Patteson

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MISSION SCIENCE REQUIREMENTS
AS-511/CSM-112/LM-10
APOLLO MISSION J-1
(APOLLO 16)

MAY 15, 1970

IN-PROCESS REVIEW COPY

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

TRW
SYSTEMS GROUP

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G. E. Teveldahl, Task Manager
MSC/TRW Task 601B
15 May 1970

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MISSION SCIENCE REQUIREMENTS

J-1 TYPE MISSION

(APOLLO 16)

MAY 15, 1970

Prepared by TRW Systems

for

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

Contract NAS 9-8166

(Document No. TBD)

MISSION SCIENCE REQUIREMENTS

J-1 TYPE MISSION

(APOLLO 16)

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INTRODUCTION

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

The MSRD is divided into eight sections as follows: Section I, General Mission Science Requirements; Section II, Science Requirements Data; Section III, Science Operational Data; Section IV, Science Detailed Objectives; Section V, Science Detailed Experiments; Section VI, Science Photographic Requirements; Section VII, Traverse Planning Data; and Section VIII, Contingency and Alternate Mission Planning Data. Also included are three Appendicies: Appendix A, Acronym List; Appendix B, Reference Document List; and Appendix C, Distribution List.

The science detailed objectives (SDO's) and detailed experiments (DE's) comply with the requirements of the Apollo Flight Mission Assignments Directive, Office of Manned Space Flight, National Aeronautics and Space Administration, Washington, D.C. They have been prepared for extraction and incorporation in the Mission Requirements Document prepared by the Systems Engineering Division, Apollo Spacecraft Program Office.

The SDO's and DE's contain the necessary details for incorporating the requirements into the flight plan. They also present the criteria for data retrieval and evaluation, and for determining whether these requirements have been met during the mission. Detailed procedures and data for implementing the requirements are included in other controlled MSC documents as follows:

Flight Plan
Lunar Surface Procedures
Photographic and Television Procedures
LM Lunar Surface Checklist
CMP Solo Book

The MSRD is under the configuration control of the MSC Configuration Control Board. It controls the science requirements for the Apollo Mission J-1 and takes precedence over all other MSC or Contractor documents in this respect. All proposed changes and requests for additional copies or changes to the distribution list (Appendix C) should be submitted in writing to the Science Mission Manager, Mr. Richard R. Baldwin/TM1 and to Mr. Bruce A. Walton/TM1, Lunar Missions Office, Science and Applications Directorate, Manned Spacecraft Center, Houston, Texas.

SECTION I

GENERAL MISSION SCIENCE REQUIREMENTS

1.1 GENERAL

This section summarizes the science requirements for the Apollo Mission J-1 (Apollo 16). It includes the following data: the mission purpose, the primary mission objectives, listings of the detailed lunar orbital and lunar surface science detailed objectives, listings of the lunar orbital and lunar surface experiments, priorities of objectives and experiments, a description of the landing site, and ground rules for contingency planning.

1.2 MISSION PURPOSE

The primary purposes of this mission are to investigate the lunar surface environment, emplace experiments on the lunar surface, enhance the capability for manned lunar exploration, and conduct orbital science experiments.

1.3 MISSION OBJECTIVES

Mission objectives are divided into two categories. These are the primary objectives assigned by the Office of Manned Space Flight (OMSF) in the Apollo Flight Mission Assignments Directive (Reference 1), and the detailed objectives which are derived from the primary objectives at the NASA Manned Spacecraft Center (MSC). Both types of objectives are described in the following paragraphs:

1.3.1 Primary Objectives

Primary objectives are statements of the primary purpose of the mission. Those assigned to Apollo Mission J-1 are as follows:

a. Sample a wide variety of highland rock types ejected by a large impact event.

b. Emplace geophysical experiments for the purpose of examining highland structure characteristics.

c. Deploy seismic experiment consistent with a seismic net.

d. Assess extravehicular activity (EVA) operations in rough topography.

e. Assess EVA communications during surface traverse and sampling.

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

1.3.2 Detailed Objectives

Detailed objectives are of the following three types: operational objectives, engineering tests, and science objectives. Only the science detailed objectives are covered in this document; the others are presented in the Mission Requirements Document (Reference 2), prepared by the Systems Engineering Division (SED), Apollo Spacecraft Program Office (ASPO).

For presentation purposes, detailed science objectives are divided into the lunar orbital science detailed objectives and the lunar surface science detailed objectives, listed in Tables 1-1 and 1-2, respectively. Also listed are the Principal Investigators and the Points-of-Contact assigned within Science and Applications Directorate (S&AD) for these objectives. Any questions concerning individual objectives should be directed to the appropriate Point-of-Contact. Problems involving the integration of these objectives into program and mission planning and the implementation of science requirements should be referred to the assigned S&AD Science Mission Manager.

Lunar orbital and lunar surface science detailed objectives are contained in Section IV of this document. They will be extracted and incorporated in the Mission Requirements Document (MRD) for mission planning and implementation purposes.

1.4 MISSION EXPERIMENTS

Mission experiments are those which have been approved by the Manned Space Flight Experiments Board and assigned to the mission by the Office of Manned Space Flight (Reference 1). For presentation purposes these experiments are divided into the lunar orbital experiments and the lunar surface experiments, listed in Tables 1-3 and 1-4, respectively. Also listed are the S&AD Points-of-Contact for these experiments. Any questions concerning individual experiments should be directed to the appropriate Point-of-Contact; problems involving the integration of these experiments into program and mission planning and the implementation of science requirements should be referred to the assigned S&AD Science Mission Manager.

Lunar orbital and lunar surface detailed experiments are contained in Section V of this document. They will be extracted and incorporated in the MRD for mission planning and implementation purposes.

1.5 OBJECTIVES AND EXPERIMENTS PRIORITIES

All science detailed objectives and experiments assigned to this mission are listed below in descending order of priority. Prioritization is of significance only when scheduled objectives and/or experiments cannot be accomplished because of some contingency or abnormal condition which occurs during the mission with resulting impacts on crew operations and the timeline. The priority listing is provided to facilitate the assessment of the relative importance of the mission detailed objectives and experiments, and the selection of those which can be performed and will yield the greatest scientific return in terms of trade-off factors such as crew requirements, spacecraft capabilities, and time availability.

Priority	Detailed Objectives and Experiments
1	Contingency Sample Collection Objective
2	Apollo Lunar Surface Experiments Package (ALSEP)
3	Selected Sample Collection Objective
4	Lunar Field Geology Experiment
5	Photographs of Candidate Exploration Sites Objective
6	Soil Mechanics Experiment
7	Gamma-Ray Spectrometer Experiment

Priority	Detailed Objectives and Experiments
8	X-Ray Fluorescence Experiment
9	SM Orbital Science Photography Objective
10	Subsatellite Experiment
11	CSM/LM S-band Transponder Experiment
12	Alpha-Particle Spectrometer Experiment
13	Mass Spectrometer Experiment
14	UV Photography - Earth and Moon Experiment
15	Laser Ranging Retro-Reflector Experiment
16	CM Orbital Science Photography Objective
17	Cosmic Ray Detector (Sheets) Experiment
18	Portable Magnetometer Experiment

1.6 LANDING SITE DESCRIPTION

The landing site scheduled for the Apollo Mission J-1 is Copernicus. This site is a relatively young, very large bright-rayed probable impact crater approximately 95 km in diameter located just south of Mare Imbrium. The walls of the crater expose a vertical section of about 4 km of the lunar crust. The floor, 60 km in diameter, is nearly circular, and contains an almost central, multiple peak, with large masses to the east and the west, where the highest peak rises 800 meters. These peaks probably represent deep-seated material, which is of importance in determining the internal characteristics of the moon.

Examination of the domes and textured material of the crater floor will provide an understanding of the processes of crater floor filling and help clarify the role of volcanism in post-event crater modification. Age determination of the central peak material, the cratering event, and the subsequent crater fill material will provide a time scale of importance in understanding the origin and modification of large impact craters.

Table 1-1. Lunar Orbital Science Objectives and Responsible Personnel

LUNAR ORBITAL OBJECTIVES		PRINCIPAL INVESTIGATOR	S&AD POINT-OF-CONTACT
NO.	TITLE		
	Photographs of Candidate Exploration Sites	CSM Orbital Science Photographic Team: Mr. Frederick J. Doyle, Chairman Topographic Division U.S. Geological Survey U.S. Department of Interior Washington, D. C. 20242	Mr. Lewis C. Wade/TJ NASA Manned Spacecraft Center Mapping Sciences Laboratory Houston, Texas 77058 (713) 483-6167
	SM Orbital Science Photography, including: 24-Inch Panoramic Camera	CSM Orbital Science Photographic Team: Mr. Frederick J. Doyle, Chairman Topographic Division U.S. Geological Survey U.S. Department of Interior Washington, D.C. 20242 (202) 343-9445	Mr. Samuel N. Hardee, Jr./TM3 NASA Manned Spacecraft Center Experiments Requirements Office Houston, Texas 77058 (713) 483-4611
	3-Inch Mapping Camera	CSM Orbital Science Photographic Team: Mr. Frederick J. Doyle, Chairman Topographic Division U.S. Geological Survey U.S. Department Of Interior Washington, D.C. 20242 (202) 343-9445	Mr. Samuel N. Hardee, Jr./TM3 NASA Manned Spacecraft Center Experiments Requirements Office Houston, Texas 77058 (713) 483-4611

Table 1-1. Lunar Orbital Science Objectives and Responsible Personnel

LUNAR ORBITAL OBJECTIVES		PRINCIPAL INVESTIGATOR	S&AD POINT-OF-CONTACT
NO.	TITLE		
	Laser Altimeter	CSM Orbital Science Photographic Team: Mr. Frederick J. Doyle, Chairman Topographic Division U.S. Geological Survey U.S. Department of Interior Washington, D.C. 20242 (202) 343-9445	Mr. Samuel N. Hardee, Jr./TM3 NASA Manned Spacecraft Center Experiments Requirements Office Houston, Texas 77058 (713) 483-4611
	CM Orbital Science Photography	CSM Orbital Science Photographic Team: 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 NASA Manned Spacecraft Center Mapping Sciences Laboratory Houston, Texas 77058 (713) 483-6287

Table 1-2. Lunar Surface Science Objectives and Responsible Personnel

LUNAR SURFACE OBJECTIVES			
NO.	TITLE	PRINCIPAL INVESTIGATOR	S&AD POINT-OF-CONTACT
	Contingency Sample Collection	None	Mr. Martin L. Miller/TM3 NASA Manned Spacecraft Center Experiments Office Houston, Texas 77058 (713) 483-2666
	Selected Sample Collection	None	Mr. Martin L. Miller/TM3 NASA Manned Spacecraft Center Experiments Office Houston, Texas 77058 (713) 483-2666

Table 1-3. Lunar Orbital Experiments and Responsible Personnel

LUNAR ORBITAL EXPERIMENTS			
NO.	TITLE	PRINCIPAL INVESTIGATOR	S&AD POINT-OF-CONTACT
S-160	Gamma-Ray Spectrometer	Dr. James R. Arnold Chemistry Department University of California, San Diego LaJolla, California 92037 (714) 453-2000, Ext. 1453	Mr. Leo E. James/TM2 NASA Manned Spacecraft Center Science Requirements Office Houston, Texas 77058 (713) 483-4611
S-161	X-Ray Fluorescence	Dr. Isidore Adler NASA Goddard Space Flight Center Theoretical Studies Branch, 641 Greenbelt, Maryland 20771 (301) 982-5759	Mr. Leo E. James/TM2 NASA Manned Spacecraft Center Science Requirements Office Houston, Texas 77058 (713) 483-4611
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 NASA Manned Spacecraft Center Science Requirements Office Houston, Texas 77058 (713) 483-4611
S-164	CSM/LM S-band Transponder	Mr. William L. Sjogren, 156-251 Jet Propulsion Laboratory 4800 Oak Grove Drive Pasadena, California 91103 (213) 354-4868	Mr. Patrick E. Lafferty/TM2 NASA Manned Spacecraft Center Science Requirements Office Houston, Texas 77058 (713) 483-4611

Table 1-3. Lunar Orbital Experiments and Responsible Personnel

LUNAR ORBITAL EXPERIMENTS		PRINCIPAL INVESTIGATOR	S&AD POINT-OF-CONTACT
NO.	TITLE		
S-165	Mass Spectrometer	Dr. John H. Hoffman University of Texas at Dallas P. O. Box 30365 Dallas, Texas 75230 (214) 231-1471, Ext. 347	Mr. Vernon M. Dauphin/TM2 NASA Manned Spacecraft Center Science Requirements Office Houston, Texas 77058 (713) 483-4521
S-177	UV Photography - Earth and Moon	Dr. Tobias Owen IIT Research Institute 10 West 35th Street Chicago, Illinois 60616 (312) 225-9630	Mr. Samuel N. Hardee, Jr./TM3 NASA Manned Spacecraft Center Science Requirements Office Houston, Texas 77058 (713) 483-4611
	Subsatellite, including:		
S-164	S-band Transponder	Mr. William L. Sjogren, 156-251 Jet Propulsion Laboratory 4800 Oak Grove Drive Pasadena, California 91103 (213) 354-4868	Mr. Patrick E. Lafferty/TM2 NASA Manned Spacecraft Center Science Requirements Office Houston, Texas 77058 (713) 483-4611
S-173	Particle Shadows/ Boundary Layer	Dr. Kinsey A. Anderson University of California Space Sciences Laboratory Berkeley, California 94720 (415) 642-1313	Mr. Patrick E. Lafferty/TM2 NASA Manned Spacecraft Center Science Requirements Office Houston, Texas 77058 (713) 483-4611

Table 1-3. Lunar Orbital Experiments and Responsible Personnel

LUNAR ORBITAL EXPERIMENTS			
NO.	TITLE	PRINCIPAL INVESTIGATOR	S&AD POINT-OF-CONTACT
S-174	Magnetometer	Dr. Paul J. Coleman, Jr. Department of Planetary & Space Sciences University of California, Los Angeles Los Angeles, California 90024 (213) 825-1776	Mr. Patrick E. Lafferty/TM2 NASA Manned Spacecraft Center Science Requirements Office Houston, Texas 77058 (713) 483-4611

Table 1-4. Lunar Surface Experiments and Responsible Personnel

LUNAR SURFACE EXPERIMENTS		PRINCIPAL INVESTIGATOR	S&AD POINT-OF-CONTACT
NO.	TITLE		
	Apollo Lunar Surface Experiments Package (ALSEP), including:		
S-031	Passive Seismic	Dr. Gary V. Latham Lamont-Doherty Geological Observatory - Columbia University Palisades, N. Y. 10964 (914) 359-2900	Mr. Wilbert E. Eichelman/TM3 NASA Manned Spacecraft Center Experiments Office Houston, Texas 77058 (713) 483-2666
S-033	Active Seismic	Dr. Robert L. Kovach Department of Geophysics Stanford University Palo Alto, California (415) 286-2525, Ext. 4827	Mr. Wilbert F. Eichelman/TM3 NASA Manned Spacecraft Center Experiments Office Houston, Texas 77058 (713) 483-2666
S-034	Lunar Surface Magnetometer	Dr. Palmer Dyal Ames Research Center Moffett Field, California 94035 (415) 961-1111, Ext. 2706	Mr. Timothy T. White/TM3 NASA Manned Spacecraft Center Experiments Office Houston, Texas 77058 (713) 483-3811
S-037	Heat Flow	Dr. Marcus G. Langseth Lamont-Doherty Geological Observatory - Columbia University Palisades, N. Y. 10964 (914) 359-2900, Ext. 335	Mr. Wilbert F. Eichelman/TM3 NASA Manned Spacecraft Center Experiments Office Houston, Texas 77058 (713) 483-2666

Table 1-4. Lunar Surface Experiments and Responsible Personnel

LUNAR SURFACE EXPERIMENTS			
NO.	TITLE	PRINCIPAL INVESTIGATOR	S&AD POINT-OF-CONTACT
M-515	Lunar Dust Detector	Dr. Brian J. O'Brian University of Sidney Sidney, Australia Co-Principal Investigator: Dr. David Reasoner Department of Space Science Rice University Houston, Texas 77001 (713) 528-4141, Ext. 1135	Mr. Martin L. Miller/TM3 NASA Manned Spacecraft Center Experiments Office Houston, Texas 77058 (713) 483-2666
S-059	Lunar Field Geology	Dr. William Muelberger Geology Department University of Texas at Austin Austin, Texas (512) 475-5011	Mr. Martin L. Miller/TM3 NASA Manned Spacecraft Center Experiments Office Houston, Texas 77058 (713) 483-2666
S-078	Laser Ranging Retro- Reflector	Dr. J. E. Faller Scott Laboratory Wesleyan University Middletown, Connecticut 06457 (203)	Mr. Timothy T. White/TM3 NASA Manned Spacecraft Center Experiments Office 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. Manual D. Lopez/TM3 NASA Manned Spacecraft Center Experiments Office Houston, Texas 77058 (713) 483-2666

Table 1-4. Lunar Surface Experiments and Responsible Personnel

LUNAR SURFACE EXPERIMENTS		PRINCIPAL INVESTIGATOR	S&AD POINT-OF-CONTACT
NO.	TITLE		
S-198	Portable Magnetometer	Dr. Palmer Dyal Ames Research Center Moffett Field, California 94035 (415) 961-1111, Ext. 2706	Mr. Timothy T. White/TM3 NASA Manned Spacecraft Center Experiments Office Houston, Texas 77058 (713) 483-2666
S-200	Soil Mechanics	Dr. James K. Mitchell University of California, Berkeley Berkeley, California 94720 (415) 642-1262	Mr. Martin L. Miller/TM3 NASA Manned Spacecraft Center Experiments Office Houston, Texas 77058 (713) 483-2666

SECTION II

SCIENCE REQUIREMENTS DATA

2.1 GENERAL

Section II defines the requirements data for the science detailed objectives and experiments assigned to Apollo Mission J-1. These data represent authoritative source data for program and mission planning purposes, and form the basis for the science detailed objectives (SDO's) and detailed experiments (DE's) located in Sections IV and V of this document, respectively.

2.2 PHYSICAL DESCRIPTION/INTERFACE DATA SUMMARY

Physical characteristics of all SDO's and DE's assigned to the mission, and the associated spacecraft interface requirements are presented in Tables 2-1 through 2-4. Data for lunar orbital SDO's and DE's are listed in Tables 2-1 and 2-2, and data for lunar surface DE's in Tables 2-3 and 2-4.

2.3 SCIENCE REQUIREMENTS DATA DEFINITION

Science requirements data are provided for all mission SDO's and DE's. Data for a particular SDO or DE are presented on an individual Science Requirements Data Sheet (SRDS). Requirements data on each SRDS include, as applicable, a brief functional description, an objective(s), operating requirements, data requirements, and constraints/problem areas.

For presentation purposes, lunar orbital and lunst surface SDO's are presented in one group, and lunar orbital and lunar surface DE's in a second group. SDO's and DE's in each of these groups are listed in the following paragraphs. Each paragraph references a figure for an SRDS which contains the associated science requirements data.

2.3.1 Lunar Orbital and Lunar Surface SDO's

2.3.1.1 Photographs of Candidate Exploration Sites Objective

(Refer to Figure 2-1.)

2.3 SCIENCE REQUIREMENTS DATA DEFINITION (Cont'd)

2.3.1.2 <u>SM Orbital Science Photography Objective</u>

Includes:

a. 24-Inch Panoramic Camera
b. 3-Inch Mapping Camera
c. Laser Altimeter

(Refer to Figure 2-2.)

2.3.1.3 <u>CM Orbital Science Photography Objective</u>

(Refer to Figure 2-3.)

2.3.1.4 <u>Contingency Sample Collection Objective</u>

(Refer to Figure 2-4.)

2.3.1.5 <u>Selected Sample Collection Objective</u>

(Refer to Figure 2-5.)

2.3.2 <u>Lunar Orbital and Lunar Surface DE's</u>

2.3.2.1 <u>Gamma-Ray Spectrometer Experiment (S-160)</u>

(Refer to Figure 2-6.)

2.3.2.2 <u>X-Ray Fluorescence Experiment (S-161)</u>

(Refer to Figure 2-7.)

2.3.2.3 <u>Alpha-Particle Spectrometer Experiment (S-162)</u>

(Refer to Figure 2-8.)

2.3.2.4 <u>CSM/LM S-band Transponder Experiment (S-164)</u>

(Refer to Figure 2-9.)

2.3.2.5 <u>Mass Spectrometer Experiment (S-165)</u>

(Refer to Figure 2-10.)

2.3.2.6 <u>UV Photography - Earth and Moon Experiment (S-177)</u>

(Refer to Figure 2-11.)

2.3.2.7 <u>Subsatellite Experiment</u>

Includes:

a) S-band Transponder Experiment (S-164)
b) Particle Shadows/Boundary Layer Experiment (S-173)
c) Magnetometer Experiment (S-174)

(Refer to Figure 2-12.)

2.3.2.8 <u>Apollo Lunar Surface Experiments Package (ALSEP)</u>

Includes:

a) Passive Seismic Experiment (S-031)
b) Active Seismic Experiment (S-033)
c) Lunar Surface Magnetometer Experiment (S-034)
d) Heat Flow Experiment (S-037)
e) Lunar Dust Detector Experiment (M-515)

(Refer to Figure 2-13.)

2.3.2.9 <u>Lunar Field Geology Experiment (S-059)</u>

(Refer to Figure 2-14.)

2.3.2.10 <u>Laser Ranging Retro-Reflector Experiment (S-078)</u>

(Refer to Figure 2-15.)

2.3.2.11 <u>Cosmic Ray Detector (Sheets) Experiment (S-152)</u>

(Refer to Figure 2-16.)

2.3.2.12 <u>Portable Magnetometer Experiment (S-198)</u>

(Refer to Figure 2-17.)

2.3.2.13 <u>Soil Mechanics Experiment (S-200)</u>

(Refer to Figure 2-18.)

