11, dated October 1969, and as amended by the following APO-CCBD Nos.: 164; 173; 181; 188; 194; 195; and 199.

2. Mission Requirements, J-1 Type Mission, MSC Document No. TBD, dated TBD.

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