Table 2-1. Lunar Orbital Objectives and Experiments, Physical Description

EXP. NO.	EXPERIMENT/INSTRUMENT	SIM LOCATION	WEIGHT	DESCRIPTIONS
S-160	GAMMA RAY SPECTROMETER	SUSPENDED FROM SIM SHELF ABOVE SIM BAY BOTTOM	22 LBS.	• DEPLOYED ON 25 FT. EXTENDIBLE BOOM WHEN GATHERING PRIME DATA. • INSTRUMENT CYLINDRICAL AXIS TO POINT WITHIN $\pm 10°$ OF LUNAR NADIR WHEN GATHERING PRIME DATA. • BOOM IS SPRING-LOADED FOR JETTISONING WHEN ALL PLANNED EXPERIMENT DATA HAVE BEEN ACQUIRED. • HELICAL CABLE FOR TRANSMISSION OF SENSOR SIGNALS TO SIM IS WRAPPED AROUND BOOM.
S-161/S-162	X-RAY/ALPHA PARTICLE SPECTROMETERS	• MOUNTED AS INTEGRAL UNIT ON BOTTOM OF SIM BAY • X-RAY SOLAR MONITOR MOUNTED IN SM SECTOR IV WITH VIEW DIRECTION 180° FROM LUNAR X-RAY ALBEDO MONITOR	• EXP. UNIT - 130 LBS • X-RAY SOLAR MONITOR ASSY. - 22 LBS	• X-RAY FOV: $\pm 30°$ OF NADIR • SOLAR MONITOR FOV: $\pm 53°$ OF ZENITH • ALPHA PARTICLE FOV: $\pm 45°$ OF NADIR • X-RAY SOLAR MONITOR HAS A SPRING-LOADED PROTECTIVE DOOR
S-165	MASS SPECTROMETER	SUSPENDED FROM SIM SHELF ABOVE SIM BAY BOTTOM	22 LBS.	• FOV: HEMISPHERE • DEPLOYED ON 20 FT. EXTENDIBLE BOOM WHEN GATHERING PRIME DATA. SEPARATION DISTANCE OF 15 FT. (NOMINAL) FROM GAMMA RAY SPECTROMETER WHEN BOTH EXPERIMENTS ARE FULLY DEPLOYED. • BOOM IS SPRING-LOADED FOR JETTISONING WHEN ALL EXPERIMENT DATA HAVE BEEN ACQUIRED. • HELICAL CABLE FOR TRANSMISSION OF SENSOR SIGNALS TO SIM IS WRAPPED AROUND BOOM.
S-164	S-BAND TRANSPONDER	DATA ACQUIRED FROM S-BAND TRANSPONDERS LOCATED ON THE SUB-SATELLITE, CSM, AND LM.	0 LBS. (TRANSPONDER WEIGHT NOT CHARGED TO SCIENCE PAYLOAD)	• EXPERIMENT MAKES DEMANDS ONLY ON SUB-SATELLITE/SPACECRAFT OPERATIONS • EXPERIMENT MAKES USE OF EXISTING SUB-SATELLITE/SPACECRAFT S-BAND COMMUNICATION/COMMAND SYSTEM
S-173	LUNAR PARTICLE SHADOWS AND BOUNDARY LAYER	EXPERIMENT MOUNTED ON SUB-SATELLITE THAT IS EJECTED FROM SIM BAY AT START OF ORBITAL EXPERIMENT PERIOD.	EXPERIMENT WEIGHT CHARGED TO TOTAL SUB-SATELLITE WEIGHT.	• EXPERIMENT DETAILS ARE TBD.
S-174	MAGNETOMETER	EXPERIMENT MOUNTED ON SUB-SATELLITE THAT IS EJECTED FROM SIM BAY AT START OF ORBITAL EXPERIMENT PERIOD.	EXPERIMENT WEIGHT CHARGED TO TOTAL SUB-SATELLITE WEIGHT.	• EXPERIMENT DETAILS ARE TBD. • MAGNETOMETER SENSORS TO BE DEPLOYED ON BOOMS (3) FROM SUB-SATELLITE TO RESIDE IN A MAGNETICALLY-CLEAN ENVIRONMENT.
	SUB-SATELLITE	SUB-SATELLITE IS MOUNTED ON A DEPLOYMENT ASSEMBLY LOCATED IN THE SIM BAY TO THE LEFT OF THE PANORAMIC CAMERA (LOOKING INTO THE SIM).	• 70 LBS. - LUNAR ORBIT EJECTED WEIGHT • 15 LBS. - ASSEMBLY WEIGHT IN SIM AFTER EJECTION.	• SUB-SATELLITE DETAILS ARE ESSENTIALLY TBD. • SUB-SATELLITE CONFIGURATION ASSUMES THE SHAPE OF A HEXAGONAL PRISM. • A SPRING-LOADED SUB-SATELLITE SPIN-UP AND EJECTION SYSTEM IS USED. • A GUIDE-RAIL ASSEMBLY IS USED TO AID IN SUB-SATELLITE DEPLOYMENT.
S-177	UV PHOTOGRAPHY OF EARTH AND MOON	PHOTOGRAPHS MADE FROM RH CM WINDOW (QUARTZ WINDOW INSTALLED)	NEGLIGIBLE	• EXPERIMENT USES EXISTING CM HASSELBLAD CAMERA EQUIPPED WITH UV LENSES. • PHOTOGRAPHS ACQUIRED DURING PERIODS OF EARTH ORBIT, TRANS-LUNAR COAST, LUNAR ORBIT, AND TRANS-EARTH COAST.
	CM PHOTOGRAPHY TASKS	PHOTOGRAPHY TASKS ARE CONDUCTED FROM THE COMMAND MODULE	OPERATIONAL CAMERA EQUIPMENT NOT CHARGED TO SCIENCE PAYLOAD.	• PHOTOGRAPHY TASKS ARE CONDUCTED WITH OPERATIONAL CAMERAS SUCH AS THE HASSELBLAD, HYCON, ETC. • SUCH SCIENCE PHOTOGRAPHY TASKS AS DIM LIGHT PHOTOGRAPHY ARE CONDUCTED. SEE PHOTO OPERATIONS PLAN FOR J-1 MISSIONS.
	24" PANORAMIC CAMERA (SM PHOTOGRAPHY TASK)	MOUNTED TO BEAMS BETWEEN THE SIM SHELVES	323 LBS. (INCLUDES WT. OF FILM CASETTE - 88 LBS. - TO BE RETRIEVED BY AN EVA)	• ANGULAR COVERAGE: 108° CROSSTRACK SWEEP 11° FORE AND AFT • STEREO CAPABILITY - TWO POSITIONS WITH 25° SEPARATION. • 5-INCH WIDE FILM IS USED • N_2 SUPPLY PROVIDED FOR FILM TRANSPORTATION SYSTEM • USED PRIMARILY FOR LUNAR SURFACE TARGET PHOTOGRAPHY SUCH AS LANDING SITES, GEOLOGICAL FORMATION, ETC.
	3" MAPPING CAMERA (SM PHOTOGRAPHY TASK)	MOUNTED ON TOP SIM SHELF	185 LBS. (INCLUDES WT. OF FILM CASETTE - 25 LBS. - TO BE RETRIEVED BY AN EVA)	• MAPPING CAMERA AND LASER ALTIMETER ARE MOUNTED AS AN INTEGRAL UNIT. • CAMERA IS DEPLOYED FROM THE SIM ON A RAIL MECHANISM (INTEGRAL PART OF CAMERA) IN A DIRECTION 30° OFF THE SIM CENTERLINE DURING OPERATION. • ANGULAR COVERAGE: LURAIN LENS $\sim$74° SQUARE STELLAR LENS $\sim$28° CONE WITH FLATS • LURAIN-STELLAR LENS INTERLOCK ANGLE OF 96° • INTEGRAL STELLAR CAMERA INCORPORATED WITH MAPPING CAMERA TO PROVIDE STAR FIELD REFERENCE FOR POST-FLIGHT LURAIN LENS POINTING KNOWLEDGE. • LURAIN FILM $\sim$5 IN.; STELLAR FILM $\sim$35mm • USED PRIMARILY FOR THE ATTAINMENT OF PHOTOGRAPHS TO BE USED IN CARTOGRAPHIC/GEODETIC CONTROL (MAPPING) OF THE LUNAR SURFACE.
	LASER ALTIMETER (SM PHOTOGRAPHY TASK)	MOUNTED ON TOP SIM SHELF AS AN INTEGRAL UNIT WITH THE 3" MAPPING CAMERA	45 LBS.	• ALTIMETER PRIMARILY PROVIDES ALTITUDE REFERENCE DATA FOR THE MAPPING CAMERA. • ALTIMETER CAN OPERATE IN COUPLED (SYNCHRONIZED WITH MAPPING CAMERA OPERATION) OR UNCOUPLED MODES. • TRANSMITTED BEAM WIDTH - 300 μ RADIANS.

Table 2-2. Lunar Orbital Objectives and Experiments, Interface Data

EXP. NO.	EXPERIMENT/INSTRUMENT	POWER REQUIREMENTS	TELEMETRY DATA REQUIREMENTS	OPERATING TEMPERATURE REQUIREMENTS	COMMAND MODULE CONTROLS/DISPLAYS
S-160	GAMMA RAY SPECTROMETER	• ELECTRONICS: 1.4 WATTS • HEATER: 20 WATTS MAX. (INTERNALLY CONTROLLED) • STANDBY: 6.8 WATTS • AVERAGE: 8 WATTS • PEAK: 21 WATTS (STANDBY/AVERAGE/PEAK: EXPECTED USAGE)	• SCIENCE DATA: 4 KILOBITS/SEC DIGITAL SERIAL (TO USE 165 KHz SCO) • HOUSEKEEPING DATA: 2 ANALOG CHANNELS AT 10 SAMPLES/SEC.	-4°F to +120°F	• EXP. ON/OFF SWITCH WITH TALKBACK • EXP. BOOM EXTEND/RETRACT SWITCH WITH TALKBACK • EXP. HIGH VOLTAGE GAIN SETTING AND VETO SWITCH • BOOM JETTISON SWITCH
S-161/S-162	X-RAY/ALPHA PARTICLE SPECTROMETER	• ELECTRONICS: X-RAY ~ 21.5 WATTS ALPHA ~ 7.6 WATTS • HEATER: X-RAY ~ 3.4 WATTS ALPHA ~ NONE • EXPECTED USE: X-RAY / ALPHA • STANDBY: 26.2 WATTS / 4 WATTS • AVERAGE: 34.0 WATTS / 6 WATTS • PEAK: 34.0 WATTS / 6 WATTS	• SCIENCE DATA: X-RAY: PHA-PARALLEL DIGITAL 10 SAMPLES/SEC ALPHA: PHA-PARALLEL DIG. 10 SAMPLES/SEC. • HOUSEKEEPING DATA: X-RAY: 8 ANALOG CHANNELS AT 1 SAMPLE/SEC. ALPHA: 2 ANALOG CHANNELS AT 10 SAMPLE/SEC. 10 ANALOG CHAN. AT 1 SAMPLE/SEC.	X-RAY: -4°F TO +122°F (60°F PREFERRED) ALPHA: -4°F TO +122°F	• X-RAY: ON/OFF/STANDBY SWITCH WITH TALKBACK SOLAR MONITOR DOOR SWITCH WITH TALKBACK • ALPHA: ON/OFF SWITCH WITH TALKBACK
S-165	MASS SPECTROMETER	• STANDBY: 5 WATTS • AVERAGE: 13 WATTS • PEAK: 18 WATTS (STANDBY/AVERAGE/PEAK: EXPECTED USAGE) • ION HEATER: 10 WATTS ON 0°C • EXP. HEATER: 5 WATTS OFF 6°C	• SCIENCE DATA: 21 DIGITAL PARALLEL BITS AT 10 SAMPLES/SEC. • HOUSEKEEPING DATA: 14 ANALOG CHANNELS MULTIPLEXED ON ONE OUTPUT AT 10 SAMPLES/SEC.	• NON OPERATING: -50°F TO +176°F • OPERATING: 0°F TO 125°F	• EXP. ON/OFF/STANDBY SWITCH • ION SOURCE ON/OFF/STANDBY SWITCH • MULTIPLIER HI-LOW CONTROL • DISCRIMINATOR HI-LOW CONTROL • BOOM EXTEND/RETRACT SWITCH WITH TALKBACK • BOOM JETTISON SWITCH
S-164	S-BAND TRANSPONDER	• EXISTING S/C AND SUBSATELLITE S-BAND COMM. SYSTEM • NO ADDITIONAL POWER REQUIRED FOR SCIENCE OBJECTIVES ON CSM/LM. • S-BAND TRANSPONDER POWER REQUIREMENTS OF 12 WATTS FOR SUBSATELLITE LIMIT TRACKING PERIOD TO MAXIMUM OF ONE TRACKING PERIOD PER EVERY 24 HOURS.	• EXISTING S/C S-BAND COMM. SYSTEM • EXPERIMENT MAKES USE OF STANDARD OPERATIONAL DOPPLER TRACKING DATA FOR USE OF CSM/LM. • DOPPLER TRACKING DATA FOR ANALYSIS ACQUIRED DURING PERIODS OF SUBSATELLITE "BROADCASTING".	• NO SCIENCE REQUIREMENT FOR CSM/LM APPLICATION. • REQUIREMENTS FOR SUBSATELLITE APPLICATION ARE TBD.	• NO REQUIREMENT FOR EITHER CSM/LM OR SUBSATELLITE APPLICATION.
S-173	LUNAR PARTICLE SHADOWS AND BOUNDARY LAYER	• POWER REQUIREMENTS FOR SUBSATELLITE INTEGRATION ARE TBD.	• DATA REQUIREMENTS FOR SUBSATELLITE INTEGRATION ARE TBD.	• TEMPERATURE REQUIREMENTS FOR SUBSATELLITE INTEGRATION ARE TBD.	• NO CONTROL/DISPLAY REQUIREMENTS FOR EXPERIMENT WITH RESPECT TO CSM.
S-174	MAGNETOMETER	• POWER REQUIREMENTS FOR SUBSATELLITE INTEGRATION ARE TBD.	• DATA REQUIREMENTS FOR SUBSATELLITE INTEGRATION ARE TBD.	• TEMPERATURE REQUIREMENTS FOR SUBSATELLITE INTEGRATION ARE TBD.	• NO CONTROL/DISPLAY REQUIREMENTS FOR EXPERIMENT WITH RESPECT TO CSM.
	SUBSATELLITE	• POWER REQUIREMENTS FOR SUBSATELLITE ARE TBD.	• DATA REQUIREMENTS FOR SUBSATELLITE ARE TBD.	• TEMPERATURE REQUIREMENTS FOR SUBSATELLITE ARE TBD.	• SUBSATELLITE EJECTION SWITCH WITH TALKBACK.
S-177	UV PHOTOGRAPHY OF EARTH AND MOON	NO INTERFACE REQUIREMENT	NO INTERFACE REQUIREMENT	• NO INTERFACE REQUIREMENT. • CAMERA AND FILM ARE COMPATIBLE WITH CM CABIN ENVIRONMENT.	• NO CM INTERFACE WITH RESPECT TO CONTROLS/DISPLAYS IS REQUIRED. CREW WILL BE REQUIRED TO CHANGE LENS FILTERS, TAKE PHOTOS, RECORD LENS SETTINGS, ETC.
	CM PHOTOGRAPHY TASKS	NO INTERFACE REQUIREMENT	NO INTERFACE REQUIREMENT	• NO INTERFACE REQUIREMENT. • OPERATIONAL CAMERAS AND FILM ARE COMPATIBLE WITH CM CABIN ENVIRONMENT.	• NO CM INTERFACE WITH RESPECT TO CONTROLS/DISPLAYS IS REQUIRED. • CREW WILL BE REQUIRED TO TAKE PHOTOS, RECORD EXPOSURE TIMES, ETC.
	24" PANORAMIC CAMERA (SM PHOTOGRAPHY TASK)	• AC: OPERATE MODE: 30 VA/Ø AVG., 100 VA/Ø PEAK; STANDBY MODE: 20 VA/Ø AVG., 30 VA/Ø PEAK • DC: STANDBY/HEATERS: 75 WATTS, AVG., 150 WATTS, PEAK; STANDBY/HEATERS & TORQUERS: 75 WATTS AVG., 250 WATTS, PEAK OPERATE: 150 WATTS, AVG., 430 WATTS, PEAK	• SCIENCE DATA: 5-IN. FILM • HOUSEKEEPING DATA: 7 ANALOG CHANNELS AT 10 SAMPLES/SEC.	• NON-OPERATING: 40°F TO 100°F • OPERATING: 70°F to 80°F	• CONTROLS: • ON/OFF SWITCH FOR PRIMARY POWER CONTROL • OPERATE/STANDBY SWITCH FOR CAMERA MODE SELECTION • OFF/TEST SWITCH TO INITIATE AUTOMATIC CAMERA TEST CYCLE • DISPLAYS: • CAMERA GO/NO GO INDICATION TALKBACK

Table 2-2. Lunar Orbital Objectives and Experiments, Interface Data (Continued)

EXP. NO.	EXPERIMENT/INSTRUMENT	POWER REQUIREMENTS	TELEMETRY DATA REQUIREMENTS	OPERATING TEMPERATURE REQUIREMENTS	COMMAND MODULE CONTROLS/DISPLAYS
	3" MAPPING CAMERA (SM PHOTOGRAPHY TASK)	• CAMERA: OPERATE MODE: 100 WATTS, AVG.; 200 WATTS, PEAK. STANDBY MODE: 10 WATTS, AVG.; 20 WATTS, PEAK • HEATERS: OPERATE MODE: 15 WATTS. STANDBY MODE: 15 WATTS	• SCIENCE DATA: LURAIN 5-IN. FILM; STELLAR 35 MM FILM • HOUSEKEEPING DATA: ANALOG: • 10 CHANNELS AT 1 SAMPLE/SEC. • 1 CHANNEL AT 10 SAMPLES/SEC. DIGITAL EVENTS: • 1 EVENT AT 160 SAMPLES/SEC. • 1 EVENT AT 10 SAMPLES/SEC.	• NON-OPERATING: 40°F TO 120°F • OPERATING: 60°F TO 80°F	• CONTROLS: • OPERATE/ON/OFF SWITCH FOR CAMERA MODE SELECTION • EXTEND/OFF/RETRACT SWITCH TO CONTROL CAMERA DEPLOYMENT • V/H INCREASE/ON/OFF CONTROL FOR IMAGE MOTION CONTROL • FILM CUT MOM. ON/OFF-MOMENTARY CONTACT SWITCH FOR FILM CUT • DISPLAYS: • GO/NO GO TALKBACK FOR INDICATION OF FAULTY CAMERA OPERATION • DEPLOYMENT STATUS OF CAMERA IS INDICATED BY THE CAMERA EXTEND/RETRACT SWITCH AND THE "DEPLOY" TALKBACK.
	LASER ALTIMETER (SM PHOTOGRAPHY TASK)	• AC: 7 VA/Ø AVG. AND PEAK OPERATION • DC: STANDBY MODE: 8 WATTS. OPERATE MODE: 52 WATTS AVG.; 94 WATTS PEAK	• SCIENCE DATA: 24 BIT DIGITAL PARALLEL WORD • HOUSEKEEPING DATA: ANALOG • 5 CHANNELS AT 1 SAMPLE/SEC. • 1 CHANNEL AT 10 SAMPLES/SEC.	• NON-OPERATING: -30°F TO 257°F • OPERATING: 65°F TO 160°F	• CONTROLS: • ON/OFF/STANDBY SWITCH FOR ALTIMETER OPERATION SELECTION. • SYNC EXTERNAL (CAMERA) OFF/SYNC INTERNAL (AUTOMATIC) FOR ALTIMETER MODE SELECTION.

Table 2-3. Lunar Surface Experiments, Physical Description

EXP. NO.	EXPERIMENT	DEPLOYED LOCATION RELATIVE TO CENTRAL STATION/LM	WEIGHT	SIZE	DESCRIPTIONS
	ALSEP CENTRAL STATION	• CENTRAL STATION IS EMPLACED 300 FT. MINIMUM FROM THE LM TO AVOID ASCENT STAGE ENGINE BLAST/PARTICLE EFFECTS TO 1000 FT. MAX. (PLSS ABORT CONSTRAINT) FROM THE LM. • RTG IS EMPLACED 10 FT. FROM THE CENTRAL STATION. • ALL ALSEP EXPERIMENTS AND SUBSYSTEMS WITH EXCEPTION OF RTG FUEL CAPSULE ARE STOWED IN THE LM SEQ (SCIENTIFIC EXPERIMENT) BAY.	• STRUCTURE/THERMAL PORTION OF SUB PKG. NO. 1: 24.9 LBS. • STRUCTURE/THERMAL PORTION OF SUB PKG. NO. 2: 25.2 LBS. • ANTENNA: 2.6 LBS. • RTG: 28.0 LBS. • PCU: 4.5 LBS. • DATA SUBSYSTEM: 25 LBS.	• STRUCTURE/THERMAL PORTION OF SUB PKG. NO. 1: 26.8 IN. X 27.4 IN. X 6.9 IN. • STRUCTURE/THERMAL PORTION OF SUB PKG. NO. 2: 25.9 IN. X 27.1 IN. X 3.4 IN. • ANTENNA MAST (2 SECTIONS) SECTION LENGTH: 20.8 IN. SECTION DIA.: 1.75 IN.	• THE CENTRAL STATION CONSISTS OF THE TRANSMITTERS AND RECEIVERS, THE DATA SUBSYSTEM, ELECTRONICS FOR THE SEISMIC INSTRUMENTS, AND A SWITCH PANEL FOR SYSTEM ACTIVATION BY THE ASTRONAUT. • DC ELECTRICAL POWER FOR THE DATA AND EXPERIMENT SUBSYSTEMS IS PROVIDED BY A SNAP 27 RTG AND A POWER CONDITIONING UNIT. • EACH EXPERIMENT (ALSEP INSTRUMENT) ARE CONNECTED TO THE CENTRAL STATION BY FLAT, RIBBON-LIKE CONDUCTOR CABLING.
S-031	PASSIVE SEISMIC EXPERIMENT (PSE)	• PSE IS EMPLACED 10 FT. EAST OR WEST OF THE CENTRAL STATION DIRECTLY OPPOSITE THE RTG.	• SENIOR ASSEMBLY: 21 LBS. • CENTRAL STATION ELECTRONICS: 4.0 LBS.	• SENSOR ASSEMBLY DIAMETER: 11.8 IN. HEIGHT: 15.2 IN. • CENTRAL STATION ELECTRONICS ASSEMBLY: 2.8 IN. (HIGH) X 7.2 IN. (WIDE) X 6.5 IN. (LONG)	THE PSE WHICH COMPOSES A PORTION OF THE ALSEP PACKAGE IS A PORTABLE ASSEMBLY WITH A SHAPE SIMILAR TO THAT OF A DRUM ROUNDED ON ONE END.
S-033	ACTIVE SEISMIC EXPERIMENT (ASE)	• MORTAR BOX ASSEMBLY IS EMPLACED 10 FT. FROM THE CENTRAL STATION, POINTING AWAY FROM THE IMAGINARY LINE UPON WHICH THE GEOPHONE LINE IS TO BE LAID. • GEOPHONES (DETECTORS) WITH CONNECTING CABLES TO THE CENTRAL STATION ARE INSERTED IN THE LUNAR SURFACE AT DISTANCES OF 10 FT., 160 FT., AND 310 FT. FROM THE CENTRAL STATION.	• THUMPER-GEOPHONE ASSEMBLY: 7 LBS. • MORTAR PACKAGE (INCL. GRENADES): 15 LBS. • CENTRAL STATION ELECTRONICS ASSEMBLY: 3 LBS.	• THUMPER-GEOPHONE ASSY: LENGTH (FOLDED): 14.5 IN. THUMPER DEPLOYED: 44.5 IN. GEOPHONES (3): 4.8 IN. HIGH (INCL. SPIKE) 1.7 IN. DIAMETER • MORTAR PACKAGE: 9.5 IN (HIGH) X 4.0 IN. (WIDE) X 15.6 IN. (LONG) • CENTRAL STATION ELECTRONICS ASSY: 2.8 IN. (HIGH) X 6.2 IN. (WIDE) X 6.8 IN. (LONG)	• THIS ALSEP EXPERIMENT EMPLOYS TWO DIFFERENT ENERGY SOURCES TO ARTIFICIALLY PRODUCE SEISMIC EVENTS. THEY ARE: • MORTAR BOX ASSEMBLY FROM WHICH FOUR EXPLOSIVE GRENADES WILL BE FIRED TO DETONATE AT VARYING DISTANCES UP TO 5000 FT. FROM THE GEOPHONE DETECTORS. GRENADES TO BE LAUNCHED BY EARTH COMMAND NEAR THE END OF ONE YEAR EXPERIMENT PERIOD. • "THUMPER" ASSEMBLY CONSISTING OF 21 EXPLOSIVE (ASI) CARTRIDGES, FIRING MECHANISM, AND CONTACT POINTS IN AN UPPER SECTION AND A LOWER CYLINDRICAL SECTION CONTAINING A PLATE FOR COUPLING OF SEISMIC ENERGY TO LUNAR SURFACE. CHARGES ARE FIRED AT 15 FT. INTERVALS BY ASTRONAUT ON RETURN LEG OF THE GEOPHONE LINE DEPLOYMENT BEGINNING AT 310 FT. WITH RESPECT TO CENTRAL STATION.
S-034	LUNAR SURFACE MAGNETOMETER (LSM)	• THE LUNAR SURFACE MAGNETOMETER IS SET-UP ABOUT 55 FT. FROM THE CENTRAL STATION IN A DIRECTION AWAY FROM THE LM. AN INTERCONNECTING CABLE LINKS THE EXPERIMENT WITH THE STATION.	20 LBS.	BOOM LENGTH (3): 3 FT. DEPLOYED HEIGHT: 40 IN. SENSOR HEAD SEPARATION: 60 IN.	• THIS ALSEP EXPERIMENT CONSISTS OF A 3-AXIS, FLUX-GATE MAGNETOMETER CONSISTING OF THREE SENSORS MOUNTED AT MUTUAL RIGHT-ANGLES ON THE ENDS OF 3-FOOT BOOM. • BOOMS ARE JOINED TO AN ELECTRONICS PACKAGE THAT IS PLACED ON THE LUNAR SURFACE. • SENSOR ROTATIONS WITHIN THE HOUSING ON THE END OF EACH BOOM ARE AUTOMATICALLY PROGRAMMED AND DRIVEN BY SMALL ELECTRONIC MOTORS TO PROVIDE BOTH THE SCIENTIFIC MEASUREMENTS AND SITE-SURVEY GRADIENT MEASUREMENTS.
S-037	HEAT FLOW EXPERIMENT (HFE)	• TWO HOLES ARE DRILLED WITH THE APOLLO LUNAR SURFACE DRILL AT A SUITABLE DRILLING SITE TYPICALLY 16 FT. FROM ELECTRONICS UNIT WHICH IS 30 FT. FROM CENTRAL STATION. EACH HOLE IS APPROXIMATELY ONE-INCH IN DIAMETER AND 10 FT. DEEP. • HOLES ARE CASED TO PREVENT CAVE-IN AND TO FACILITATE INSERTION OF HEAT PROBES. • SUBSURFACE CORE MATERIAL FROM SECOND HOLE IS RETAINED IN THE DRILL STRING AND PLACED IN THE SRC FOR EARTH RETURN.	• PROBES (2): 3.5 LBS. • ELECTRONICS UNIT: 6 LBS. • APOLLO LUNAR SURFACE DRILL (ALSD): 29.5 LBS.	• PROBES (2) PKG. FOR LAUNCH: 9 IN. X 4 IN. X 26 IN. (LAUNCH) • ELECTRONICS UNIT: 13 IN. X 9 IN. X 8 IN. • HOLE CASINGS (12): LENGTH (EACH): 22 IN. • ALSD VOLUME (STOWED): 7.0 IN. X 9.6 IN. X 22.7 IN.	• 45-INCH LONG PROBES ARE EMPLACED IN THE BOTTOMS OF THE DRILLED HOLES WITH A SPECIAL TOOL. • PROBES ARE CONNECTED BY CABLES TO AN ELECTRONICS PACKAGE WHICH IS, IN TURN, CABLE CONNECTED TO THE ALSEP CENTRAL STATION. • ASTRONAUT SETS THE ELECTRONICS PACKAGE ON THE LUNAR SURFACE TO SUCH AN ALIGNMENT THAT WILL SATISFY THERMAL (SUN-SHIELD) REQUIREMENTS.
M-515	LUNAR DUST DETECTOR	• DUST DETECTOR PACKAGE IS MOUNTED ON TOP OF THE CENTRAL STATION SUNSHIELD WITH THE PHOTOCELLS FACING THE ECLIPTIC PATH OF THE SUN.	0.5 LBS. (SENSOR) 0.10 LBS. (ELECTRONICS)	1.8 IN. X 1.8 IN. X 2.6 IN.	• DETECTOR MEASURES THE ACCUMULATION AND EFFECT OF LUNAR DUST ACCRETION OVER THE ALSEP CENTRAL STATION. • EACH PHOTOCELL IS PROTECTED BY A BLUE FILTER TO CUT OFF UV WAVELENGTH BELOW 0.4μ AND A COVER SLIDE FOR PROTECTION AGAINST RADIATION DAMAGE. INDIVIDUAL CELL TEMPERATURE IS MONITORED BY A THERMISTOR ATTACHED TO THE REAR OF EACH CELL.
S-078	LASER RANGING RETRO-REFLECTOR	• DEPLOYED MINIMUM OF 300 FT. FROM AND SOUTH OF LM. • EMPLACED 10 FT. MINIMUM FROM PSE TO AVOID THERMAL INTERACTION. • DEPLOYED ON LEVEL SITE WITH ASTRONAUT PERFORMING NECESSARY LEVELING AND ADJUSTMENTS WITH RESPECT TO ELEVATION AND ALIGNMENT.	52 LBS.	26 IN. X 27 IN. X 17 IN. (LAUNCH)	• LRRR IS A PASSIVE DEVICE REQUIRING NO ELECTRICAL POWER, TELEMETRY, MSFN OR MCC MISSION SUPPORT. • THE RETRO-REFERENCE ARRAY CONSISTS OF A PANEL STRUCTURE INCORPORATING 100 RETRO-REFLECTORS (FUSED SILICA OPTICAL CORNERS) AND AN AIM-ANGLE HANDLE. • LRRR IS TO REFLECT LASER RADIATION BEAMED FROM ONE OR MORE EARTH-BASED STATIONS.
S-198	LUNAR PORTABLE MAGNETOMETER	• ASTRONAUT REMOVES THE EXPERIMENT FROM EXTERNAL STORAGE ON THE LM AND THEN WALKS 250 FT. FROM THE LM TO EMPLACE THE EXP. TRIPOD, UNREEL THE 50 FT. CABLE WITH ATTACHED ELECTRONICS BOX AND THEN RETURN TO THE SENSOR HEAD/TRIPOD ASSEMBLY. SITE POINT AND GRADIENT MEASUREMENTS ARE THEN TAKEN. • USING THE SAME EXPERIMENT ERECTION PROCEDURES, SINGLE MEASUREMENTS ARE THEN MADE AT THREE DIFFERENT POINTS ALONG THE GEOLOGICAL TRAVERSE ROUTE FOR VOICE DOWN-LINK TRANSMISSION.	TOTAL: 7 LBS. EXP. ASSY.: 5 LBS. TRIPOD: 2 LBS.	4 IN. X 4 IN. X 13 IN. PLUS TRIPOD (LAUNCH)	• THE PORTABLE MAGNETOMETER CONSISTS OF A SENSOR ASSEMBLY MOUNTED ON A TRIPOD CONNECTED TO AN ELECTRONICS BOX WITH A 50 FT. FLAT RIBBON CABLE (ASTRONAUT READS DATA FROM METERS REMOTELY - AT 50 FT. - BECAUSE OF PLSS MAGNETIC PROPERTIES). • SENSOR ASSEMBLY HAS THREE ORTHOGONAL FLUX GATE MAGNETIC SENSORS AND A BUBBLE LEVEL WITH SHADOWGRAPH USED TO VISUALLY ORIENT THE ASSEMBLY WITH RESPECT TO LOCAL VERTICAL AND AZIMUTHAL SUN ANGLE. • ELECTRONICS BOX CONSISTS OF SENSOR ELECTRONICS, BATTERIES, AND THREE METERS TO READ THE OUTPUT OF THREE SENSORS (ASTRO. SENDS DATA TO MCC OVER VOICE COMM. LINK).

Table 2-3. Lunar Surface Experiments, Physical Description (Continued)

EXP. NO.	EXPERIMENT	DEPLOYED LOCATION RELATIVE TO CENTRAL STATION/LM	WEIGHT	SIZE	DESCRIPTIONS
S-152	COSMIC RAY DETECTOR (PLASTICS)	• SEVERAL STACKS OF 40 0.01 IN. THICK SHEETS OF LEXAN POLYCARBONATE PLASTIC DETECTORS WILL BE MOUNTED ON A FRAME THAT ATTACHES TO THE LM EXTERIOR PRIOR TO LAUNCH.	LAUNCH WT.: 20 LBS. RETURN WT.: 8 LBS.	(LAUNCH) 1/2 IN. X 7 1/2 IN. X (RETURN) 2 IN. X 12 IN. X 7 1/2 IN.	• PRE-ETCHED AND CALIBRATED DETECTOR STACKS ARE EXPOSED TO COSMIC RAYS ON THE OUTSIDE OF THE LM FOR ABOUT 100 HRS. THE STACKS ARE THEN RETRIEVED ON AN EVA AND PLACED IN THE LM ASCENT STAGE FOR EVENTUAL EARTH RETURN FOR PROCESSING AND ANALYSIS. • HALF OF THE DETECTOR SHEETS IN EACH STACK WILL BE TRANSLATED WITH RESPECT TO EACH OTHER PRIOR TO EARTH RETURN IN ORDER TO DIFFERENTIATE COSMIC RAYS THAT ENTER THE PLASTIC ON THE RETURN TRIP. • EXPERIMENT IS COMPLETELY PASSIVE WITH RESPECT TO OPERATION.

S-200	SOIL MECHANICS	EXPERIMENT DOES NOT HAVE A SPACECRAFT INTERFACE SINCE IT INVOLVES ONLY ANALYSIS OF DATA ACQUIRED FROM VARIOUS SOURCES.	NOT APPLICABLE	NOT APPLICABLE	• NO ADDITIONAL HARDWARE OR OPERATIONAL REQUIREMENTS ARE NECESSARY.
					• EVALUATION OF SOIL MECHANICAL PROPERTIES IS BASED UPON DATA RESULTING FROM NORMAL, PLANNED LUNAR SURFACE ACTIVITIES.
					• SOURCES OF SUCH DATA INCLUDE:
					  • PHOTOGRAPHS OF ASTRONAUT'S FOOTPRINTS AND LM FOOTPAD IMPRESSIONS
					  • PHOTOGRAPHS OF TERRAIN FEATURES
					  • LUNAR SOIL SAMPLES
					  • SOIL PENETRATION CHARACTERISTICS OF HAND TOOLS, DRILL BITS, ETC.
					  • CREW OBSERVATIONS AND COMMENTS

S-059	LUNAR GEOLOGY INVESTIGATION	EXPERIMENT COVERS A WIDE RANGE OF LUNAR GEOLOGY TASKS RANGING FROM DOCUMENTED SAMPLES OBTAINED FROM THE VICINITY OF THE LM TO SAMPLES OBTAINED ON FAR-REACHING TRAVERSES UTILIZING THE CAPABILITIES OF THE LUNAR ROVING VEHICLE (LRV).	TOOL KIT (ALHT): 25 LBS. HASSELBLAD CAM.: 8 LBS. GEOLOGICAL CAM.: 10 LBS. CLOSEUP STEREO CAM.: 11 LBS. SPARE MAGAZINES: 6 LBS. SAMPLES: 30 LBS. TOTAL: 97 LBS.	NOT APPLICABLE	• IN ADDITION TO THE USE OF THE LRV, THIS EXPERIMENT WILL REQUIRE USE ONLY OF THE STANDARD APOLLO LUNAR HAND TOOLS (HAMMER, TONGS, SCOOP, ETC.), FIELD SAMPLE BAGS, SAMPLE RETURN CONTAINERS, CAMERA EQUIPMENT, AND ASSOCIATED ACCESSORIES ALREADY IN USE. • PI STUDIES FOR USE OF LUNAR SURVEYING STAFF, HIGH RESOLUTION LUNAR SURFACE TV, TOOL AND SAMPLE BAG MODIFICATIONS, ETC. ARE NOT COMPLETE. STUDIES ARE DIRECTED PRIMARILY TO THE LATER J-MISSIONS. • GEOLOGICAL OPERATIONS TO BE PERFORMED ON THE LRV TRAVERSE HAVE NOT BEEN DEFINED BY THE PI AS YET.

Table 2-4. Lunar Surface Experiments, Interface Data

EXP. NO.	EXPERIMENT	POWER REQUIREMENTS	DATA REQUIREMENTS	TEMPERATURE REQUIREMENTS	ASTRONAUT INTERFACE FUNCTION
	ALSEP CENTRAL STATION	• THE ELECTRICAL POWER SUBSYSTEM GENERATES 63-74 WATTS OF POWER FOR ALSEP OPERATION • POWER IS DEVELOPED BY A THERMO-PILE SYSTEM HEATED BY A RADIOISOTOPE FUEL CAPSULE. • PRIMARY COMPONENTS OF THE ELECTRICAL POWER SUBSYSTEM ARE: RTG; FUEL CAPSULE; POWER CONDITIONING UNIT; AND FUEL CASK.	• DATA SUBSYSTEM RECEIVES, DECODES, AND APPLIES DISCRETE LOGIC COMMANDS FROM MSFN TO THE DEPLOYED UNITS OF ALSEP. • THESE COMMANDS PROVIDE FOR: POWER SWITCHING; THERMAL CONTROL; OPERATING MODE CHANGES; AND EXPERIMENT CONTROL. • SUBSYSTEM ACCEPTS AND PROCESS DATA FROM EXPERIMENTS, STATUS DATA FROM ITSELF AND OTHER SUBSYSTEMS, AND TRANSMITS DATA TO MSFN RECEIVING STATIONS.	• THE STRUCTURE/THERMAL SUBSYSTEM PROVIDES STRUCTURAL INTEGRITY AND THERMAL PROTECTION OF THE ALSEP EQUIPMENT IN LM TRANSPORT AND IN THE LM ENVIRONMENT (-300°F to + 250°F). THIS INCLUDES PACKAGING, STRUCTURAL SUPPORT AND ISOLATION FROM HEAT, COLD, SHOCK, AND VIBRATION.	• ASTRONAUTS REMOVE THE ALSEP EQUIPMENT FROM THE SEQ BAY OF THE LM. • ASTRONAUT REMOVES THE FUEL ELEMENT FROM THE FUEL CASK LOCATED ON THE SIDE OF THE LM AND EMPLACES IT IN THE RTG FUEL GENERATOR CAVITY. • ASTRONAUT CARRIES THE ALSEP EQUIPMENT TO THE PLANNED DEPLOYMENT SITE (AT LEAST 300 FT. FROM LM). • ASTRONAUT ASSEMBLES CENTRAL STATION, DEPLOYS ALSEP EXPERIMENTS, LEVELS AND ALIGNS THE CENTRAL STATION ANTENNA SUBSYSTEM, TURNS-ON ASTRO SWITCH NO. 1 WITH UHT, REQUESTS TRANSMITTER TURN-ON FROM MCC-H, CHECKS ANTENNA ORIENTATION, AND RECEIVES CONFIRMATION OF RF SIGNAL RECEIPT AND USEFUL DATA FROM MCC-H.
S-031	PASSIVE SEISMIC EXPERIMENT (PSE)	• ANALOG ELECTRONICS: 1.61 WATTS • DIGITAL ELECTRONICS: 1.21 WATTS • POWER CONVERTER LOSS: 1.71 WATTS • HEATER: 2.40 WATTS • LEVEL SYSTEM: 3.10 WATTS • FUNCTIONAL POWER/HEATER: 6.70 WATTS • FUNCTIONAL POWER/LEVEL: 7.20 WATTS	• EIGHT SCIENTIFIC DATA CHANNELS: • THREE LONG PERIOD SEISMIC DATA CHANNELS • ONE SHORT PERIOD SEISMIC DATA CHANNEL • ONE SENSOR ASSEMBLY MONITORING TEMPERATURE • 15 SEPARATE GROUND COMMAND CHANNELS ARE PROVIDED • DATA/COMMAND CHANNELS INTERFACE WITH ALSEP DATA SUBSYSTEM	• SENSOR ASSEMBLY TEMPERATURE RANGE: 107°F - 143°F ±1%	• ASTRONAUT RELEASES AND REMOVES THE PSE FROM THE ALSEP SUBPACKAGE, CARRIES IT AND THE UNIT TO THE EMPLACEMENT SITE. • ASTRONAUT THEN RELEASES THE THERMAL SHROUD RESTRAINT, EMPLACES AND ALIGNS THE PSE, DEPLOYS THE THERMAL SHROUD, AND LEVELS THE PSE. • ASTRONAUTS REPORTS SUN SHADOW ALIGNMENTS TO MCC-H.
S-033	ACTIVE SEISMIC EXPERIMENT (ASE)	• OPERATIONAL: 8.0 WATTS • THERMAL CONTROL: 1.75 WATTS (STANDBY)	• THREE CHANNELS OF SEISMIC DATA AND THIRTEEN CHANNELS OF HOUSEKEEPING DATA. • 20 BIT DIGITAL WORD FORMAT AND 10,600 BIT/SEC DATA RATE OF ASE PROVIDES FOR TRANSMISSION OF ACCURATELY ENCODED CRITICAL REAL TIME EVENT DATA WHICH PRECLUDES OTHER ASLEEP EXPERIMENT OPERATION DURING CRITICAL DATA GATHERING PERIODS. • SEVEN COMMANDS FROM MSFN REQUIRED TO ARM AND FIRE GRENADES AND TO CALIBRATE GEOPHONES. OTHER COMMANDS PROVIDE FOR POWER DISTRIBUTION AND ASE MODE CHANGES.	• THERMAL CONTROL OF THE GRENADE LAUNCH ASSEMBLY IS PROVIDED BY AN INTERNAL HEATER	• ASTRONAUT REMOVES THUMPER-GEOPHONE ASSEMBLY AND MORTAR PACKAGE FROM EXPERIMENT PACKAGE, ASSEMBLES THUMPER, AND PARTIALLY DEPLOYS MORTAR PACKAGE. • USING UHT TOOL THE ASTRONAUT TURNS THE CENTRAL STATION ASE SAFE/ENABLE SWITCH TO ENABLE. • ASTRONAUT EMPLACES GEOPHONES AT 10, 160, AND 360 FOOT POINTS ALONG A NORTHWEST LINE, DEPLOYING GEOPHONE AND THUMPER CABLES ENROUTE. • ASTRONAUT RETURNS ALONG THE GEOPHONE CABLES ACTIVATING THE THUMPER (FIRING AN ASI CHARGE) APPROX. EVERY 15 FEET. HE RETURNS TO THE CENTRAL STATION AFTER THE FINAL THUMPER ACTIVATION. • HE THEN USES THE UHT TO TURN THE CENTRAL STATION ASE SAFE/ENABLE SWITCH TO SAFE. • ASTRONAUT REMOVES SAFETY RODS FROM MORTAR PACKAGE, TURN ON MORTAR PACKAGE SAFE/ARM SWITCHES, RETURNS TO CENTRAL STATION, AND ENABLES THE ASE MORTAR PACKAGE. GRENADES ARE ACTIVATED BY MSFN ABOUT ONE YEAR LATER.
S-034	LUNAR SURFACE MAGNETOMETER (LSM)	• SITE SURVEY MODE: 12.25 WATTS • SCIENTIFIC MODE: 5.8 WATTS 10.9 WATTS (NIGHT) • CALIBRATION MODE: 12 WATTS	• EIGHT EARTH COMMANDS • THREE ANALOG CHANNELS OF SCIENTIFIC DATA FROM SENSOR (3) ELECTRONICS. EACH ANALOG SAMPLE IS CONVERTED INTO A 10-BIT DIGITAL WORD. • EIGHT ANALOG CHANNELS OF HOUSEKEEPING DATA. THESE SAMPLES ARE LIKEWISE CONVERTED INTO 10-BIT DIGITAL WORDS WHICH ARE SUBSEQUENTLY TRUNCATED TO SEVEN BITS.	• INTERIOR OF BASE PACKAGE AND EACH SENSOR HEAD OPERATING RANGE: -50°C to +65°C	• ASTRONAUT EMPLACES THE LSM 55 FEET FROM THE CENTRAL STATION IN A DIRECTION AWAY FROM THE LM. ITS INTERCONNECTING CABLE IS DEPLOYED DURING THE 55-FOOT TRAVERSE. • UPON ARRIVAL AT THE LSM SITE, HE UNFOLDS THE LEGS OF THE LSM, PLACES THE INSTRUMENT ON THE LUNAR SURFACE IN AN APPROXIMATE PROPER EAST-WEST ALIGNMENT. FOLLOWING THIS, HE UNFOLDS THE BOOMS WHICH CARRY THE SENSORS, AND MAKE THE FINAL LEVELING AND ALIGNMENT ADJUSTMENTS. • THE ASTRONAUT REPORTS THE ALIGNMENT TO MCC-H AND THEN RETURNS TO THE CENTRAL STATION.
S-037	HEAT FLOW EXPERIMENT (HFE)	• MODE 1: 6.0 WATTS (DAY) 9.5 WATTS (NIGHT) • MODE 2: 11.0 WATTS (DAY OR NIGHT) • MODE 3: 9.0 WATTS (DAY ONLY)	• TEN EARTH COMMANDS • FOUR TIMING AND CONTROL SIGNALS FROM ALSEP DATA SUBSYSTEM • SEVEN ANALOG HOUSEKEEPING DATA CHANNELS • SCIENTIFIC DATA TEMPERATURE MEASUREMENTS APPEAR IN THE FIRST 16 FRAMES OF EACH 90 FRAME ALSEP TELEMETRY CYCLE, MEASUREMENTS VARY ACCORDING TO HFE OPERATIONAL MODE IN USE.	• HFE ELECTRONICS OPERATING RANGE: 10°C to 60°C	• THE HFE ASSEMBLY IS CARRIED WITH THE AID OF THE UHT FROM SUBPACKAGE NO. 1 TO ABOUT 30 FEET SOUTH OF THE CENTRAL STATION. THE ASTRONAUT THEN RETRIEVES THE ALSD FROM SUBPACKAGE NO. 2 AND RETURNS TO THE HFE ASSEMBLY AND THEN AN ADDITIONAL 16 FEET TO THE SITE FOR THE NO. 1 PROBE EMPLACEMENT. • THE PROBE HOLE IS DRILLED WITH THE ASLD AND CASED. • RETURNING TO THE HFE ASSEMBLY, HE DETACHES THE PROBE BOX AND SEPARATES IT INTO ITS TWO HALVES. THE HALF PROBE BOX WITH PROBE EMPLACEMENT TOOL IS THEN CARRIED TO THE CASED PROBE HOLE WITH THE ELECTRONICS CABLE BEING DEPLOYED ENROUTE. THE HFE PROBE IS THEN INSERTED INTO THE CASED HOLE. • THE ASTRONAUT THEN PROCEEDS TO THE SECOND PROBE EMPLACEMENT SITE WITH THE ALSD AND PROBE EMPLACEMENT TOOL. A SECOND HOLE IS THEN DRILLED AND CASED. HE THEN RETURNS TO THE HFE ASSEMBLY, PICKS UP THE SECOND PROBE BOX HALF, RETURNS TO THE DRILLING SITE, AND EMPLACES THE PROBE AS BEFORE. • HE THEN RETURNS TO AND ALIGNS THE ELECTRONICS PACKAGE IN A MANNER THAT SATISFIES THE THERMAL (SUNSHIELD) REQUIREMENTS.
M-515	LUNAR DUST DETECTOR	• ON MODE: 540 MILLIWATTS (MAX) • OFF MODE: 70 MILLIWATTS (MIN)	• THREE SUB-COMMUTATED ANALOG CHANNELS CARRY OUTPUTS OF THREE ILLUMINATION DETECTORS AND THREE THERMISTOR TEMPERATURE MEASUREMENTS • TWO EARTH COMMANDS	• DUST DETECTOR ELECTRONICS THERMALLY PROTECTED WITHIN CENTRAL STATION.	• ASTRONAUT MOUNTS DUST DETECTOR TO TOP OF ALSEP CENTRAL STATION.

Table 2-4. Lunar Surface Experiments, Interface Data (Continued)

EXP. NO.	EXPERIMENT	POWER REQUIREMENTS	DATA REQUIREMENTS	TEMPERATURE REQUIREMENTS	ASTRONAUT INTERFACE FUNCTION
S-078	LASER RANGING RETRO-REFLECTOR (LRRR OR LR^3))	• PASSIVE EXPERIMENT-NO POWER REQUIRED.	• PASSIVE EXPERIMENT - NO TELEMETRY DATA OR COMMANDS REQUIRED.	• THERMAL PROTECTION PROVIDED BY DESIGN OF INDIVIDUAL RETRO-REFLECTOR CAVITIES AND COMPONENTS. • OPERATING RANGE: 40°K TO 400°K	• LRRR IS DEPLOYED BY ASTRONAUT ON A LEVEL, FIRM SITE AT LEAST 30-50 FEET FROM LM TO PREVENT RADIOACTIVE HEAT TRANSFER AND BLAST EFFECTS FROM FIRING OF LM ASCENT ENGINE AND IS EMPLACED GENERALLY DUE SOUTH OF LM TO MAXIMIZE VISIBILITY BY CREW. • ASTRONAUT LEVELS LRRR WITH BUBBLE LEVEL TO WITHIN $\pm$ 5° OF INDICATOR AS WELL AS SETTING TILT PLATE TO ONE OF FOUR A PRIORI CHOSEN INDEX MARKS ON PRE-LAUNCH INSTALLED TILT PLATE. • FINAL CHORE INVOLVES ALIGNING LRRR USING THE PARTIAL ROSE COMPASS PLATE AND SETTING THE GNOMON SHADOW MARK WITHIN $\pm$5° MAX. OF THE INDICATOR LINE FOR THE LANDING SITE CHOSEN.
S-198	LUNAR PORTABLE MAGNETOMETER	• ONE WATT SUPPLIED BY BATTERY INTERNAL TO EXPERIMENT INSTRUMENT (4 HOUR MIN. LIFETIME)	• THERE ARE NO TELEMETRY DATA OR COMMAND REQUIREMENTS. • MAGNETIC FIELD READINGS READ BY ASTRONAUT FROM THREE DIALS ON PORTABLE CONSOLE ARE VOICE DOWN-LINKED TO MCC-H.	• OPERATING TEMPERATURE: -30°C TO 50°C • THERMAL CONTROL MAINTAINS INSTRUMENT AT $\pm$60°C.	• ASTRONAUT REMOVES MAGNETOMETER COMPONENTS FROM LM SEQ BAY AND PREPARES FOR SITE POINT MEASUREMENTS TO BE TAKEN AT LEAST 250 FEET FROM LM (TO AVOID LM EMI WITH EXPERIMENT). • HE LEVELS AND ALIGNS SENSOR ASSEMBLY ON A TRIPOD ARRANGEMENT USING A BUBBLE LEVEL AND SHADOWGRAPH. HE THEN WALKS BACK 50 FEET TO THE CABLE-CONNECTED ELECTRONICS BOX TO VISUALLY READ FIELD MEASUREMENT COMPONENTS ON THREE DIALS. OTHER MEASUREMENTS IN THE SITE AND GRADIENT MODES WILL BE TAKEN. • ASTRONAUT WILL THEN TAKE TRAVERSE MEASUREMENTS AT THREE DIFFERENT POINTS ALONG THE LUNAR TRAVERSE. SENSOR ASSEMBLY WILL HAVE TO BE REDEPLOYED, LEVELED, AND ALIGNED FOR EACH TRAVERSE MEASUREMENT.
S-152	COSMIC RAY DETECTOR (PLASTICS)	• PASSIVE EXPERIMENT - NO POWER REQUIREMENTS.	• PASSIVE EXPERIMENT - NO TELEMETRY OR COMMAND REQUIREMENTS. "DATA" CONSIST OF PRE-ETCHED AND SCANNED PLASTIC SHEETS THAT HAVE BEEN EXPOSED TO COSMIC RAYS AND PARTICLES FOR EARTH RETURN.	• SHIELD THE DETECTOR STACKS FROM THE SUN AND FROM RCS THRUSTER PLUMES SO AS TO KEEP THEIR TEMPERATURE BELOW 120°F. • PROTECT DETECTOR STACKS FROM UV RADIATION BY THE USE OF A THIN OPAQUE LAYER.	• AFTER EVA THE ASTRONAUT WILL RELEASE THE DETECTOR STACKS FROM THE LUNAR MODULE AND STORE THEM IN THE LM ASCENT STAGE. • ASTRONAUT MAY BE REQUIRED TO ACTIVATE A SIMPLE DEVICE TO TRANSLATE THE DETECTOR STACKS WITH RESPECT TO EACH OTHER BY ABOUT 1/4 INCH SO AS TO DIFFERENTIATE PARTICLE EXPOSURE INCURRED ON RETURN TRIP TO EARTH. • DETECTOR STACKS WILL BE RETURNED TO EARTH FOR SCIENTIFIC ANALYSIS.
S-200	SOIL MECHANICS	• NO REQUIREMENT	• NO REQUIREMENT FOR TELEMETRY DATA OR COMMANDS. • DATA USED FOR EXPERIMENT ARE DERIVED PRINCIPALLY AS A BY-PRODUCT OF THE LUNAR GEOLOGY ACTIVITIES AND OTHER DATA SOURCES; E.G., LM LANDING PAD IMPRINT PHOTOS. AND ASTRO. DESCRIPTIONS, PHOTOS. OF SOIL IMPRESSIONS MADE BY GEOLOGY TOOLS, ETC.	• NO REQUIREMENT	• IN GENERAL, NO SPECIAL "EXTRA" ACTIVITIES ARE REQUIRED FROM THE FLIGHT CREW TO SUPPORT THIS EXPERIMENT OTHER THAN SPECIAL NARRATIVE DESCRIPTIONS AND SUPPLEMENTARY PHOTOGRAPHS ACQUIRED IN THE PERFORMANCE OF OTHER ACTIVITIES SUCH AS LUNAR GEOLOGY.
S-059	LUNAR GEOLOGY INVESTIGATION	• NO REQUIREMENT	• NO REQUIREMENT FOR TELEMETRY DATA OR COMMANDS. • DATA WILL CONSIST OF LUNAR SOIL AND ROCK SAMPLES WITH DOCUMENTARY CREW LOGS, COMMENTS AND PHOTOGRAPHS. SUPPORTING LUNAR TV MAY ALSO BE EMPLOYED. • OBTAINMENT OF SUB-SURFACE CORE SAMPLES STILL UNDER STUDY.	• NO REQUIREMENT	• CREW WILL PARTICIPATE IN SELECTING, GATHERING, DOCUMENTING, AND STORING GEOLOGICAL SAMPLES FOR EARTH RETURN WHETHER OBTAINED ON A FOOT OR LRV TRAVERSE OR LOCALLY IN THE VICINITY OF THE LM. • DOCUMENTATION ACTIVITIES WILL INVOLVE INDIVIDUALLY "BAGGING" SAMPLES, DESCRIBING SAMPLE AND SURROUNDING GEOLOGICAL ENVIRONMENT WHERE OBTAINED - WRITTEN AND VOICE DOWN-LINK DESCRIPTIONS, AND TAKING THE PROPER SEQUEL OF CLOSEUP STEREO AND PANORAMIC PHOTOGRAPHS.

SDO NO. 4.3.1 APOLLO MISSION J-1 DATE: 15 May 1970

DE NO. ______ SRDS NO. 1 ISSUE: Review Draft

TITLE: PHOTOGRAPHS OF CANDIDATE EXPLORATION SITES

1. FUNCTIONAL DESCRIPTION

Camera equipment includes a Hasselblad electric data camera with 80 mm lens, a 16 mm data acquisition camera operating through the sextant, and a Lunar topographic camera.

2. OBJECTIVE

The objective is to obtain stereoscopic, sequence, and high resolution photographs of a candidate exploration site for a future Apollo mission.

3. OPERATING REQUIREMENTS

a. Operating Time

Five light side passes, including simultaneous operation of independent cameras.

b. Weight and Volume

Weight: 73.2 lbs., excluding brackets and extra film magazines.

c. Stowage Location

CM

d. Crew Activities

(1) Unstow and stow cameras, brackets, and magazines
(2) Mount cameras and brackets
(3) Operate cameras
(4) Initiate orbital attitude rate for stereo strip photographs
(5) Perform sightings on eight landmarks

e. Spacecraft Attitude/Body Rates

CSM attitude in 2-degree deadband mode while stereo strip photography is in progress.

Figure 2-1. Photographs of Candidate Exploration Sites (Sheet 1 of 2)

4. DATA REQUIREMENTS

a. Experiment Data

Photographs as follows:

(1) Hasselblad stereoscopic photographs (with 60 percent forward overlap) covering the ground track from terminator to terminator for the site.

(2) Two strips of high resolution photographs of the site.

(3) 16 mm sextant sequence photographs from terminator to terminator for the pass that Hasselblad stereoscopic photographs are also obtained.

(4) 16 mm sextant sequence photographs for each of the landmarks tracked.

b. Telemetry Measurements

Measurement Number	Description	TM	Mode	Priority
CG 0001 V	Computer Digital Data 40 Bits	PCMD+	2	M
CK 1043 X	70 mm Camera Shutter Open	PCM	1	M
CK 1044 X	Lunar Topographic Camera Shutter Open	PCM	1	M

c. Astronaut Logs or Voice Records

Record of magazine number and any pertinent visual observations for each photographic sequence.

d. Trajectory Data (M)

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

5. CONSTRAINTS/PROBLEM AREAS

Avoid urine and waste water dumps during periods of photography.

Figure 2-1. Photographs of Candidate Exploration Sites (Sheet 2 of 2)

SDO NO. 4.3.2	APOLLO MISSION J-1	DATE: 15 May 1970
DE NO. ______	SRDS NO. 2	ISSUE: Review Draft

TITLE: SM ORBITAL SCIENCE PHOTOGRAPHY

NOTE

Science Requirements Data TBS

Figure 2-2. SM Orbital Science Photography (Sheet 1 of 1)

SDO NO. 4.3.3 APOLLO MISSION J-1 DATE: 15 May 1970

DE NO. ______ SRDS NO. 3 ISSUE: Review Draft

TITLE: CSM ORBITAL SCIENCE PHOTOGRAPHY

1. FUNCTIONAL DESCRIPTION

Camera equipment includes a Lunar Topographic camera, a Hasselblad electric data camera with 80 mm lens, a Hasselblad electric camera with 250 mm lens, and a 16 mm data acquisition camera with 18 mm lens.

2. OBJECTIVE

The objective is to obtain photographs from lunar orbit 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.

3. OPERATING REQUIREMENTS

a. Operating Time

One light side pass plus a variable time dependent on number of areas of photographic interest.

b. Weight and Volume

Weight: 79 lbs., excluding brackets and extra film magazines.

c. Stowage Location

CM

d. Crew Activities

(1) Unstow and stow cameras, brackets, and magazines.
(2) Mount cameras and brackets.
(3) Operate cameras

e. Spacecraft Attitude/Body Rates

CSM attitudes such that photographic targets are available through the CM windows.

Figure 2-3. CM Orbital Science Photography (Sheet 1 of 2)

4. DATA REQUIREMENTS

a. Experiment Data

Photographs of specified areas of scientific interest, of the lunar surface in earthshine, and of the lunar surface in dim light near the terminator.

b. Telemetry Measurements

Measurement Number	Description	TM	Mode	Priority
CK 1043 K	70 mm Camera Shutter Open	PCM	1	HD
CK 1044 X	Lunar Topographic Camera Shutter Open	PCM	1	HD

c. Astronaut Logs or Voice Records

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

d. Trajectory Data

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

5. CONSTRAINTS/PROBLEM AREAS

Avoid urine and waste water dumps during periods of photography.

Figure 2-3. CM Orbital Science Photography (Sheet 2 of 2)

SDO NO. 4.3.4 APOLLO MISSION J-1 DATE: 15 May 1970

DE NO. ______ SRDS NO. 4 ISSUE: Basic

TITLE: CONTINGENCY SAMPLE COLLECTION

1. FUNCTIONAL DESCRIPTION

The contingency sample will be collected as early as practical during the initial EVA period. The astronaut will scoop up a loose sample of lunar material, seal the sample container and stow the container in the LM ascent stage at the termination of the EVA period. Photographs will be made showing the sample while it is on the lunar surface and showing the lunar surface after the sample is collected.

2. OBJECTIVE

The scientific objective is to collect a sample of loose material in the immediate vicinity of the LM as soon as practical during the initial EVA period to insure returning a lunar sample in the event of early termination of lunar stay.

3. OPERATING REQUIREMENTS

a. Crew Activities

(1) Astronaut scoops up a loose sample of lunar material during early part of first EVA period.

(2) Photograph the sample on the lunar surface and photograph the lunar surface after the sample is collected.

(3) Astronaut describes the character of the area where sample is obtained and location of area relative to the LM.

b. Stowage Location

(1) Translunar: Contingency container stowed in the LM ascent stage.

(2) Transearth: Contingency container stowed in location A7 in the CM.

4. DATA REQUIREMENTS

a. Sample of lunar material

b. Photograph of the sample on the lunar surface and a photograph of the lunar surface after the sample is collected.

c. Voice records describing the area where the sample was obtained and location of the area relative to the LM.

Figure 2-4. Contingency Sample Collection (Sheet 1 of 1)

SDO NO. 4.3.5 APOLLO MISSION J-1 DATE: 15 May 1970

DE NO. ______ SRDS NO. 5 ISSUE: Basic

TITLE: SELECTED SAMPLE COLLECTION

1. FUNCTIONAL DESCRIPTION

   Selected samples of rock which are geologically interesting and fine-grained fragmental material representative of the landing area will be collected during the first EVA period to assure the return of a reasonable sized sample of selected material should subsequent EVA(s) 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 (SRC) No. 1.

2. OBJECTIVE

   The scientific objective is to collect geologically interesting lunar material.

3. OPERATING REQUIREMENTS

   a. Crew Activities

      (1) Collect selected samples of rock and fine-grained fragmental material representative of the landing area.

      (2) Collect one large rock

      (3) Samples to be sealed in SRC No. 1 and transferred to the LM ascent stage.

      (4) It is highly desirable that photographs of the samples and immediate sample gathering area be obtained.

   b. Stowage Location

      SRC No. 1 will be stowed in the LM ascent stage for launch from the lunar surface and will be transferred to the CM and stowed in location B5 for the trip to Earth.

4. DATA REQUIREMENTS

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

   b. One large rock.

   c. Photographs of lunar samples and the surrounding sample gathering area.

   d. Voice records describing the area where the samples were obtained and location of the areas relative to the LM.

Figure 2-5. Selected Sample Collection (Sheet 1 of 1)

SDO NO. ______ APOLLO MISSION J-1 DATE: 15 May 1970

DE NO. S-160 SRDS NO. 6 ISSUE: Basic

TITLE: GAMMA-RAY SPECTROMETER

1. FUNCTIONAL DESCRIPTION

The Gamma-Ray Spectrometer, a portion of which is mounted on an extendable boom attached to the Apollo Command and Service Module (CSM), consists of three major sub-assemblies: the gammy-ray detector (boom-mounted), the gamma-ray electronics, and the thermal shield and experiment support bracketry.

The gamma-ray detector (GRD) is sensitive to charged particles and gamma rays and is designed to analyze gamma rays using a NaI(Tl) scintillator viewed by a 3-inch photomultiplier tube (PMT). Charged particles are identified by a plastic scintillator (pilot-B) which surrounds, but is optically decoupled from the NaI(Tl) crystal. The plastic is viewed by a separate 1 1/2-inch photomultiplier tube.

The gamma-ray electronics provides the operating voltages for the photomultiplier tubes and contains thermal control circuitry to stabilize the GRD thermal environment. The gamma-ray electronics processes the charge pulses from the detector into digital data for transmission on the Apollo telemetry system. This processing includes the rejection of charged-particle signals using anticoincidence techniques between plastic and inorganic scintillators, digitizing of gamma-ray signals, and the generation of a serial PCM bit train to modulate the spacecraft-provided sub-carrier oscillator (SCO). The PCM format is a 128 10-bit word frame including frame/word sync and parity checks. Both gamma-ray analyses and instrument operating mode monitors are included in the PCM data format.

2. OBJECTIVE

The science objective of the Gamma Ray Spectrometer Experiment is to obtain evidence on the origin and evolution of the moon by determining the degree of chemical differentiation that the moon has undergone during its development. [Concurrent operation to as large a degree as possible with the other geochemistry - related

Figure 2-6. Gamma-Ray Spectrometer (Sheet 1 of 4)

experiments (X-Ray Fluorescence and Alpha Particle Spectrometers) will enhance the analysis and interpretation of results obtained from this experiment.]

3. OPERATING REQUIREMENTS

a. Power:

(1) Voltage: 28 Vdc
(2) Standby: 6.8 watts
(3) Average: 8.0 watts
(4) Peak: 21.0 watts

b. Pointing Requirements:

(1) Real-Time Accuracy: ±10° of local lunar vertical.
(2) Postflight Reconstruction Accuracy: ±7° of local lunar vertical

c. Temperature Requirements:

(1) Operating Range: -4°F to +120°F.

d. Operating Time:

(1) Lunar orbit: Data collection for 10 hours minimum (complete orbital as practical): highly desirable for additional 20 hours.

(2) Transearth coast: Data collection for 6 hours minimum between 12 and 36 hours after TEI (all additional time desirable), and 1 hour minimum with boom retracted in SIM (additional 1 hour highly desirable).

e. Weight and Volume:

(1) Weight: 16 lb excluding brackets.
22 lb including brackets

(2) Volume: 377 cu. in.

f. Stowage Locations:

(1) SM: Part of SIM.

g. Crew Activities:

(1) Jettison SIM door.
(2) Operate experiment controls and switch.
(3) Deploy/retract/jettison boom.
(4) Orient CSM

h. Concurrent Experiment Operation:

(1) X-Ray Fluorescence (highly desirable).
(2) Alpha-Particle Spectrometer (highly desirable).

Figure 2-6. Gamma-Ray Spectrometer (Sheet 2 of 4)

i. Spacecraft Attitude/Body Rates:

(1) As required to satisfy 3a above.

4. DATA REQUIREMENTS

a. Experiment Data:

(1) Gamma-Ray Spectrometer Output: 1 digital channel, 128 10 bit words, 4 kbs

b. Housekeeping Data:

(1) Detector Temperature: analog channel, 1 SPS, 8 bit word.
(2) Electronics Temperature: analog channel, 1 SPS, 8 bit word.

c. Checkout Data:

(1) Instrument calibration data required within 2 weeks at launch. CSM T/M readout of experiment data is required during calibration.

d. Spacecraft Support Data:

(1) Time correlation, I RIG B.
(2) S/C altitude and selenographic ephermis, BET
(3) S/C attitude
(4) SIM temperature

3. 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 Spacetrometer Output	FM	3	M*
SL 1208 T	Temp. Thermal Environment-Gamma Ray	PCM	1	HD

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

f. Astronaut Logs or Voice Records:

(1) Description and GET related to:

a. Change of experiment mode
b. Deployment/retraction/jettison of boom
c. operation of experiment controls

g. Concurrent Science Data:

(1) Photographs taken by 3-Inch Mapping Camera
(2) Postflight Scientific results, for time periods of concurrent operation, of X-Ray Fluorescence and Alpha-Particle Spectrometer experiments.

Figure 2-6. Gamma-Ray Spectrometer (Sheet 3 of 4)

h. Trajectory Data:

(1) Best estimate of trajectory (BET) during periods of data collection.

i. Preflight Data:

(1) Preflight calibration and checkout data (see item 4c).

5. CONSTRAINTS/PROBLEM AREAS

a. After SIM Door Jettison

(1) "On" or "Standby" for internal heater operation
(2) Deploy boom to prevent detector overheating (only retract out of camera field-of-view during camera operation)

Figure 2-6. Gamma-Ray Spectrometer (Sheet 4 of 4)

SDO NO. ______ APOLLO MISSION J-1 DATE: 15 May 1970

DE NO. S-161 SRDS NO. 7 ISSUE: Basic

TITLE: X-RAY FLUORESCENCE

1. FUNCTIONAL DESCRIPTION

The experimental hardware consists of gas-filled proportaional counters, passive filters, plus supporting electronics. The proportional counters are of two types: two identical detectors each of which is made of beryllium, that remain oriented towards the lunar surface, and a small beryllium counter that monitors the solar X-ray emission. All the detectors are filled to a pressure of one atmosphere with the standard P-10 mixture, 90 percent argon-10 percent methane. These counters are sealed and have entrance windows of beryllium. Fixed filters that significantly modify the spectral responses are placed in front of two of the lunar sensors; the two filters consist of magnesium and aluminum. In this manner, the difference between adjacent pairs of lunar sensors is conditioned mostly by the fluorescent line from a single element. Operation of the detectors requires a very stable high voltage source of about 2300 volts. This will be part of the experimental equipment.

A charge-sensitive preamplifier is mounted directly on the back of each detector. This circuit will integrate and amplify the proportional counter output to a level of between 0.3 and 3 volts while preserving the analog information contents of the signal amplitude and rise time. To increase reliability and prevent a complete loss of experimental data because of failure of any one component, the three X-ray detectors have been broken into two groups of one and two detectors, respectively.

The outputs of the preamplifiers are stored in a unity gain buffer amplifier. This main amplifier produces a waveform that is suitable for the data processor pulse height analyzer. For operation of these circuits, regulated sources supplying ± 7 volts at 100 ma will be included in the experimental equipment. Packaging of the counter and the electric components will include shielding

Figure 2-7. X-Ray Fluorescence (Sheet 1 of 5)

against possible electromagnetic interference from the spacecraft system.

2. OBJECTIVE

The science objective of the X-Ray Fluorescence Experiment is to perform a compositional survey of the lunar surface. Such a survey should yield data relating to the nature of surface material, a measure of surface homogeneity, and a measure of surface/subsurface similarity. Concurrent operation to as large a degree as possible with the other geochemistry experiments (Gamma-Ray and Alpha-Particle Spectrometers) will enhance the analysis and interpretation of results obtained from this experiment.

3. OPERATING REQUIREMENTS

a. Power

(1) Voltage: 28 Vdc
(2) Standby: 26.2 watts
(3) Average: 34.0 watts
(4) Peak: 34.0 watts

b. Pointing Requirements:

(1) Real-time Accuracy: $\pm 5°$ of local lunar vertical
(2) Post-flight Reconstruction Accuracy: $\pm 2°$ of local lunar vertical

c. Temperature Requirements:

(1) Operating Range: -4°F to +122°F
(2) Operating Point: 100°F maximum, 60°F preferred.

d. Operating Time:

(1) Lunar orbit: The instrument shall be operated for not less than 10 hours (minimum requirement) with as much additional operating time to be provided as possible. Full revolution increments shall be utilized where possible with data obtained from the sunlit portion of the lunar surface representing "prime" data and the lunar night surface data representing desirable but secondary data.

In order to obtain the benefit of the expanded bandwidth (2:1) mode of the instrument, continuous data gathering duty cycles of at least 8 1/2 hours duration should be employed.

Once each operational day the CSM shall be rolled 135 to 180 degrees while on the dark side of the moon so as to direct the fluorescence X-Ray sensor at deep space for background measurements to be taken for about 15 minutes.

Figure 2-7. X-Ray Fluorescence (Sheet 2 of 5)

(2) Transearth Coast:

Data shall be collected for TBD hours during transearth coast.

e. Weight and Volume:

(1) Weight: X-Ray/Alpha Particle Unit - 130 lbs
X-Ray Solar Monitor Assembly - 22 lbs

(2) Volume:

f. Stowage Location

(1) SM: Lower portion of SIM (integral unit with alpha particle spectrometer)

g. Crew Activities

(1) Jettison SIM door.
(2) Operate experiment controls.
(3) Orient CSM.

h. Concurrent Experiment Operation

(1) Gamma-Ray Spectrometer (highly desirable)
(2) Alpha-Particle Spectrometer (highly desirable)

i. Spacecraft Attitude/Budgets

(1) As required to satisfy 3b and 3d.

4. DATA REQUIREMENTS

a. Experiments Data:

(1) 9 analog channels as defined below:

Type of Channel	Sample Rate	Variable Measured	Remarks
analog	1 s/sec	X-Ray low voltage power supply summed monitor	8 bit words
analog	1 s/sec	X-Ray discriminator reference voltage monitor	8 bit words
analog	1 s/sec	X-Ray +6.75 volts analog power supply monitor	8 bit words
analog	1 s/sec	X-Ray +500 volts digital power supply monitor	8 bit words
analog	1 s/sec	X-Ray processor temperature monitor	8 bit words
analog	1 s/sec	X-Ray detector temperature monitor	8 bit words
analog	1 s/sec	X-Ray low voltage power supply temperature monitor	8 bit words
analog	1 s/sec	X-Ray lunar detector temperature monitor	8 bit words
analog	1 s/sec	X-Ray solar detector temperature monitor	8 bit words

Figure 2-7. X-Ray Fluorescence (Sheet 3 of 5)

c. Checkout Data:

(1) Instrument calibration within two weeks of launch. Data readout via the spacecraft telemetry system and associated ground support equipment is required during the instrument calibration tests.

d. Spacecraft Support Data:

(1) S/C attitude
(2) S/C altitude and selenographic ephemeris
(3) Times at RCS firing
(4) SIM temperature

e. Telemetry Measurements:

Measurement Number	Description	TM	Mode	Priority
CG 0001 V	Computer Digital Data - 40 Bits	PCMD+	2	M*
(TBD)	SIM Temperature	(TBD)	(TBD)	HD
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

Figure 2-7. X-Ray Fluorescence (Sheet 4 of 5)

Measurement Number	Description	TM	Mode	Priority
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 Temperatue 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 for the mandatory experiment operation periods and HD for the highly desirable experiment operation periods.

f. Astronaut Logs or Voice Records:

(1) GET of experiment switch operation and start and stop of each experiment mode during experiment operating periods.

g. Concurrent Science Data:

(1) Photographs taken by the 24-Inch Panoramic Camera and 3-Inch Mapping Camera during operation of the X-Ray Fluorescence experiment.

(2) Postflight scientific results for periods of concurrent operation from Gamma-Ray and Alpha-Particle Spectrometer experiments.

h. Trajectory Data:

(1) Best estimate of trajectory (BET) during all periods of data collection.

i. Preflight Data:

(1) See paragraph 4c above.

5. CONSTRAINTS/PROBLEM AREAS

a. After SIM door jettison

(1) "Standby" or "On" mode
(2) Prevent sunlite from entering 30° conceal field of view, turn off if cannot be prevented

b. During data collection

(1) Inhibit RCS firing from adjacent jets
(2) Avoid urine, waste water dumps, etc.

Figure 2-7. X-Ray Fluorescence (Sheet 5 of 5)

SDO NO. ______ APOLLO MISSION J-1 DATE: 15 May 1970

DE NO. S-162 SRDS NO. 8 ISSUE: Basic

TITLE: Alpha-Particle Spectrometer

1. FUNCTIONAL DESCRIPTION

The Alpha-Particle Spectrometer experiment is housed in a unit which also includes the X-Ray Fluorescence Experiment. Both are mounted in the SIM bay in the Service Module. The experiment consists essentially of an array of detectors and supporting electronics. Its purpose is to detect alpha particles on the lunar surface and to localize the emission source.

2. OBJECTIVE

The science objective of the Alpha Particle Experiment is to survey as large a portion of the lunar surface as possible (at a spatial resolution of a few kilometers) for emission of alpha particles. Detection and localization of radon emissions from the lunar crust should be possible by detection of monenergetic alpha particles produced in Rn^{220}. Concurrent operation to as large a degree as possible with the X-Ray Fluorescence and Gamma Ray Spectrometer Experiments will enhance the analysis and interpretation of data obtained from this experiment.

3. OPERATING REQUIREMENTS

a. Operating Time

(1) Voltage: 28 Vdc
(2) Standby: 4.0 watts
(3) Average: 6.0 watts
(4) Peak: 6.0 watts

b. Pointing Requirements

(1) Real-Time Accuracy: $\pm 5°$ of local lunar vertical
(2) Postflight Reconstruction Accuracy: $\pm 5°$ of local lunar vertical

c. Temperature Requirements

(1) Operating Range: -4°F to +122°F

Figure 2-8. Alpha-Particle Spectrometer (Sheet 1 of 5)

d. Operating Time

(1) Lunar Orbit: a) Data collection for 10 hours minimum with as much additional time as possible highly desirable. Full orbit increments are highly desirable. b) 15 minutes of background measurements per day while on dark side of moon.

e. Weight and Volume

(1) Weight: X-Ray/Alpha Particle Unit - 130 lbs

(2) Volume:

f. Stowage Location

(1) SM: Lower portion of SIM (integral unit with X-Ray Spectrometer)

g. Crew Activities

(1) Jettison SIM door

(2) Operate experiment controls

(3) Orient CSM

h. Concurrent Experiment Operation

(1) X-Ray Fluorescence (highly desirable)

(2) Gamma Ray Spectrometer (highly desirable)

i. Spacecraft Attitude/Budgets

(1) As required to satisfy 3 b and 3 d above.

4. DATA REQUIREMENTS

a. Experiment Data

(1) Alpha-Particle Pulse Height Analyzer Count: 8 bit digital parallel word, 10 SIS

(2) Detector Channel Identification: analog, 10 S/S

(3) Alpha Particle Count Rate Mate: analog, 10 S/S

Figure 2-8. Alpha-Particle Spectrometer (Sheet 2 of 5)

b. Housekeeping Data

The housekeeping data consists of 11 analog measurements described below. The last two have not as yet been incorporated in the T/M system.

Type of Channel	Sample Rate	Variable Measured	Remarks
Analog	1 sample/sec	detector temperature monitor No. 1	8 bit word
Analog	1 sample/sec	detector temperature monitor No. 2	8 bit word
Analog	1 sample/sec	+6.75 voltage power supply monitor	8 bit word
Analog	1 sample/sec	low voltage power supply temperature monitor	8 bit word
Analog	1 sample/sec	detector bias voltage	8 bit word
Analog	1 sample/sec	discriminator reference -12 volts monitor	8 bit word
Analog	1 sample/sec	+6.75 volt analog-to-digital power supply monitor	8 bit word
Analog	1 sample/sec	+5 volt digital power supply monitor	8 bit word
Analog	1 sample/sec	summed low voltage power supply monitor	8 bit word
Analog	1 sample/sec	temperature, high voltage power supply monitor	8 bit word
Analog	1 sample/sec	voltage conditioner monitor No. 2	8 bit word

c. Checkout Data

(1) All instrument calibration and checkout data as recorded (strip chart, test logs, etc.) are required.

Figure 2-8. Alpha-Particle Spectrometer (Sheet 3 of 5)

d. Spacecraft Support Data

(1) S/C attitude and attitude rates

(2) S/C altitude and selenographic ephemeris

(3) S/C SIM temperature

(4) RCS firing data on adjacent jets (if not inhibited) (See Section 5)

e. 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
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.

Figure 2-8. Alpha-Particle Spectrometer (Sheet 4 of 5)

f. Astronaut Logs or Voice Records

1. During experiment operation.

a) GET and description of waste dumps

b) GET of start and end of operation periods and of mode changes

2. GET of SIM door jettison

g. Concurrent Science Data

1. Photographs taken by 3-Inch Mapping Camera and 24-Inch Panoramic Camera concurrent with experiment operation.

2. Postflight scientific results from X-Ray and Gamma-Ray Spectrometers during concurrent operation with Alpha-Particle.

h. Trajectory Data

1. Best estimate of trajectory (BET) during experiment period.

i. Preflight Data

1. See paragraph 4c above.

5. CONSTRAINTS/PROBLEM AREAS

a. After SIM Door Jettison

1. Switch to "OPERATE" mode for thermal control.

2. Prevent sunlight from entering ±45° field-of-view.

b. During Data Collection

1. Prevent sunlight from entering ±45° field-of-view.

Figure 2-8. Alpha-Particle Spectrometer (Sheet 5 of 5)

SDO NO. ______ APOLLO MISSION J-1 DATE: 15 May 1970

DE NO. S-164 SRDS NO. 9 ISSUE: Basic

TITLE: CSM/LM S-BAND TRANSPONDER

1. FUNCTIONAL DESCRIPTION

This experiment utilizes existing S-band transponder equipment installed in the CSM and in the LM. This equipment supports MSFN and DSN ground stations in LM Doppler tracking operations, and thus provides the data needed to satisfy experiment requirements.

2. OBJECTIVE

The science objective is to obtain data to develop an improved lunar mass and gravitational field models by analysis of Doppler tracking data.

3. OPERATING REQUIREMENTS

a. Operating Time

1) CSM and CSM/LM: Record tracking data between LOI and TEI.

2) LM: Record tracking data during lunar descent.

3) LM Ascent Stage: Record tracking data between LM deorbit burn and lunar impact.

4. DATA REQUIREMENTS

a. Experiment Data

1) MSFN and DSM Doppler tracking tapes.

b. Trajectory Data

1) Best estimate of trajectory (BET) during experiment data collection (See 3a).

Figure 2-9. CSM/LM S-Band Transponder

SDO NO. ______ APOLLO MISSION J-1 DATE: 15 May 1970

DE NO. S-165 SRDS NO. 10 ISSUE: Basic

TITLE: MASS SPECTROMETER

1. FUNCTIONAL DESCRIPTION

The Mass Spectrometer Experiment consists essentially of a single unit containing the mass spectrometer and associated electronics, and a 21-foot retractable boom. The unit is installed in the SIM bay of the Service Module. The purpose of the experiment is to obtain data which will be used to determine the composition and distribution of gases in the lunar atmosphere.

2. OBJECTIVE

The science objective of the Mass Spectrometer Experiment is to obtain data on the composition of the lunar ambient atmosphere as an aid in understanding mechanisms of release of gases from the lunar surface, as a tool to locate areas of volcanism, and for determining the distribution of gases in the lunar atmosphere. Gases with masses of 12 - 28 amu and 28 - 66 amu can be detected.

3. OPERATING REQUIREMENTS

a. Power

1. Voltage: 28 Vdc
2. Standby: 5 watts
3. Average: 13 watts
4. Peak: 18 watts

b. Pointing Requirements

1. Real-Time Accuracy: ±10° in pitch and ±15° in yaw with respect to CSM velocity vector. (CSM requirement is -X axis within ±5° of velocity vector).
2. Postflight Reconstruction Accuracy: ±7° in pitch and yaw.

Figure 2-10. Mass Spectrometer (Sheet 1 of 4)

c. <u>Temperature Requirements</u>

1. Operating Range: 0°F to +125°F.

2. Instrument Limits: -58°F to +176°F.

d. <u>Operating Time</u>

1. Lunar Orbit: Data collection for a minimum of 2 complete orbits with an additional 10 complete orbits highly desirable.

2. Transearth Coast: a) Data collection for a minimum of 2 hours.

   b) Data collection for 7 minutes at each step while boom is retracted in 5 equal steps.

e. <u>Weight and Volume</u>

1. Weight: 22 lbs. excluding boom

2. Volume: 880 cu. in.

f. <u>Stowage Location</u>

1. SM: Part of SIM

g. <u>Crew Activities</u>

1. Jettison SIM door

2. Operate experiment controls, including boom deploy/retract/ jettison.

3. Orient CSM.

h. <u>Spacecraft Attitude/Budgets</u>

1. CSM -X axis within ±5 degrees of velocity vector to satisfy 3b above.

4. DATA REQUIREMENTS

a. <u>Experiments Data</u>

1. Ion Counter No. 1 (masses of 12 - 28 amu); 10 bit digital parallel word, 10 S/S.

Figure 2-10. Mass Spectrometer (Sheet 2 of 4)

2. Ion Counter No. 2 (masses of 28 - 66 amu); 10 bit digital parallel word, 10 S/S.

3. Sweep Start Flag; one bit digital parallel event, 10 S/S.

b. Housekeeping Data

1. The 16 measurements are subcommutated at the rate of one measurement/second for a frame time of 16 seconds. The variables measured are:

- o +12 volt monitor
- o +5 volt monitor
- o -12 volt monitor
- o -15 volt monitor
- o emission current monitor
- o filament current monitor
- o instrument current monitor
- o electrical multiplier high voltage (12 - 28 amu)
- o electrical multiplier high voltage (28 - 66 amu)
- o sweep high-voltage monitor
- o temperature no. 1 (electronics)
- o temperature no. 2 (ion source)
- o multiplier flag (event)
- o discriminator flag (event)
- o filament flag (event)
- o market ID (event)

c. Checkout Data

1. Obtained by PI at his facility.

d. Spacecraft Support Data

1. Spacecraft attitude data.

2. Spacecraft ephemeris data.

e. 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.

Figure 2-10. Mass Spectrometer (Sheet 3 of 4)

f. Astronaut Logs and Voice Records

1. Description and GET of changes to experiment control settings.

g. Trajectory Data

1. Best estimate of trajectory (BET) during data collection.

5. CONSTRAINTS/PROBLEM AREAS

1. During Data Collection

a) Activate ion source heaters a min. of 3 hours before data collection.

b) Prohibit waste dumps for a minimum period of 2 hours before to 2 hours after data collection. (5 hours is preferable).

Figure 2-10. Mass Spectrometer (Sheet 4 of 4)

SDO NO. ______ APOLLO MISSION J-1 DATE: 15 May 1970

DE NO. S-177 SRDS NO. 11 ISSUE: Review Draft

TITLE: UV PHOTOGRAPHY - EARTH AND MOON

1. FUNCTIONAL DESCRIPTION

The photographic assembly includes a Hasselblad electric camera with a 105 mm UV transmitting lens, mounting bracket and filter slide, three UV filters centered at 3750 Å, 3250 Å and 2600 Å, a visible range filter (4000-6000 Å), and a special UV transmitting quartz window in the CM.

2. OBJECTIVE

The scientific objective is to obtain 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.

3. OPERATING REQUIREMENTS

a. Operating Time

Sufficient time to obtain 13 sets of four photographic exposures each. Photographs will be obtained from EPO, TLC, lunar orbit, and TEC.

b. Weight and Volume

(1) Weight: 5.8 lbs excluding bracket and filter slide
(2) Envelope Volume: TBD

c. Stowage Location

CM

d. Crew Activities

(1) Unstow and stow camera, bracket, and filter slide
(2) Mount camera/bracket assembly, attach filter slide
(3) Make photographic exposures with different filters

e. Spacecraft Attitude/Body Rates

Photographic subject areas must be visible through the RH CM window.

Figure 2-11. UV Photography - Earth and Moon (Sheet 1 of 2)

4. DATA REQUIREMENTS

a. Experiment Data

Thirteen sets of photographs, each set containing one photograph with each of the four filters.

b. Astronaut Logs and Voice Records

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

c. Trajectory Data

Best Estimate of Trajectory (BET) for the period of each set of photographs.

5. CONSTRAINTS/PROBLEM AREAS

Due to higher than usual UV transmission through the RH CM window, UV radiation hazard is proportionately higher through this window.

Figure 2-11. UV Photography - Earth and Moon (Sheet 2 of 2)

SDO NO. ______ APOLLO MISSION J-1 DATE: 15 May 1970

DE NO. ______ SRDS NO. 12 ISSUE: Review Draft

TITLE: SUBSATELLITE

NOTE

Includes the following experiments:

S-band Transponder (S-164)

Particle Shadows/Boundary Layer (S-173)

Magnetometer (S-174)

Requirements Data TBS.

Figure 2-12. Subsatellite (Sheet 1 of 1)

SDO NO. ______	APOLLO MISSION J-1	DATE: 15 May 1970
DE NO. S-031	SRDS NO. 14	ISSUE: Basic

TITLE: PASSIVE SEISMIC EXPERIMENT (ALSEP)

1. FUNCTIONAL DESCRIPTION

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 sensor assembly consists of a sensor package, thermal shroud, leveling stool, and a 10 foot section of double, flat ribbon cables plus a reel. The experiment electronics package is mounted within the ALSEP central station.

2. OBJECTIVE

The science objective is to detect seismic disturbances resulting from tectonic activity, meteoroid impacts, tidal deformations, and free oscillations of the lunar body.

3. OPERATING REQUIREMENTS

a. Power Requirements

(1) Analog electronics: 1.61 watts
(2) Digital electronics: 1.21 watts
(3) Power converter loss: 1.71 watts
(4) Heater: 2.40 watts
(5) Level system: 3.10 watts
(6) Functional power/heater: 6.70 watts
(7) Functional power/level: 7.20 watts

Figure 2-13A. Apollo Lunar Surface Experiments Package, Passive Seismic (Sheet 1 of 2)

3. OPERATING REQUIREMENTS (Cont'd)

b. Temperature Requirements

Sensor assembly temperature range: 107°F - 143°F ±1%.

c. Operating Time

Data shall be received from the ALSEP central station and from the PSE upon activation on the lunar surface and shall continue for a year.

d. Weight and Volume

(1) Weight: 20.9 lbs. (Sensor; Thermal Shroud; Leveling Stool)
(2) Volume: 1652.5 cu. in. (Shroud, stowed configuration)

e. Stowage Location

Mounted on an ALSEP subpackage which is stowed in the LM Scientific Equipment (SEQ) Bay.

f. Crew Activities

(1) Astronaut releases and removes the PSE from the ALSEP subpackage, carries it and the unit to the emplacement site.
(2) Astronaut then releases the thermal shroud restraint, emplaces and aligns the PSE, deploys the thermal shroud, and levels the PSE.
(3) Astronaut reports sun shadow alignments to MCC-H.

4. DATA REQUIREMENTS

a. Eight Scientific Data Channels

(1) Three long period seismic data channels.
(2) Three long period tidal data channels.
(3) One short period seismic data channel.
(4) One sensor assembly monitoring temperature.

b. 15 separate ground command channels are provided.

c. Data/command channels interface with ALSEP data subsystem.

Figure 2-13A. Apollo Lunar Surface Experiments Package, Passive Seismic (Sheet 2 of 2)

SDO NO. ______ APOLLO MISSION J-1 DATE: 15 May 1970

DE NO. S-033 SRDS NO. 13 ISSUE: Basic

TITLE: ACTIVE SEISMIC EXPERIMENT (ALSEP)

1. FUNCTIONAL DESCRIPTION

Seismic waves will be artifically produced by explosive devices, and detected by geophones. The resulting data will be telemetered to Earth for study and interpretation. By varying the location and magnitude of the explosives with respect to the geophones, penetration of seismic waves to depths of approximately 500 feet can be achieved, and wave velocities through several layers of subsurface materials investigated.

Two seismic energy sources will be employed. A thumper device containing 21 explosive initiators will be fired every 15 feet along a previously emplaced geophone line (310 feet in length) by the astronaut. The astronaut will also emplace a mortar package containing four high explosive grenades. The grenades will be rocket-launched by Earth command near the end of the ALSEP mission (about one year after deployment) 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.

2. OBJECTIVE

The science objective is to generate and monitor artificial seismic waves in the 3 to 250 HZ range so as to enable the determination of the physical properties of the lunar surface and near subsurface materials. The ASE is also used to monitor natural seismic waves in the same frequency range in a manner similar to the PSE.

3. OPERATING REQUIREMENTS

a. Power Requirements

(1) Operational: 8.0 watts
(2) Thermal Control: 1.75 watts (standby)

b. Temperature Requirements

Thermal control of the grenade launch assembly is provided by an internal heater.

Figure 2-13B. Apollo Lunar Surface Experiments Package, Active Seismic (Sheet 1 of 3)

c. Operating Time

Data shall be relayed to the ALSEP central station from the three emplaced cable-connected geophones during thumper activation of the 21 Apollo standard initiators (ASI) by the astronaut , during the grenade firing sequence and during the monitoring of natural seismic waves for the year that the ALSEP is operating.

d. Weight and Volume

(1) Weight: 6.96 lbs (Thumper; Geophones)
14.69 lbs (Mortar Box; Grenade Launch Assembly, including grenades)

(2) Volume: 592.8 cu. in. (Mortar Box)
768.2 cu. in. (Grenade Launch Assembly)

e. Stowage Location

Mounted on an ALSEP subpackage which is stowed in the LM Scientific Equipment (SEQ) Bag.

f. Crew Activities

(1) Astronaut removes thumper-geophone assembly and mortar package from experiment package, assembles thumper, and partially deploys mortar package.

(2) Using UHT tool the astronaut turns the central station ASE safe/enable switch to enable.

(3) Astronaut emplaces geophones at 10, 160, and 310 foot points along Northwest line, deploying geophone and thumper cables enroute.

(4) Astronaut returns along the geophone cables activating the thumper (firing an ASI Charge) approx. every 15 feet. He returns to the central station after the final thumper activation.

(5) He then uses the UHT to turn the central station ASE safe/enable switch to safe.

(6) Astronaut removes safety rods from mortar package, turns on mortar package safe/arm switches, returns to central station, and enables the ASE mortar package grenades which are activated by MSFN about one year later.

4. DATA REQUIREMENTS

a. Three channels of seismic data and thirteen channels of housekeeping data.

b. Twenty bit digital work format and 10,600 bit/sec data rate of ASE provides for transmission of accurately encoded critical real time event data which precludes other ALSEP experiment operation during critical data gathering periods.

Figure 2-13B. Apollo Lunar Surface Experiments Package, Active Seismic (Sheet 2 of 3)

c. Seven commands from MSFN required to arm and fire grenades and to calibrate geophones. Other commands provide for power distribution and ASE mode changes.

5. CONSTRAINTS

During the thumper operation of the ASE, no crew activity is allowed 10 seconds prior to and 20 seconds after each ASI firing.

Figure 2-13B. Apollo Lunar Surface Experiments Package, Active Seismic (Sheet 3 of 3)

SDO NO. ______ APOLLO MISSION J-1 DATE: 15 May 1970

DE NO. S-034 SRDS NO. 15 ISSUE: Basic

TITLE: MAGNETOMETER EXPERIMENT (ALSEP)

1. FUNCTIONAL DESCRIPTION

The ME consists of three magnetic sensors, each mounted in a sensor head and located at the ends of three-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.

2. OBJECTIVE

The science objective is 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 interplanetory magnetic field that diffuses through the moon.

3. OPERATING REQUIREMENTS

a. Power Requirements

(1) Site survey mode: 12.25 watts
(2) Scientific mode: 5.8 watts
10.9 watts (night)
(3) Calibration mode: 12 watts

b. Temperature Requirements

Interior of base package and each sensor head operating range -50°C to +65°C

c. Operating Time

Data shall be received from the ALSEP central station and from the ME upon activation on the lunar surface and shall continue for a year.

d. Weight and Volume

Weight: 19.4 lbs

Volume: 2750 cu. in.

e. Stowage Location

Mounted on an ALSEP subpackage which is stowed in the LM Scientific Equipment (SEQ) Bay.

Figure 2-13C. Apollo Lunar Surface Experiments Package, Magnetometer (Sheet 1 of 2)

f. Crew Activities

(1) Astronaut emplaces the ME 55 feet from the central station in a direction away from the LM. Its interconnecting cable is deployed during the 55-foot traverse.

(2) Upon arrival at the ME site, he unfolds the legs of the ME places the instrument on the lunar surface in an approximate proper East-West alignment. Following this, he unfolds the booms which carry the sensors, and make the final leveling and alignment adjustments.

(3) The astronaut reports the alignment to MCC-H and then returns to the central station.

4. DATA REQUIREMENTS

(1) Eight earth commands

(2) Three analog channels of scientific data from sensor (3) electronics. Each analog sample is converted into a 10-bit digital word.

(3) Eight analog channels of housekeeping data. These samples are likewise converted into 10-bit digital words which are subsequently truncated to seven bits.

Figure 2-13C. Apollo Lunar Surface Experiments Package, Magnetometer (Sheet 2 of 2)

SDO NO. ______ APOLLO MISSION J-1 DATE: 15 May 1970

DE NO. S-037 SRDS NO. 16 ISSUE: Basic

TITLE: HEAT FLOW EXPERIMENT (ALSEP)

1. FUNCTIONAL DESCRIPTION

The experiment electronics unit is deployed for the purpose of recording cable-relayed signals from two sensor probes implanted in the lunar surface in three-meter deep boreholes. These holes are drilled by the astronaut with the Apollo Lunar Surface Drill (ALSD). Each probe has eight gradient sensors surrounded by heater coils, four ring sensors and four thermocouples located in the cable of the probe.

The normal gradient mode is used to monitor the heat flow in and out of the lunar surface crust. Thermal conductivity of the lunar material is measured with the principal of creating a known quantity of heat at a known location by exciting one of the eight probe heaters, and measuring the resultant probe temperature change for a period of time.

2. OBJECTIVE

The science objective is to determine the net outward flux of heat from the moon's interior which will provide additional information on:

- A comparison of the radioactive content of the moon's interior and the earth's mantle.
- A thermal history of the moon.
- A temperature versus depth profile.
- The value of thermal parameters in the first three meters of the moon's crust.

3. OPERATING REQUIREMENTS

a. Power Requirements

(1) Mode 1: 6.0 watts (day) 9.5 watts (night)
(2) Mode 2: 11.0 watts (day or night)
(3) Mode 3: 9.0 watts (day only)

Figure 2-13D. Apollo Lunar Surface Experiments Package, Heat Flow (Sheet 1 of 3)

3. OPERATING REQUIREMENTS (Cont'd)

b. Temperature Requirements

HFE electronics operating range: 10°C to 60°C

c. Operating Time

Data shall be received from the ALSEP central station and from the HFE upon receipt of Earth commands.

d. Weight and Volume

Weight: 3.5 lbs. (Probes, packaged for flight)
6.2 lbs. (Electronics unit)

Volume: 406.1 cu. in. (Probes, packaged for flight)
936 cu. in. (Electronics unit)

e. Stowage Location

Mounted on an ALSEP subpackage which is stowed in the LM Scientific Equipment (SEQ) Bay.

f. Crew Activities

(1) The HFE assembly is carried with the aid of the UHT from subpackage No. 1 to about 30 feet south of the central station. The astronaut then retrieves the ALSD from subpackage No. 2 and returns to the HFE assembly and then an additional 16 feet to the site for the No. 1 probe emplacement.
(2) The probe hole is drilled with the ALSD and cased.
(3) Returning to the HFE assembly, he detaches the probe and separates it into its two halves. The half probe box with probe emplacement tool is then carried to the cased probe hole with the electronics cable being deployed enroute. The HFE probe is then inserted into the cased hole.
(4) The astronaut then proceeds to the second probe emplacement site with the ALSD and probe emplacement tool. A second hole is then drilled and cased. He then returns to the HFE assembly, picks up the second probe box half, returns to the drilling site, and emplaces the probe as before.
(5) He then returns to and aligns the electronics package in a manner that satisfies the thermal (Sunshield) requirements.

Figure 2-13D. Apollo Lunar Surface Experiments Package, Heat Flow (Sheet 2 of 3)

4. DATA REQUIREMENTS

a. Ten earth commands
b. Four timing and control signals from ALSEP data subsystem
c. Seven analog houskeeping data channels
d. Scientific data temperature measurements appear in the first 16 frames of each 90 frame ALSEP telemetry cycle, measurements vary according to HFE operational mode in use.

Figure 2-13D. Apollo Lunar Surface Experiments Package, Heat Flow (Sheet 3 of 3)

SDO NO. ______ APOLLO MISSION J-1 DATE: 15 May 1970

DE NO. M-515 SRDS NO. 17 ISSUE: Basic

TITLE: LUNAR DUST DETECTOR EXPERIMENT (ALSEP)

1. FUNCTIONAL DESCRIPTION

The dust detector has two components; a sensor package, and a printed circuit board. The sensor package is mounted on the subpackage No. 1 sunshield. The sensor has three photocells oriented on three sides to face the ecliptic path of the sun. Dust accumulation on the surfaces of the three solar cells will reduce the solar illumination detected by the cells which will be reflected accordingly in the cell readouts.

2. OBJECTIVE

The scientific objective is to acquire data on the effects of dust accumulation on the surface of the ALSEP central station as a result of either material deposition or from the effects of LM ascent.

3. OPERATING REQUIREMENTS

a. Power Requirements

(1) On mode: 540 milliwatts (MAX)
(2) Off mode: 70 milliwatts (MIN)

b. Temperature Requirements

Dust detector electronics thermally protected within central station.

c. Operating Time

Dust detector operation is controlled by on and off commands from the Earth.

d. Weight and Volume

(1) Weight: 0.35 lb (Sensor package)
0.26 lb (Circuit board)

(2) Volume: 5.4 cu. in. (Sensor package)

e. Stowage Location

Mounted on an ALSEP subpackage which is stowed in the LM Scientific Equipment (SEQ) Bay.

Figure 2-13E. Apollo Lunar Surface Experiments Package, Lunar Dust Detector (Sheet 1 of 2)

f. Crew Activities

Astronaut mounts dust detector to top of ALSEP central station.

4. DATA REQUIREMENTS

(1) Six sub-commutated analog channels carry outputs of three illumination detectors and three thermistor temperature measurements.

(2) Two earth commands.

Figure 2-13E. Apollo Lunar Surface Experiments Package, Lunar Dust Detector (Sheet 2 of 2)

SDO NO. ______ APOLLO MISSION J-1 DATE: 15 May 1970

DE NO. S-059 SRDS NO. 18 ISSUE: Basic

TITLE: LUNAR FIELD GEOLOGY EXPERIMENT

The exact objectives, test conditions, etc. of the Lunar Field Geology Experiment are TBD for Apollo 16.

Based on an Apollo 16 landing at Copernicus, the probable science operations to be performed will be as follows:

1. To determine the age, origin, and evolution of the crater Copernicus.
2. To determine the origin, age, and structure of the central peak material
3. To determine the origin, age, and structure of the crater floor filling materials (smooth floor material, textured floor material, hills and hummocks).
4. To investigate the character of superposed craters.

Figure 2-14. Lunar Field Geology (Sheet 1 of 1)

SDO NO. ______ APOLLO MISSION J-1 DATE: 15 May 1970

DE NO. S-078 SRDS NO. 19 ISSUE: Basic

TITLE: LASER RANGING RETRO-REFLECTOR

1. FUNCTIONAL DESCRIPTION

The LRR is a passive device requiring no electrical power or telemetry support. The LRRR reflects laser radiation beamed from one or more Earth-based stations. Maximum return radiation will be reflected when the retro-reflector array is oriented as nearly normal to the incident radiation as possible. The retro-reflector array consists of a panel structure incorporating 100 retro-reflectors and an aim-angle handle. The retro reflectors are fused silica optical corners. One hundred retro-reflectors are mounted in individual cavities in the panel structure. Each retro-reflector is aligned in its cavity to within $\pm$ 2° of the average alignment for all retro-reflectors.

2. OBJECTIVE

The scientific objective is to obrain laser ranging data at earth by use of the passive corner reflective system of the LRRR on the moon. The moon's size and orbit can be accurately determined by making a comparison of measured range data over long time periods of up to 10 years.

3. OPERATING REQUIREMENTS

a. Power Requirements

Passive experiment - no power required

b. Temperature Requirements

(1) Thermal protection provided by design of individual retro-reflector cavaties and components.

(2) Operating range: 40°K to 400°K

c. Operating Time

Reflected radiation shall be received from the LRRR when laser radiation is beamed from one or more Earth-based stations.

Figure 2-15. Laser Ranging Retro-Reflector (Sheet 1 of 2)

d. Weight and Volume

(1) Weight: 32.83 lbs (retro-reflector array)
19.53 lbs (structural/alignment assembly)
14.56 lbs (pallet assembly)

(2) Volume: 3056.6 cu. in. (retro-reflector array)
2302.6 cu. in. (pallet assembly)

e. Storage Location

Stowed in the LM Scientific Equipment (SEQ) Bay.

f. Crew Activities

(1) LRRR is deployed by astronaut on a level, firm site at least 500 feet from LM to prevent radioactive heat transfer and blast effects from firing of LM ascent engine and is emplaced generally due South of LM to maximize visibility by crew.

(2) Astronaut levels LRRR with bubble level to within $\pm$ 5° of indicator as well as setting tilt plate to one of the four pre-chosen index marks on prelaunch installed tilt plate.

(3) Final chore involves aligning LRRR using the partial sun compass plate and setting the gnomon shadow mark within $\pm$ 5° max. of the indicator line for the landing site chosen.

4. DATA REQUIREMENTS

Passive experiment - no telemetry data or commands required.

Figure 2-15. Laser Ranging Retro-Reflector (Sheet 2 of 2)

SDO NO. ______ APOLLO MISSION J-1 DATE: 15 May 1970

DE NO. S-152 SRDS NO. 20 ISSUE: Basic

TITLE: COSMIC RAY DETECTOR (SHEETS)

1. FUNCTIONAL DESCRIPTION

High resolution, thin plastic detectors will be exposed to cosmic rays during the trip to the moon, deployed on the surface of the moon during the lunar staytime for further cosmic ray exposure, and then stowed in the CM for the return trip to the earth. The lengths of the resulting cinical tracks along cosmic ray trajectories, as revealed by etching processes, will be measured with an optical microscope.

2. OBJECTIVE

The scientific objective is to measure the charge, mass and energy spectrum of cosmic rays with atomic number greater than 8 at energies between 10 and 200 Mev/nucleon.

3. OPERATING REQUIREMENTS

a. Power Requirements

Passive experiment - no power requirements.

b. Temperature Requirements

(1) Shield the detector stacks from the sun and from RCS thruster plumes so as to keep their temperature below 120°F.

(2) Protect detector stacks from UV radiation by the use of a thin opaque layer.

c. Weight and Volume

(1) Weight: 20 lbs (Launch)
8 lbs (Return)

(2) Volume: 180 cu. in.

d. Stowage Location

(1) Attached to LM exterior during trip to the moon.

(2) Compartment A-8 on aft bulkhead of CM on return trip.

Figure 2-16. Cosmic Ray Detector (Sheets) (Sheet 1 of 2)

e. Crew Activities

(1) Remove detector stacks from the LM.
(2) Deploy detector stacks on surface of the moon during the first EVA.
(3) Retrieve and stow the stacks in the LM during the last EVA.
(4) Transfer the stacks to the CM.
(5) Astronaut may be required to activate a simple device to translate half of the detector stacks with respect to the other half to differentiate particle exposure incurred on trip to moon.

4. DATA REQUIREMENTS

Passive experiment - no telemetry or command requirements. "Data" consist of pre-etched and scanned plastic sheets that have been exposed to cosmic rays and particles for earth return.

Figure 2-16. Cosmic Ray Detector (Sheets) (Sheet 2 of 2)

SDO NO. ______ APOLLO MISSION J-1 DATE: 15 May 1970

DE NO. S-198 SRDS NO. 21 ISSUE: Basic

TITLE: PORTABLE MAGNETOMETER

1. FUNCTIONAL DESCRIPTION

A portable flux gate magnetometer is used to measure the magnetic field on the lunar surface. A series of site point measurements will be taken at a location at least 250 feet from the LM and following these measurements, readings will be made at six different locations along the geological traverse. Due to the magnetic properties of the PLSS being used, the magnetic sensors and readout meters must be separated by a 50 foot cable. The astronaut aligns the sensors and walks back to the end of the cable and reads out the measurements over the voice link to the MCC.

2. OBJECTIVE

The science objectives are to obtain data on the local magnetic field and obtain data on the magnetic field over a large area by use of a portable magnetometer.

3. OPERATING REQUIREMENTS

a. Power Requirements

The instrument is battery powered and has a minimum lifetime of four hours at the one watt operating level.

b. Temperature Requirements

(1) Operating temperature: -30°C to 50°C
(2) Thermal control maintains instrument at 30°C ± 10°C

c. Operating Time

(1) Site measurements: 10 minutes
(2) Traverse Measurements: 3 minutes per measurement

Figure 2-17. Portable Magnetometer (Sheet 1 of 2)

d. Weight and Volume

(1) Weight: 5 lbs (Instrument)
2 lbs (Tripod)

(2) Volume: 500 cu. in. (Instrument and Tripod)

e. Stowage Location

The experiment is to be stowed on a pallet and mounted on the exterior of the LM Descent Stage.

f. Crew Activities

(1) The astronaut removes the magnetometer components from the LM Descent Stage and prepares for site point measurements to be taken at least 250 feet from the LM.

(2) The astronaut levels and aligns the sensor assembly on a tripod using a bubble level and shadowgraph. He then walks back 50 feet to the cable-connected electronics box to read the field measurement components on three dials. A total of three measurements will be taken with the sensor head oriented in the prescribed manner for each measurement.

(3) The astronaut will then take traverse measurements at six different points along the geological traverse with the final measurement to be made at the same location as the initial site measurement. Sensor assembly will have to be redeployed, leveled and aligned for each traverse measurement.

(4) The readings obtained during the site point and traverse measurements will be readout over the voice link to the MCC.

(5) It is intended to utilize the Lunar Roving Vehicle (LRV) in the deployment of the portable magnetometer along the traverse. LRV requirements and constraints for the Portable Magnetometer Experiment are to be defined.

4. DATA REQUIREMENTS

(1) There are no telemetry data or command requirements

(2) Magnetic field readings read by the astronaut from three dials on the portable console are voice down-linked to MCC.

(3) Photographs of the sensor deployment at each measurement are to be taken.

5. CONSTRAINTS

The portable magnetometer will be used at least 250 feet from the LM and at least 50 feet from any other equipment or material the crew has deployed including the PLSS.

Figure 2-17. Portable Magnetometer (Sheet 2 of 2)

SDO NO. ______ APOLLO MISSION J-1 DATE: 15 May 1970

DE NO. S-200 SRDS NO. 22 ISSUE: Basic

TITLE: SOIL MECHANICS EXPERIMENT

The exact objectives, test conditions, etc. of the Soil Mechanics Experiment are TBD for Apollo 16.

Photographic data, crew observations, returned samples, and core tubes will be obtained during the Lunar Field Geology Experiment and Selected Sample Collection and utilized for scientific analysis of the lunar soil. The Soil Mechanics Experiment may include a trenching operation and the use of a recording penetrometer.

Figure 2-18. Soil Mechanics (Sheet 1 of 1)

SECTION III

SCIENCE OPERATIONAL DATA

NOTE

The contents proposed for this section are described under tentative main paragraph headings listed below.

3.1 GENERAL

(This paragraph will summarize the purpose and contents of the section.)

3.2 EQUIPMENT REQUIREMENTS

(This paragraph will describe the equipment needed to support the requirements of the SDO's and DE's assigned to the mission. Tables, figures, and matrices would be used to the maximum possible extent to correlate required equipment to the appropriate SDO's and DE's. Equipment would include: LRV; Lunar Field Geology equipment such as SRC's, containers, cameras; special tools; etc.)

3.3 CREW ACTIVITIES

(This paragraph will describe crew activities required by each SDO and DE. These activities will be detailed only to the extent necessary for identification of crew training requirements and procedures for planning and implementation purposes by appropriate organizations. Examples of crew activities are as follows: photographic tasks; unloading of science equipment from the LM MESA, loading on LRV, and deployment on the lunar surface; collection of contingency soil sample; etc.).

3.4 GROUND SUPPORT ACTIVITIES

(This paragraph will include ground activities required to support SDO and DE requirements. Examples of such activities would include the following: voice data to elicit necessary comments from the crew, ground commands, etc.).

3.5 OPERATIONAL CONSTRAINTS

(This paragraph will include any time critical sequences and any conditions or circumstances which may be hazardous to the crew.)

SECTION IV

SCIENCE DETAILED OBJECTIVES

4.1 GENERAL

This section contains lunar surface and lunar orbital science detailed objectives scheduled to be accomplished during the mission. These science detailed objectives were developed from the primary objectives assigned to this mission by the office of Manned Space Flight in the Apollo Flight Mission Assignments Directive (Reference 1). Each detailed objective presents the information necessary to support mission planning, integration, and implementation.

4.2 IMPLEMENTATION

The flight plan timeline schedules the sequential accomplishment of all science detailed objectives and the functional test objectives (FTO's) associated with each. Detailed procedures for the implementation of these objectives and FTO's are located in the MSC-controlled documents listed in the Introduction. Any questions concerning the data contained in this section should be directed to the appropriate S&AD Point-of-Contact listed in the tables in Section I. Any issues which need further resolution should be referred to the Science Mission Manager assigned to the mission.

4.3 CONTENTS

The lunar orbital and lunar surface science detailed objectives contained in this section are listed below in the order of appearance.

a) Photographs of Candidate Exploration Sites

b) SM Orbital Science Photography

c) CM Orbital Science Photography, which includes:

   (1) 24-Inch Panoramic Camera
   (2) 3-Inch Mapping Camera
   (3) Laser Altimeter

d) Contingency Sample Collection

e) Selected Sample Collection

4.3.1 PHOTOGRAPHS OF CANDIDATE EXPLORATION SITES

Obtain photographs of a candidate lunar exploration site.

Purpose

The purpose is to obtain photographs of a candidate exploration site for a future Apollo mission.

The functional test objectives are as follows:

FTO 1) Obtain stereoscopic and sequence photographs of a selected lunar site.

FTO 2) Obtain high resolution photographs of a selected lunar site.

Test Conditions

FTO 1)
FTO 2) After the LM is jettisoned, the CSM will execute an orbital plane change to provide a ground track over the candidate lunar exploration site shown in Table 1.

FTO 1) Photographs of a candidate lunar site as identified in Table 1 will be obtained using a Hasselblad electric data camera with an 80 mm lens. Photographs of the ground track will be obtained from terminator to terminator for one pass over the site. Photographs will be taken every 20 seconds or less in order to achieve a 60 percent forward overlap thereby providing stereoscopic data. In order to reduce picture distortion, the spacecraft +X axis will be aligned with the local vertical downward. An attitude maneuver rate (orbital pitch rate) will be established to maintain this relative orientation throughout the pass over the site. The -Z axis will be pointed in the downrange direction.

The field of view of the above pass will include at least eight landmarks spaced to bracket the candidate exploration site and to control each end of the strip photographs. During the above pass, photographs will be obtained at one frame per second through the sextant with the 16 mm data acquisition camera operating from terminator to terminator.

After taking the above photographs, landmark tracking of the above landmarks will be accomplished during two successive orbits to provide at least eight sets of tracking data (i.e., using four landmarks on one orbit and the other four landmarks

Test Conditions (Cont'd)

FTO 1) (Continued)

on the second orbit) in accordance with CSM Apollo Operations Handbook, SM2A-03-Block II (2), Volume 2, procedure "Orbital Navigation (P22)". During both orbits of landmark tracking, photographs will be obtained at one frame per second through the sextant with the 16 mm data acquisition camera. For each landmark, the camera will be turned ON just prior to the first mark and will be turned OFF just after the last mark of the set of sightings.

FTO 2) High resolution photographs will be taken of the site shown in Table 1 with the Lunar Topographic Camera. One pass, with the camera axis vertical, will be taken on the revolution passing most nearly over the site. The camera cycle rate will be set to provide 60 percent forward overlap. On either the preceding or succeeding revolution, a second strip of high resolution photographs will be taken with the camera optical axis aligned approximately 30 degrees aft of the local vertical. The spacecraft will utilize the orbital pitch rate during both of the above passes. The same camera frame cycle rate will be used during the second pass. Updated camera pointing angles will be provided by MCC to the crew, if required, prior to the use of the Lunar Topographic Camera. The pointing angles will be based on MSFN tracking data. The high resolution photographic sequences will extend from at least 120 NM uprange to 30 NM downrange from the site.

Success Criteria

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

Evaluation

FTO 1) A terrain profile for the ground track leading to the photographed candidate exploration site will be constructed (Astronaut records, low altitude photographs, stereoscopic photographs, BET and CK 1044 X).

FTO 1)
FTO 2) The location of the photographed candidate exploration site will be updated. The requirements, if any, for changes in hardware, software or operational procedures for any particular type of photographed candidate exploration site will be determined. (Astronaut records, stereoscopic and high resolution photographs, 16 mm sequence photographs, BET, CG 0001 V, CK 1043 X and CK 1044 X).

Evaluation (Cont'd)

FTO 2) The feasibility of exploring the photographed candidate exploration site will be determined. (Astronaut records, high resolution photographs, and BET).

Data Requirements

1) Telemetry Measurements:

Measurement Number	Description	TM	Mode	Priority
CG 0001 V	Computer Digital Data 40 Bits	PCMD+	2	M*
CK 1043 X	70 mm Camera Shutter Open	PCM	1	M**
CK 1044 X	Lunar Topographic Camera Shutter Open	PCM	1	M***

*Required only during the landmark tracking as specified by FTO 1).
**Required only in support of the Test Conditions for FTO 1).
***Required only in support of the Test Conditions for FTO 2).

2) Astronaut Logs or Voice Records: (M)

Record of magazine number and any pertinent visual observations for each photographic sequence.

3) Photographs: (M)

a) 70 mm Hasselblad stereoscopic photographs (with 60 percent forward overlap) covering the ground track from terminator to terminator for the site.

b) Two strips of high resolution photographs of the site (one strip with camera axis vertical and one strip with camera axis 30 degrees aft of local vertical).

c) 16 mm sextant sequence photographs from terminator to terminator for the pass that 70 mm Hasselblad stereoscopic photographs are also obtained.

d) 16 mm sextant sequence photographs for each of the landmarks tracked during successive orbits.

4) Trajectory Data: (M)

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

PHOTOGRAPHS OF CANDIDATE EXPLORATION SITES

Background and Justification

Future Apollo missions have as their prime objective the scientific exploration of lunar sites outside the original Apollo zone. In order to accomplish this, sufficient photographic data of the candidate sites must be obtained. Additional photographic data of candidate sites within the original Apollo zone are also desired. These data will supplement the data obtained during unmanned missions and during Apollo missions 8, 10, 11, 12, H-3, and H-4.

The photographic requirements for site evaluation, mission planning, operational procedures determination and crew training are rather extensive. In order to satisfy the many different categories of photographic requirements and allow adequate lead time for data preparation, a bootstrap method of site photography has been adopted. That is, the site chosen for photography on the Apollo J-1 mission is a site that is considered a prime site for a subsequent mission.

The high resolution photographs are required for touchdown hazard evaluation and redesignation ΔV budget definition. In addition, they will provide data for crew training and onboard data.

Tracking of the eight landmarks on subsequent orbits (i.e., four landmarks per orbit) will provide spacecraft state vector data via telemetry which will allow an additional correlation of the 70 mm strip photographs with the spacecraft ephemeris. Correlation of the stereo photographs with the spacecraft ephemeris will improve the accuracy of the landing site coordinates with respect to known landmarks.

The 16 mm sextant photographs will provide additional horizontal control data for the 70 mm strip photographs and will supplement the 70 mm photographs for crew training.

Table 1 presents the photographic requirements in order of priority for the candidate exploration sites.

Previous Flight Objectives

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

TABLE 1. Candidate Exploration Sites For Stereoscopic And High Resolution (HR) Photographs

<u>TBD</u>

(Candidate exploration sites will depend on the lunar groundtrack for the J-1 mission, ΔV available for a CSM plane change following LM jettison, available camera equipment, and film budget.)

4.3.2 SM ORBITAL SCIENCE PHOTOGRAPHY

Obtain lunar surface photographs and altitude data from lunar orbit.

<u>Purpose</u>

The purpose is to obtain lunar surface photographic and topographic data from the SM 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 using the 3-Inch Mapping Camera.

FTO 2) Obtain high-resolution photographs of potential landing sites and exploration areas on the lunar surface using the 24-Inch Panoramic Camera.

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

<u>Test Conditions</u>

FTO 1) During periods of operation of the 3-Inch Mapping
FTO 2) Camera, 24-Inch Panoramic Camera, and Laser
FTO 3) Altimeter, the CSM attitude will be controlled to prevent direct sunlight from impinging on the

camera lenses or the altimeter photocell. To avoid contamination, liquid dumps (urine, waste water, etc.) will be prohibited and the RCS quad adjacent to the SIM bay will not be fired during equipment operation. The equipment is not in operation, lenses and photocell will be protected by (TBD).

FTO 1)
FTO 2) To prevent film set in the film casettes 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 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.

The +X axis of the CSM will be oriented in the direction of the velocity vector during camera operation. The attitude of the CSM will be controlled so that the optical axes of the cameras and the Laser Altimeter are aligned within ± 2 degrees of the lunar local vertical. 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 approximately 3 hours prior to operation. Following completion of all photography, the crew will EVA and retrieve film casettes 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. The 3-Inch Mapping Camera will be operated in support of other experiments and objectives (as indicated in Table 2) on a non-interference basis with the SM Orbital Science Photography Objective.

FTO 2) The 24-Inch Panoramic Camera will be operated on lunar orbit light side passes (terminator to terminator) in accordance with the schedule in Table 3. This schedule may be altered by instructions provided by MCC to the crew to obtain possible transient events and/or higher priority targets of opportunity photography.

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 a minimum of 4 complete lunar orbits. 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 and altitude support data defined under the Test Conditions for FTO 1) and FTO 2) shall be acquired and returned to earth for processing.

FTO 3) The altitude data and photographic data defined under Test Conditions for FTO 3) shall be acquired and returned to earth for processing.

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 1030 V, SL 1038 V, and TBD.)

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, SL 1122 K, CG 0001, and TBD.)

Data Requirements

1) Telemetry Measurements:

Measurement Number	Description	TM	Mode	Priority
CG 0001 V	Computer Digital Data - 40 Bits	PCMD+	2	M
CT 0145 F	CTE Time from Launch - 32 Bits	PCMD	2	TBD
SL 1030 V	Pan Camera V/H Command Voltage	PCM	2	M
SL 1031 X	Pan Camera Air Solenoid	PCME	2	TBD
SL 1032 T	Pan Camera Film Mag Temp	PCM	2	TBD
SL 1033 H	Pan Camera Framing Roll Position	PCM	2	TBD
SL 1034 H	Pan Camera Shuttle Position	PCM	2	TBD
SL 1035 C	Pan Camera Lens Torque Current	PCM	2	TBD
SL 1036 X	Pan Camera Capping Shutter Pos	PCMG	2	TBD
SL 1037 V	Pan Camera FMC Tach Voltage	PCM	2	TBD
SL 1038 H	Pan Camera Exposure Command	PCM	2	M
SL 1039 T	Pan Camera Lens Barrel Temp	PCM	2	HD
SL 1040 T	Pan Camera Fwd Lens Temp	PCM	2	HD
SL 1041 T	Pan Camera Aft Lens Temp	PCM	2	HD
SL 1042 T	Pan Camera Mech Temp	PCM	2	TBD
SL 1043 P	Pan Camera N_2 Tank Press	PCM	1	TBD
SL 1091 V	Laser Altimeter Reg - -5.0 Volt	PCM	2	TBD
SL 1092 V	Laser Altimeter Photomult Volt	PCM	2	TBD
SL 1093 V	Laser Altimeter PFN Volt	PCM	2	TBD
SL 1094 T	Laser Altimeter Cavity Temp	PCM	2	TBD
SL 1122 K	Laser Altimeter Output 24 Bit Ser	PCMD	2	M
SL 1210 T	Temp Thrm Envir - Pan Camera Shell	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
SL 1216 T	Temp Thrm Envir - Map Camera Body	PCM	1	TBD

2) Astronaut Logs or Voice Records: (M)

a) Record of pertinent visual observations during all photographic sequences

b) GET of instrument control functions (3-Inch Mapping Camera, 24-Inch Panoramic Camera, and Laser Altimeter)

c) GET of water and urine dumps, and SPS and/or RCS burns for TEI and midcourse corrections during TLC while equipment is in operation.

3) Photographs: (M)

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

4) 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.

5) 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

Orbit Inclination		Photo Passes
5°	Rev 1	35° cross track 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%)
20°	Rev 1	same as 5° inclination
	Rev 2	same as 5° inclination
	Rev 9	Vertical (sidelap with Rev 2-57%)
8 Photo Revs	Rev 16	Vertical (sidelap with Rev 9-57%)
	Rev 23	Vertical (sidelap with Rev 16-57%)
	Rev 30	Vertical (sidelap with Rev 23-57%)
	Rev 35	Vertical (sidelap with Rev 30-75%)
	Rev 36	same as 5° inclination
25°	Rev 1	same as 5° inclination
	Rev 2	same as 5° inclination
	Rev 8	Vertical (sidelap with Rev 2-54%)
	Rev 14	Vertical (sidelap with Rev 8-54%)
9 Photo Revs	Rev 20	Vertical (sidelap with Rev 14-54%)
	Rev 26	Vertical (sidelap with Rev 20-54%)
	Rev 32	Vertical (sidelap with Rev 26-54%)
	Rev 35	Vertical (sidelap with Rev 32-77%)
	Rev 36	same as 5° inclination

Table 1. Photographic Requirements for 3-Inch Mapping Camera (Continued)

Orbit Inclination	Photo Passes
30°	Rev 1 same as 5° inclination
	Rev 2 same as 5° inclination
	Rev 7 Vertical (sidelap with Rev 2-55%)
	Rev 12 Vertical (sidelap with Rev 7-55%)
	Rev 17 Vertical (sidelap with Rev 12-55%)
10 Photo Revs	Rev 22 Vertical (sidelap with Rev 17-55%)
	Rev 27 Vertical (sidelap with Rev 22-55%)
	Rev 32 Vertical (sidelap with Rev 27-55%)
	Rev 35 Vertical (sidelap with Rev 32-64%)
	Rev 36 same as 5° inclination
35°	Rev 1 same as 5° inclination
	Rev 2 same as 5° inclination
	Rev 6 Vertical (sidelap with Rev 2-59%)
	Rev 10 Vertical (sidelap with Rev 6-59%)
	Rev 14 Vertical (sidelap with Rev 10-59%)
10 Photo Revs	Rev 18 Vertical (sidelap with Rev 14-59%)
	Rev 22 Vertical (sidelap with Rev 18-59%)
	Rev 26 Vertical (sidelap with Rev 22-59%)
	Rev 30 Vertical (sidelap with Rev 26-59%)
	Rev 34 Vertical (sidelap with Rev 30-59%)
	Rev 36 same as 5° inclination (sidelap with Rev 34-50%)
40°	Rev 1 same as 5° inclination
	Rev 2 same as 5° inclination
10 Photo Revs	Rev 6 Vertical (sidelap with Rev 2-53%)
	Revs 10, 14, 18, 22, 26, 30, 34, same as Rev 6
	Rev 36 same as 5° inclination (sidelap with Rev 34-50%)
45°	Rev 1 same as 5° inclination
	Rev 2 same as 5° inclination
10 Photo Revs	Rev 6 Vertical (sidelap with Rev 2-49%)
	Revs 10, 14, 18, 22, 26, 30, 34, same as Rev 6
	Rev 36 same as 5° inclination (sidelap with Rev 34-50%)

Table 2. Photographic Targets of Scientific Interest for the 3-Inch Mapping Camera

(Data TBD)

Table 3. Photographic Targets for the 24-Inch Panoramic Camera

(Data TBD)

4.3.3 CM ORBITAL SCIENCE PHOTOGRAPHY

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

Purpose

The purpose is to obtain photographs from the CM 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 from the CM using the Lunar Topographic Camera of lunar surface areas of prime scientific interest.

FTO 2) Obtain photographs from the CM using the Hasselblad electric data camera with the 80 mm lens from terminator to terminator and of lunar surface areas of prime scientific interest.

FTO 3) Obtain photographs from the CM using the Hasselblad electric camera with the 250 mm lens of lunar surface areas of prime scientific interest.

FTO 4) Obtain photographs from the CM using the 16 mm data acquisition camera with the 18 mm lens and the Hasselblad electric data camera with the 80 mm lens of specific segments of the lunar surface in earthshine and in dim light near the terminator.

Test Conditions

FTO 1) High resolution black and white photographs of areas of prime scientific interest will be obtained from the CM using the Lunar Topographic Camera with image motion compensation (IMC) and 18 inch lens. This camera will be used both before rendezvous and after LM jettison to obtain photographs of scientific areas. The camera frame cycle rate will be set to provide 60 percent forward overlap. Updated camera pointing angles will be provided by MCC to the crew, if required, prior to the use of the Lunar Topographic Camera. The pointing angles will be based on MSFN tracking data. The photographic sequences will begin as indicated in Table 1. The number of frames per sequence will be as defined in the Photographic and Television Operations Plan.

FTO 1)
FTO 2)
FTO 3) Telemetry data are highly desirable relative to time of opening the shutter of the Hasselblad electric data camera and the Lunar Topographic Camera. Since shutter telemetry data can be obtained from only one of the two cameras at any specific time, first priority will be given to the use of the Hasselblad electric

Test Conditions (Cont'd)

data camera while taking terminator-to-terminator strips as defined in FTO 2). Second priority for shutter telemetry data will be given to the use of Lunar Topographic Camera. Third priority will be given to the use of the Hasselblad electric data camera as defined by FTO 4). Shutter telemetry data are not required whenever the Hasselblad electric camera is used in support of FTO 3).

FTO 2) 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. The camera frame cycle rate will be set to provide 60 percent forward overlap. This mode will also be utilized in obtaining terminator-to-terminator stereo strips at both low and high inclinations with respect to the lunar equatorial plane. The requirement for one of these terminator-to-terminator strips may be satisfied by the same strip obtained in support of FTO 1) of the objective on Candidate Exploration Sites Photography.

FTO 3) 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. The medium resolution photographs will be taken of areas listed in Table 1.

FTO 4) Black and white photographs of particular areas in earthshine and in dim light near the terminator will be obtained using the 16 mm data acquisition camera with a 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)
FTO 3)
FTO 4)

The photographic data defined under the Test Conditions for FTO 1), FTO 2), FTO 3) and FTO 4) shall be acquired and returned to earth for processing.

Evaluation

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

The photographic data will be evaluated by the Apollo Orbital Science Photographic Team for general and specific scientific interest. (Astronaut records, photographs, BET, CK 1043 X and CK 1044 X)

Data Requirements

1) Telemetry Measurements:

Measurement Number	Description	TM	Mode	Priority
CK 1043 X	70 mm Camera Shutter Open	PCM	1	HD
CK 1044 X	Lunar Topographic Camera Shutter Open	PCM	1	HD

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.

CM ORBITAL SCIENCE PHOTOGRAPHY

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 CSM	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 become available)

4.3.4 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 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) A crewman will scoop up a loose sample of lunar material during the early part of the first EVA period. Photographs will be made showing the sample while it is on the lunar surface and showing the lunar surface after the sample is collected. The sample container will be sealed and stowed in the LM ascent stage at the termination of 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

4.3.5 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 1)
FTO 2) It is highly desirable that photographs of the samples and the immediate sample gathering area be obtained. There is no specific requirement for the sample collection area to be at a certain location with respect to LM.

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

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 soil.

   b) One large rock.

SECTION V

SCIENCE DETAILED EXPERIMENTS

5.1 GENERAL

This section contains the lunar surface and lunar orbital experiments assigned to the mission by the Office of Manned Space Flight in the Apollo Flight Mission Assignments Directive (Reference 1). Each detailed experiment presents the information necessary to support mission planning, integration, and implementation.

5.2 IMPLEMENTATION

The Flight Plan Timeline schedules the sequential accomplishment of all detailed experiments and the functional test objectives (FTO's) associated with each. Detailed procedures for the implementation of these experiments are located in the MSC-controlled documents located in the Introduction. Any questions concerning experiment data contained in this section should be directed to the appropriate S&AD Point-of-Contact listed in the tables in Section I. Any issues which need further resolution should be referred to the Science Mission Manager assigned to the mission.

5.3 PASSIVE EXPERIMENTS

Some experiments assigned by the OMSF are passive in nature, i.e., no specific crew tasks are required to support the experiment. These experiments, not included as a detailed experiment, are described in the following paragraphs.

5.3.1 Pilot Describing Function Experiment (T-029)

This experiment will be accomplished during the mission to obtain data for use in evaluating a pilot describing function related to the manual control of a large flexible booster. The requirements consist of providing certain portions of voice and telemetry data recordings to the Principal Investigator, Ames Research Center. The data of interest will be selected from existing flight data by the Principal Investigator after the mission is completed.

5.4 CONTENTS

The lunar orbital and lunar surface detailed experiments contained in this section are listed below in the order of appearance:

a) Gamma-Ray Spectrometer (S-160)

b) X-Ray Fluorescence (S-161)

c) Alpha-Particle Spectrometer (S-162)

d) CSM/LM S-band Transponder (S-164)

e) Mass Spectrometer (S-165)

f) UV Photography - Earth and Moon (S-177)

g) Subsatellite, which includes:

    (1) S-band Transponder (S-164)
    (2) Particle Shadows/Boundary Layer (S-173)
    (3) Magnetometer (S-174)

h) Apollo Lunar Surface Experiments Package, which includes:

    (1) Passive Seismic (S-031)
    (2) Active Seismic (S-033)
    (3) Lunar Surface Magnetometer (S-034)
    (4) Heat Flow (S-037)
    (5) Lunar Dust Detector (M-515)

i) Lunar Field Geology (S-059)

j) Laser Ranging Retro-Reflector (S-078)

k) Cosmic Ray Detector (Sheets) (S-152)

l) Portable Magnetometer (S-198)

m) Soil Mechanics (S-200)

5.4.1 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) Measure the radiation flux at the CSM from the direction of the lunar surface while in lunar orbit to determine the degree of chemical differentiation.

FTO 2) Measure the radiation flux of cislunar space during transearth coast to obtain background reference data and a spectrum of the cosmological gamma-ray flux.

FTO 3) Measure the CSM/SIM radioactivity background during transearth coast 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. Immediately after jettison, the experiment will be placed in the "standby" mode of operation to apply 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 experiment to prevent overheating the experiment detector. During operation, this detector will be oriented toward the lunar surface within ± 10 degrees of the lunar local vertical.

The crew will actuate the VETO OFF switch and change the position of the STEP HIGH VOLTAGE switch if requested to do so by MCC. The position of the latter switch will be changed within 2 hours after an MCC request.

FTO 1) The experiment will be operated in lunar orbit with the boom fully extended for 10 hours minimum. An additional 20 hours of operation is highly desirable. Data will be obtained during as much of each 360-degree 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 experiment will be operated for a minimum of 6 hours during the period between 12 and 36 hours after TEI. It is highly desirable that the experiment boom be deployed and data accumulated as soon after TEI as feasible, and that data be accumulated for as long a period greater than 6 hours as practicable. The boom may be in the deployed position while the CSM rolls in the PTC "barbecue" thermal control mode.

FTO 3) While stowed in the SIM, the experiment will be operated for a minimum of 1 hour within the time period from 12 to 36 hours after TEI in order to measure the CSM/LM 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 by the Principal Investigator. The linearity of the system and the detector response as a function of energy will be determined by calibration of the system with mono-energetic 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 subtracted 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, BET, preflight data, concurrent experiments data, SL 1085 T, SL 1087 K and CG 0001 V).

Data Requirements

1) Telemetry Measurements:

Measurement Number	Description	TM	Mode	Priority
CG 0001 V	Computor 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	3	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 (standby, on, and off).

2) Deployment and retraction of experiment boom.

3) Operation of STEP HIGH VOLTAGE switch.

4) Operation of the VETO OFF switch.

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

1) Change of experiment modes (standby, on, and off).

2) Deployment and retraction of experiment boom.

3) Operation of the STEP HIGH VOLTAGE switch.

4) Operation of the VETO OFF switch.

3) Photographs: (HD)

Photographs taken by the 3-Inch Mapping Camera during operation of the Gamma-Ray Spectrometer experiment. Requirements for these photographs will be defined in the SM Orbital Photography Objective.

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)

Postflight scientific data from 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 Experiment (S-160) 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: One 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.

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 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		

5.4.2 X-RAY FLUORESCENCE

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

Purpose

The purpose is to monitor the instantaneous fluorescence X-ray flux from the lunar surface, the direct solar X-ray flux which produces this fluorescence, and the background galactic X-ray flux 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 in in lunar orbit, measure the lunar fluorescent X-ray flux and the solar X-ray flux incident on the lunar surface.

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

Test Conditions

FTO 1) The SIM door will be jettisoned before the X-ray Fluorescence

FTO 2) Experiment is operated. As soon as possible thereafter, the experiment will be set to "STANDBY" 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 30-degree conical field-of-view of the experiment detector.

If necessary to prevent damage, the experiment will be switched to "OFF."

Firings of RCS quads adjacent to the SIM area, urine dumps, waste water dumps, and other activities which may contaminate the experiments and degrade scientific data will be prohibited during the experiment period.

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

Concurrent operation of the Gamma-Ray Spectrometer and the Alpha-Particle Spectrometer experiments (seleno-chemical group) will be highly desirable.

The CSM will be rolled to an angle between 135° and 180° from its normal data gathering attitude for 15 minutes during each activity day, and deep space background data obtained while the CSM is over the dark portion of the lunar surface.

FTO 3) The experiment will be operated for a minimum of TBD hours during transearth coast to obtain data on background X-ray flux in deep space. The CSM PTC mode of operation will be permitted during this period.

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)
FTO 3) The Principal Investigator and investigation team will study and evaluate the data at the individual investigator's laboratories. During data analysis, the detectors will be calibrated with monoenergetic sources to determine the linearity of the given system and the detector response as a 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 selenochemical 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, CG 0001 V, SL 1050 K, 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 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
(TBD)	SIM Temperature	(TBD)	(TBD)	HD
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

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

Data Requirements (Cont'd)

1) Telemetry Measurements: (Cont'd)

Measurement Number	Description	TM	Mode	Priority
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

2) Astronaut Logs or Voice Records: (M)

a) GET of experiment switch operation and start and stop of each experiment mode during mandatory experiment operating periods. (M)

b) GET of experiment switch operation and start and stop of each experiment mode 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 Objective.

Data Requirements (Cont'd)

4) Trajectory Data:

   a) Best estimate of trajectory (BET) for all mandatory experiment periods. (M)

   b) Best estimate of trajectory (BET) for all highly desirable experiment periods. (HD)

5) Concurrent Scientific Experiments: (HD)

   Postflight scientific data of the 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).

X-RAY FLUORESCENCE

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. Their results have only been preliminary because of instrumentation limitations.

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:

- Nature of surface material.
- A measure of the homogeneity of the lunar surface as the spacecraft orbits the moon.
- By comparison with the Gamma-Ray 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 oxygen, sodium, magnesium,

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

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.

Previous Mission Experiments

Objective/Experiment Number	Title	Mission
None		

5.4.3 ALPHA-PARTICLE SPECTROMETER

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

Purpose

The purpose is to obtain data, while in lunar orbit, on the gross rate of lunar surface radon evolution and on localized sources of enhanced radon emission.

The functional test objectives are as follows:

FTO 1) Obtain alpha-particle emission data in the energy range of 4.5 to 9 Mev from RN^{222} located on the lunar surface.

FTO 2) Obtain alpha-particle emission data in the energy range of 4.5 to 9 Mev from Rn^{220} located on the lunar surface.

Test Conditions

FTO 1)
FTO 2) As soon as possible after the SIM door has been jettisoned, the experiment will be switched to the operate mode to maintain thermal control for the instrument. During data collection, the CSM attitude will be controlled so that the experiment sensor is oriented within ± 5 degrees of the lunar local vertical. The CSM will be maneuvered 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 and data collected in lunar orbit for 10 hours minimum. Additional data collection during the 72-hour SIM experiments period is 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 experiments is highly desirable. Once each activity day during the 72-hour 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. Data will be collected for 15 minutes minimum.

<u>Success Criteria</u>

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

Evaluation

FTO 1) FTO 2) The Principal Investigator (PI) will study and evaluate the data obtained from the MSFN receiving stations. These investigations will be conducted at the PI's laboratories. Inflight calibration 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 alpha lines from the RN^{222} and Rn^{220} decays and the extent to which radon has evolved. If an important Rn^{220} effect is found, then 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 measurements plus topographic maps of the lunar surface. The final result will be an attempt by the entire selenochemistry study group to incorporate all measurements obtained in order 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, CG 0001 V, SL 1065 K, SL 1066 K, 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
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

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

Measurement Number	Description	TM	Mode	Priority
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 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 operation periods and of mode changes.

b) During highly desirable experiment operation: (HD)

1) GET and description of waste dumps

2) GET of SIM door jettison

3) GET of start and end of operating periods and of 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 Objective.

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)

Postflight scientific data of Gamma-Ray Spectrometer and X-Ray Fluorescence Experiments during periods of concurrent operation with Alpha-Particle Experiment.

6) Preflight Data: (M)

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

ALPHA-PARTICLE SPECTROMETER

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.

There has been no previous attempt to look for radon on the lunar surface. Some pertinent information was learned from the Surveyor alpha-scattering observations of the lunar surface. Certainly, the detector background for the orbital experiment will be extremely low. In fact, most of the Surveyor background was consistent with imperfect containment of the alpha source that was carried as part of the instrumentation. No evidence was seen of monoenergetic alpha emission from the surface. This provides a lower limit to the strength of the active deposit at the particular Surveyor landing site. However, this lower limit is orders of magnitude more gross than the sensitivity of the alpha-particle experiment to be conducted from lunar orbit. The Surveyor detector was too close to the surface to see more than a negligible fraction of the potential radon atmosphere.

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. The gross rate of evolution is a function of the average concentration of uranium in the first meter of lunar material and its radon diffusion characteristics. 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 measurement 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 selenochemistry 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		

5.4.4 CSM/LM S-BAND TRANSPONDER

Conduct the CSM/LM S-band Transponder Experiment (S-164).

Purpose

The purpose is to obtain S-band Doppler data to determine the distribution of mass along the lunar surface 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 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 (i.e., during 60 NM circular orbit and 60 x 8 NM orbits, but not during the 170 x 60 NM orbit); the LM during descent; and the LM ascent stage during descent for impact on the lunar surface. The tracking measurement data will be that obtained during normal MSFN tracking operations. No changes to normal mission operations or crew activities will be required. The only telemetry data required for this experiment will be that needed to support the best estimate of trajectory.

Test Conditions (Cont'd.)

The DSN S-band Doppler tracking measurement will be obtained by the Principal Investigator directly from JPL. These measurements will include the docked CSM/LM during frontside passes between DOI and the circularization burn; the LM during unpowered portion of the flight during lunar descent; and the LM ascent stage during descent toward lunar surface impact.

FTO 1) The CSM S-band transponder system will be operated during the experiment period.

FTO 2) The LM S-band transponder system will be operated
FTO 3) 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 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 measurement data will be reduced postflight by the Principal Investigator. All available S-band Doppler tracking data will be processed by the JPL Orbit Determination Program to produce Doppler residual plots. These plots will be visually inspected to eliminate time increments including waste and urine dumps, RCS firing, etc. The unperturbed raw tracking data will then be reprocessed to compute the acceleration due to gravity in a continuous form, i.e., line-of-sight acceleration contour maps which 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 Mass Point Determination Program to generate an enhanced lunar mass point grid network. (MSFN and DSN data, and BET).

Data Requirements

1) MSFN and DSN Data:

a) S-band resolver and non-resolver Doppler tracking data for docked CSM/LM and CSM alone in 60 NM circular orbit. (M)

b) S-band resolver Doppler tracking data for docked CSM/LM and CSM alone in 60 x 8 NM orbit. (M)

c) S-band resolver Dopper tracking data for LM during unpowered lunar descent. (M)

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

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

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

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

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

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

2) Trajectory Data: (M)

Best estimate of trajectory (BET) during the period of the experiment.

CSM/LM S-BAND TRANSPONDER

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
None		

5.4.5 MASS SPECTROMETER

Conduct the Mass Spectrometer Experiment (S-165).

Purpose

The purpose is to obtain data on the composition of the lunar ambient atmosphere from the CSM.

The functional test objectives are as follows:

FTO 1) Obtain data on the natural distributions of gases in the lunar atmosphere.

FTO 2) Obtain data for locating areas of volcanism on the lunar surface.

FTO 3) Obtain data on the amount of contamination in the lunar atmosphere due to the firing of rocket motors near the lunar surface.

FTO 4) Obtain data on contamination present in cislunar space.

Test Conditions

FTO 1) The crew will perform necessary control functions
FTO 2) to energize the ion source heaters, to place the experiment
FTO 3) in standby, on, and off modes, and to control experiment
FTO 4) electronics.

FTO 1) Prior to experiment operation, the SIM door will be jettisoned and the ion source heaters set to "standby" for a minimum warmup period of 3 hours. The experiment will be set to "standby" for at least 5 minutes to allow outgassing before it is set to the "operate" mode.

FTO 2)

FTO 3)

During data collection the -X axis of the CSM will be oriented to within ±5 degrees of the velocity vector, (blunt and forward), and the experiment boom will be fully deployed. The CSM will be in an orbit which may vary from a minimum of 10 x 20 NM to a maximum of 60 x 60 NM, and which has the maximum feasible inclination angle.

Data will be obtained during a minimum of 2 complete orbits. At least 10 additional orbits are highly desirable. Water, urine, and other liquids will not be dumped during the period from 2 hours before to 2 hours after data collection (a period from 5 hours before to 5 hours after data collection is preferred). After data has been collected, the boom will be retracted and the experiment switched to the standby mode.

FTO 4) For data collection during transearth coast, the boom will be fully deployed and the ion source heaters set to "standby" for 6 hours minimum. Data will be collected no sooner than 6 hours after water, urine, or other liquids have been dumped or an SPS or RCS burn associated with TEI or a midcourse correction has occurred.

The -X axis of the CSM will be oriented to within ± 5 degrees of the velocity vector. Data will be collected during two discrete periods. During the first period, the boom will be fully deployed and data collected for 2 hours minimum. For the second data collection period, the boom will be retracted in 5 equal steps, and data collected for 7 minutes between each step.

Success Criteria

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

Evaluation

FTO 1)	Data obtained will be studied and evaluated by the
FTO 2)	Principal Investigator and investigation team in
FTO 3)	the individual investigator's laboratories. The
FTO 4)	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. The cislunar measurements will be used to obtain a background measurement of the contaminant gases from the spacecraft. (Astronaut records, BET, preflight, CG 0001 V, SL 1081 K, SL 1082 K, and SL 1083 K).

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 (TBD).

MASS SPECTROMETER

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 38 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 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 hydronamic 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		

5.4.6 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 UV transmitting lens. The photographs will be taken through the RH CM window. This window will be supplied with a quartz pane that passes a larger fraction of the incident UV radiation than does a standard CM window. It should be noted that the UV radiation hazard from this window will therefore be proportionately higher. The camera will be mounted on a special bracket and will be provided with a ring slide for filters. The following four 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) TBD in the range of 4000-6000 Å.

The film type to be used is Eastman Kodak spectroscopic film type IIa-0. 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 the indicated distances):	60,000 N M	4
		120,000 N M	4
		180,000 N M	4
c)	Lunar Orbit:	Earth	4 x 2 (2 sets)
		Earth and Lunar Horizon	4
		Lunar Terra	4
		Lunar Maria	4
d)	Transearth Coast (TEC) (photographs of the earth disc from the indicated distances):	180,000 N M	4
		120,000 N M	4
		60,000 N M	4
		TOTAL	52

MCC will transmit to the crew the times at which photographs are to be taken during TLC and TEC. During earth orbit and lunar orbit, photographs may be taken at any time the indicated subject areas are available. The only spacecraft attitude requirement is that the photographic subject area be visible through the RH CM window. 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, and for taking photographs with each of the four filters. Exposure parameters for the photographs are given in the Photographic and TV Operations Plan 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) for the period of each set of photographs.

UV PHOTOGRAPHY - EARTH AND MOON

Background and Justification

This experiment is an investigation of the terrestrial atmosphere by means of photographs of thee arth 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 (λ<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.

Background and Justification (Cont'd)

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.

Background and Justification (Cont'd)

Photographs of the mmon 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		

SUBSATELLITE

Conduct the Subsatellite Experiment while it is in lunar orbit.

Purpose

The purpose is to obtain data on the lunar gravitational field and on the charged particles and electric 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) By means of S-164, obtain S-band Doppler tracking measurements of the Subsatellite.

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

FTO 3) By means of S-174, obtain data on the lunar magnetic field.

Test Conditions

FTO 1) After SIM door jettison, the Subsatellite will be ejected from
FTO 2) the CSM and into orbit when the CSM is in a position to maximize
FTO 3) the distance separating the CSM and Subsatellite. MCC will transmit the command required to deploy the Subsatellite sensor booms. TBD photographs of the Subsatellite using the TBD camera will be obtained after ejection.

FTO 1) S-band Doppler tracking data will be received and recorded by MSFN and DSN stations for a minimum of 1 frontside pass per day over a 6-month period. Additional TBD frontside passes during this 6-month period and TBD frontside passes during a second 6-month period will be highly desirable.

After each tracking sequence, MCC will transmit a command to the Subsatellite to initiate battery recharge. Batteries will be charged for one orbit before any data collection period. Tracking will be conducted by at least two stations for a minimum of 2 passes per week. Additional tracking may be conducted by only one station.

It is desirable that ground stations use resolvers to improve data accuracy, and that data collection periods be rescheduled every 30 days to maximize ground track coverage.

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. The schedule for Subsatellite data collection and telemetry dump within this period will be in accordance with the following requirements:

- During the initial 45 days of Subsatellite operation, data will be obtained continuously with the Subsatellite in the Magnetotail Mode except for an 8-minute data dump to a ground station once each orbit, and during tracking passes and battery recharging. While the moon traverses the earth's magnetotail, the Subsatellite will be in the Magnetotail Mode and data will be collected continuously except during a telemetry dump of approximately 8 minutes per orbit. Data will be collected for 5 days per month except during tracking passes and battery recharging periods.
- During the remainder of each month, the Subsatellite will be in the Interplanetory or Boundary Layer Mode. During the Interplanetory Mode, data will be collected at a low rate, and dumped to a ground station once every 12 hours. The Boundary Layer Mode will be selected approximately 1 day per month. In this mode, a telemetry data dump will be required once per orbit.

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) The experiment data defined under Test Conditions for FTO 2)
FTO 3) 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 land features can then be made. The mass point grid network 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 spacial 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. (BET 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 a 60 NM lunar orbit. 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 measurement experiment which is carried on the same Subsatellite as the magnetometer. (BET and TBD Telemetry).

Data Requirements

1) Telemetry Measurements: (M)

   Data requirements for the Subsatellite (including experiment S-164, S-173, and S-174) as defined in TBD document.

2) Photographs: (TBD)

   Photographs of ejected Subsatellite with sensors deployed.

3) MSFN and DSN Data:

   a) S-band resolver and non-resolver 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 (TBD) required by S-173 and S-174 will be supplied by either S-164 P.I. or NASA.

5) Concurrent Scientific Data: (TBD)

   (TBD) concurrent data will be required from ALSEP.

6) Preflight Data:

   Preflight checkout and calibration data in accordance with procedure TBD.

SUBSATELLITE

Background and Justification

S-Band Transponder Experiment (S-164)

Accurate measurement of a satellite's natural lunar orbit position over meaningful periods of time allows definition of a lunar mass model. Such a model, when correlated with lunar shape information, will enhance and support future lunar activities by permitting greater surface landing accuracy, backside landings, and more accurate or alternate orbit determinations. In addition, the scientific community will be provided a basic model for such considerations as lunar origin and subsurface structure. An opportunity is also provided to verify an unusual Doppler anomaly discovered by data obtained from Lunar Orbiter V which has led to some speculation of a lunar atmosphere.

Some Doppler tracking has been accomplished in the past on the Lunar Orbiter and Apollo CSM spacecraft. Spacecraft maneuvering, attitude control activities, and limited periods of continuous tracking, however, resulted in less than ideal results. The "fruits" of reduced data from these missions, however, culminated in August 1968, with the discovery of the mascons.

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

Vector magnetometer surveys have been the major means of determining magnetic fields in space. Many basic properties of the interplanetary medium, bow shock, and magnetosphere have been determined by this means. 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 far behind the earth, perhaps entering 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.

The method of large absorbers in principle make it possible to quantitatively answer such fundamental questions as the following:

1. Is the magnetosphere open? If so, what fraction of the magnetotail lines are connected to the interplanetary field?
2. What fraction of the field lines are close in the magnetotail near the earth, and what is the spatial extent (thickness) of this region?
3. Can it be experimentally demonstrated that reconnection exists? If so, where is the reconnection region?
4. How does the topology of the magnetosphere respond to changes in the interplanetary medium?
5. How does the topology of the magnetosphere change during magnetospheric substorms?
6. Do regions of very strong (Bohm) diffusion exist anywhere in the magnetotail?

7. What is the strength of electric fields across the magnetotail?

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 two main results of the particle tracing method from Explorer XXXV are as follows:

1. Most of the magnetotail field lines at 60 R_e geocentric distance are connected to the interplanetary medium.
2. On one occasion, field lines of interplanetary character were found in the magnetotail near the neutral sheet at a distance of 60 R_e. This supports reconnection in the magnetotail and places the neutral line at a geocentric distance 60 R_e on this one occasion.

The experiment on Explorer XXXV was limited in several respects. 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.

Detailed investigation of the penumbra is one of the important new objectives of the proposed investigation, and one that was not carried out at all on Explorer XXXV. Electric fields can shift the position of the particle shadows in a way that is energy dependent. Although $\vec{w}^E = (\vec{E} \times \vec{B})/B^2$ is energy dependent, the distance which particles are shifted into or away from shadows is not since $\vec{w}^E$ must be multiplied by the down and back time from the moon to the mirror points. This method is highly sensitive and under some conditions fields as small as 10^{-4} volts per meter could be detected. Although it has been established that inside the moon's orbit there is no appreciable scattering of particles across field lines, more sensitive tests might reveal a certain amount. This kind of process can be separated from E field drift in principle since the energy dependence is expected to be different. There are "diffraction effects" at the magnetic terminator of the moon due to the fact that some particles with gyroradius ($R = mv /qB$) greater than their distance from the moon can miss the moon depending on the phase of their gyration. This is not something of fundamental interest, but it is an effect which must be corrected for when studying the penumbras.

Another problem of basic significance can be examined by use of lunar shadowing techniques. This is the question of flow of the very hot plasma surrounding the neutral sheet in the magnetotail. If, for example, the plasma flows away from the earth, then there should be no plasma behind the moon, at least until diffusion has had sufficient time to fill this cavity.

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 in space, 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 on the external plasma, the interior of the moon, the surface and the lunar ionosphere.

The disturbance produced in the solar wind by the moon has been observed directly using instruments on board satellites in lunar orbits. These observations were made at altitudes above 750 km. The main results are as follows:

1. That if the moon has a permanent field it is too weak to produce a lunar magnetosphere. The upper limit for the lunar dipole moment is presently placed at 10^{20} gauss-cm^3 (2 to 4 γ at the surface).

2. A substantial fraction of the solar-wind particles that are directed toward the moon in the undisturbed upstream flow probably strike the lunar surface where they stick or are re-emitted as neutral particles. This behavior was inferred from the absence of any detectable bow shock, and from the observation of an apparently permanent cavity in the solar-wind flow immediately downstream from the moon which is relatively devoid of detectable plasma. The magnetic field in the solar-wind penumbra, which is essentially the boundary between this cavity and the undisturbed solar wind, is weaker than that in the adjacent solar wind. The magnetic field in the solar-wind umbra is stronger than that in the solar wind.

Measurements along the Apollo parking orbit should provide information on both microscopic processes in the interraction region and macroscopic features of the flow.

Several models of the macroscopic features of the interaction of the solar wind with the moon are consistent with the observations obtained so far.

One model includes a standard hypersonic rarefaction wave and wake shock. The rarefaction wave is initiated at or on the dark side of the terminator. In another model this wave begins on the front (daylight) hemisphere. The actual behavior depends on the properties of the plasma and the properties of the moon.

Other features of the various models are transient bow shocks and relatively thin boundary layers, which may or may not include weak shocks, and in which the flow and the magnetic field are slightly distorted from the patterns in the undisturbed solar wind. Measurements of such distortions, transient or steady-state, would provide more information on the conductivity of the moon.

Also, the unipolar-generator model includes steady-state currents flowing normal to the lunar surface. If the conductivity of the moon is sufficiently great, the magnetic field associated with these currents would be detectable at the Apollo orbit. These currents may also depend on a work function of the surface or an effective contact resistance.

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 hit the surface in the steady-state, but photo-electric fields and ionized particles from the moon may complicate the situation.

There are several mechanisms by which the moon may be electrically charged. These involve plasma, photo, and secondary currents. Conditions should change when the moon passes between the solar wind and the geomagnetic tail.

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. Thus,the situation in the boundary layer should be quite unstable. The Apollo parking 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.

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 in space, since the inner boundary is the lunar surface, and variable in thickness. Thus, in this particular boundary layer, complications due to the motion are reduced.

The goal of this experiment is to obtain data on the physics of this inter-action 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 on the interior of the moon, its surface, and its atmosphere and ionosphere, as well as extending our knowledge of collisionless plasmas.

5.4.8 APOLLO LUNAR SURFACE EXPERIMENTS PACKAGE

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

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 includes Experiments S-031, S-033, S-034, S-037 and M-515.

The functional test objectives in order of priority 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 Magnetometer Experiment (S-034).

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

FTO 5) Deploy the Lunar Dust Detector Experiment (M-515).

Test Conditions

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

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 completion of the traverse, the two packages will be separated and set upright. The experiments will be removed from the packages, assembled and power connections made. The antenna on package number one will then be erected and aimed at the earth, ending the deployment phase.

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 be routed to the MCC for display and control, and command data generated at the MCC will be transmitted to the ALSEP.

Test Conditions (Cont'd)

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 the 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 by the Lunar Surface Procedures.

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 geophone lines.

Success Criteria

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

Telemetry data shall be received from the ALSEP central station and from each of the five 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.

Evaluation

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

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, all telemetry data and photographs)

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)

   Photographs of deployment area, the deployed experiments and the central station.

APOLLO LUNAR SURFACE EXPERIMENTS PACKAGE

Background and Justification

The Passive Seismic Experiment 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 veolcity, 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.

The Active Seismic Experiment (ASE) is designed to generate and monitor artificial seismic waves in the 3 to 250 Hz 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. A thumper device containing 21 explosive charges will be fired along the geophone lines by the astronaut. 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 one 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 compressional 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 induration and bearing strength of these materials.

Background and Justification (Cont'd.)

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

- A comparison of the radioactive content of the moon's interior and the earth's mantle.
- A thermal history of the moon.
- A lunar temperature versus depth profile.
- The value of thermal parameters in the first three meters of the moon's crust.

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

The Heat Flow Experiment is deployed with two sensor probes emplanted in the lunar surface in three meter boreholes. These boreholes will be drilled by the astronaut with the Apollo Lunar Surface Drill.

The Lunar Dust Detector Experiment (M-515) will be accomplished to provide data on the effects of dust accumulated on the surface of the ALSEP central station as a result of either natural deposition or from the effects of LM ascent.

The success criteria of these experiments are associated with satisfactory ALSEP deployment and the receipt of telemetry data from the package.

Background and Justification (Cont'd)

The ALSEP mission begins after the experiments are deployed. The ALSEP has a design goal to transmit experiment data for a period of one year; these data will be recorded continuously by MSFN ground stations. MCC monitoring and command controls of ALSEP will be exercised at intervals during each day for 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	Magnetometer Experiment	12
M-515	Lunar Dust Detector Experiment	12
S-031	Passive Seismic Experiment	H-3
S-033	Active Seismic Experiment	H-3
M-515	Lunar Dust Detector Experiment	H-3
S-031	Passive Seismic Experiment	H-4
S-034	Magnetometer Experiment	H-4
M-515	Lunar Dust Detector Experiment	H-4

5.4.9 LUNAR FIELD GEOLOGY

Conduct the Lunar Field Geology Experiment (S-059)

The Lunar Field Geology Experiment (S-059) is TBD for Apollo 16. A geology team has recently been formed and a team chairman has been appointed to organize the team effort in planning, developing, and carrying out lunar geology investigations. A detailed experiment plan has not been developed.

Based on Apollo 16 landing at Copernicus, the probable science objectives will be as follows:

1. To determine the age, origin, and evolution of the crater Copernicus.
2. To determine the origin, age, and structure of the central peak material.
3. To determine the origin, age, and structure of crater floor filling materials (smooth floor material, textured floor material, hills, and hummocks).
4. To investigate character of superposed craters.

5.4.10 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 reflector for laser ranging from earth.

The functional test objective is as follows:

FTO 1) Deploy the Laser Ranging Retro-Reflector (LRRR) Experiment (S-078).

Test Conditions

FTO 1) The crewman 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. The astronaut will deploy the LRRR a minimum of 500 feet from the LM in a direction that ascent engine plume impingement does not occur and that minimizes exposure to dust from the LM ascent. The Active Seismic Experiment (S-033) grenade impact area must also be considered when deploying the LRRR.

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 include 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, were determined from the laser ranging data. Data were 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. This 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

5.4.11 COSMIC RAY DETECTOR (SHEETS)

Conduct the Cosmic Ray Detector Experiment (S-152)

Purpose

The purpose is to use high resolution plastic detectors to measure the charge, mass and energy spectrum of cosmic rays with atomic number greater than 8 at energies between 10 and 200 Mev/nucleon.

The functional test objective is as follows:

FTO 1) Return plastic detectors that have been exposed to cosmic rays.

Test Conditions

FTO 1) The test conditions are TBD.

The following are being considered:

Four detector stacks, each consisting of 40 0.010 inch thick sheets of Lexan polycarbonate plastic, will be attached to the LM exterior and exposed to cosmic rays during the flight to the moon. The stacks will be mounted on the LM exterior during pre-launch operations and will be removed by the astronaut during the first EVA.

Lunar surface activities will include removing the detector stacks from the LM, deploying the stacks on the lunar surface, retrieving and stowing the stacks in the LM during the last EVA.

To differentiate cosmic rays that enter the detectors on the trip to the moon from those that enter during exposure on the moon's surface, half of the sheets in each stack will be translated with respect to the other half prior to deployment on the surface of the moon. The assembly will be designed so that either half of the plastic sheets in the stack will automatically be shifted with respect to the other half as they are released from the lunar module or such that a simple motion by the astronaut after dismounting the sample will provide the shifting.

The detector stacks will be folded for stowage in the LM. Cosmic rays that enter the folded stack on the return trip can be differentiated from those rays that entered on the outbound trip and those that entered while the experiment was deployed on the moon.

The detector stack temperature should be kept below 120°F during the mission and be protected from ultraviolet radiation by

Success Criteria

FTO 1) The detector stacks shall be brought to the LRL and provided to the Principal Investigator.

Evaluation

FTO 1) The Principal Investigator will evaluate the particle tracks in the detector material.

Data Requirements

Detector stacks exposed to cosmic rays

COSMIC RAY DETECTOR

Background and Justification

These high resolution measurements of charge, mass, and energy particles beyond the earth's atmosphere and magnetic field will provide unique information on the origin of particles and thus on the origin of the elements and the nature of stellar nucleosynthesis.

All of these results will be valuable in the planning of cosmic ray experiments of long duration in orbiting workshops.

This experiment is based on the discovery and scientific exploration of nuclear particle tracks in dielectric solids over the last six years. The first evidence for cosmic rays heavier than the iron-group was provided by fossil cosmic ray tracks in meteorotic crystals, and further studies of the extremely heavy cosmic rays are continuing with huge arrays of track-recording plastics in balloons.

Recent improvements in resolution have made it possible to study the isotopic and charge distribution of cosmic rays by measuring the rates of chemical etching along particle trajectories in plastics.

The Cosmic Ray Detector is a new experiment and will be conducted for the first time on mission J-1.

Previous Mission Experiments

None

5.4.12 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) Obtain data on the local magnetic field by use of a portable magnetometer

FTO 2) Obtain data on the magnetic field over a large area by use of a portable magnetometer.

Test Conditions

FTO 1)
FTO 2) During one of the EVA periods the crew will use the portable magnetometer at least 250 feet from the LM and at least 50 feet from any other equipment or material the crew has deployed.

Due to the magnetic properties of the PLSS being used, the magnetic sensors and readout meters must be separated by a 50 foot cable. This will allow the astronaut to align the sensors and walk back to the end of the cable and read out the measurements over the voice loop to the MCC.

The following two different types of magnetometer data will be obtained.

FTO 1) o Site Point Measurements

After the simple magnetometer components have been moved at least 250 feet from the LM, the sensor head will be placed on the tripod. The crewman will carry the sensor head and 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. The crewman will return to the electronics box and read the three panel meter readings to the MCC.

Test Conditions (Cont'd)

FTO 1) o Site Point Measurements (Cont'd)

The crewman will return to the sensor head and rotate the sensor head 180 degrees from top to bottom. The measurements for this orientation will be read over the voice loop to the MCC. A third measurement will be taken after rotating the sensor head 180 degrees in the horizontal plane. This set of measurements will indicate the magnetic flux at a single site.

FTO 2) o Traverse Measurements

Following the site measurements, readings will be made at six different locations along the geological traverse route. The final measurement is to be made at the same location as the initial site measurement. The orientation of the sensor head for the six traverse measurements will be maintained at the same orientation as positioned for the final site point measurement. Single measurements will be made and voiced to the MCC. These data will give an indication of the change with distance of magnetic flux.

It is intended to utilize the Lunar Roving Vehicle (LRV) in the deployment of the portable magnetometer along the traverse. LRV requirements and constraints for the Portable Magnetometer Experiment are to be defined.

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.

Success Criteria

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

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

Evaluation

1) Astronaut Logs or Voice Records: (M)

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

Data Requirements (Cont'd)

1) Astronaut Logs or Voice Records: (M) (Cont'd)

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

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

   The photograph is 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 35. Thus, several important scientific questions have been raised:

- Does a field of comparable strength exist elsewhere on the moon?
- What is its areal strength?
- What are the possible dimensions and location?
- What are the spatial variations of the field?
- Can they be used to determine geologic structure?

The data from Explorer 35 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 several locations along a traverse.

The data obtained from this experiment will supplement the results from the lunar surface magnetometer experiment on the Apollo 12 mission and H-4 mission and the portable magnetometer experiment on 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

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 35. Thus, several important scientific questions have been raised:

- Does a field of comparable strength exist elsewhere on the moon?
- What is its areal strength?
- What are the possible dimensions and location?
- What are the spatial variations of the field?
- Can they be used to determine geologic structure?

The data from Explorer 35 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 several locations along a traverse.

The data obtained from this experiment will supplement the results from the lunar surface magnetometer experiment on the Apollo 12 mission and H-4 mission and the portable magnetometer experiment on 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

5.4.13 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, to construction of a shelter and to mobility of a roving vehicle.

FTO 2) Obtain data on lunar soil mechanical behavior.

FTO 3) Obtain penetrometer data to depths of at least fifty centimeters.

FTO 4) Obtain a representative sample of fine-grained fragmental material.

Test Conditions

FTO 1) Lunar surface activities will include excavating a hole or trench, recording crew observations and biomedical data, and obtaining photographs. The excavation will be made as deep as possible within the constraints of the timeline, crew capability, or until an impenetrable stratum is encountered. An excavation at least two feet deep and aligned approximately ten degrees off the sun-line is desired. The excavated material will be piled in one heap to determine the natural slope of the material.

FTO 2) The LM will land on the lunar surface. Lunar surface activities will include obtaining the lunar samples defined in the Selected Sample Collection and Lunar Field Geology Experiments, recording crew observations, and obtaining photographs.

FTO 3) Lunar surface activities will include probing the surface with the hand penetrometer. The soil should be penetrated up to six times if possible, but at least once in virgin soil, once at the bottom of the excavation, and once in the pile of excavated soil. An astronaut will then step on the pile and record observed differences in compactness between the excavated soil and the virgin soil. If an impenetrable (or very hard) stratum or subsurface boulder is encountered, an attempt should be made to determine the lateral extent of the obstruction. The remaining three penetrations of the lunar surface will be accomplished at other sites along the traverse.

FTO 4) Approximately three 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 not include any rocks larger than approximately two 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.

Success Criteria

FTO 1) Data shall be obtained on lunar surface and subsurface characteristics relative to the origin and nature of the lunar soil and to the construction of a shelter and mobility of a roving vehicle. This shall include data on the ability of an astronaut to excavate the lunar surface, the natural slope of the excavated material, and the integrity of the sidewalls of the excavation.

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 shall be obtained on the strength and deformation characteristics of virgin lunar soil at the surface and at the bottom of a two-foot excavation, and of a pile of excavated lunar soil.

FTO 4) Approximately three kilograms of fine-grained fragmental material shall be returned to the LRL.

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. These data will be used for scientific analysis of the origin and nature of lunar surface material and to determine the types of construction that would be possible either on or under the lunar surface. (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 into lunar soil with that required to probe terrestrial soil analogs. (Astronaut records and photographs)

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

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

Measurement Number	Description	TM	Mode	Priority
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	Delt 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

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.

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

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 major traverses for ALSEP deployment or lunar field geology. (HD)

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*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 and 12.

g) Comments describing the variations in depth of boot prints in the lunar surface during the traverse. (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 difference in boot print depth observed when stepping on the pile of excavated soil and on virgin lunar soil. (HD)

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

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

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

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)*

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

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 erosive crater. (M)

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

e) Photographs showing the LM, lunar surface at the landing site, and lunar horizon, taken along the LM Y and Z axes. (HD)

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

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

h) Photographs using the LGEC of the pile of excavated material after completion of the excavation and after an astronaut steps on the pile. (M)

i) 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)

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

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

l) Sequence camera photographs of the trenching operations. (HD)

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

4) LM mass, center of gravity and mass moments of inertia at touchdown as determined from preflight measurement and consumable usage. (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 three kilograms of fine-grained fragmental material. (M)

7) Experiment S-200 penetrometer. (Mandatory only if the penetrometer has a self-recording force/depth capability; otherwise the penetrometer will be off loaded)

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 be used to predict the terrain features, the soil mechanical properties, and the correlation between the terrain features and soil conditions.

This objective will provide additional data on lunar soil mechanical properties and terrain features to include penetrometer data. These data are essential for improving methods of selecting future landing sites, establishing 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

Objective 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

SECTION VI

SCIENCE PHOTOGRAPHIC REQUIREMENTS

NOTE

The contents proposed for this section are described under tentative main paragraph headings listed below. The data suggested for inclusion must be approved and commitments made by appropriate agencies to furnish necessary data.

6.1 GENERAL

(This paragraph will summarize the purpose and contents of the section.)

6.2 FILM REQUIREMENTS

(This paragraph will list all film types approved for use and the characteristics of each type.)

6.3 FILM TESTS AND SELECTION

(This paragraph will contain a listing of the film types approved for use to satisfy mission SDO and DE requirements. It will also describe the test conditions and tests which must be performed for a new film type recommended for use if the approved film types are unsuitable for a specific application.

6.4 POST-MISSION PROCESSING REQUIREMENTS

(This paragraph will describe the processing requirements for film returned from the mission.)

6.5 PHOTOGRAPHIC/MISSION REQUIREMENTS CORRELATION

(This paragraph will correlate photographic requirements to each appropriate SDO and DE. Photographic requirements will include the following: camera equipment (lens, filters, etc.); types of photography (high resolution, stereo-strip, sequence, still, lunar surface closeup, etc.); number of photographs; sun angles; etc.)

SECTION VII

LUNAR TRAVERSE PLAN

NOTE

The contents proposed for this section are described under tentative main paragraph headings listed below. The data suggested must be approved and commitments made by appropriate agencies to furnish necessary data.

7.1 GENERAL

(This paragraph will summarize the purpose and contents of the section.)

7.2 LANDING SITE CRITERIA

(This paragraph will describe the landing site and its characteristics, the rationale for selection of the site, and scientific criteria.)

7.3 NOMINAL TRAVERSE

(This paragraph will describe the nominal traverse for each EVA period. A traverse plot for each EVA will be included. Crew activities in terms of where particular soil samples are to be obtained, photographs taken, etc., will also be discussed.)

7.4 CONSTRAINTS

(This paragraph will describe the constraints impacting accomplishment of science requirements as pertains to both the equipment and the crew.)

SECTION VIII

CONTINGENCY PLANNING

The contents proposed for this section are described under tentative main paragraph headings listed below.

8.1 GENERAL

(This paragraph will summarize the purpose and contents of the section.)

8.2 CONTINGENCY PLANNING RATIONALE

(This paragraph will include the rationale for changing SDO and DE priorities in the event that mission or spacecraft contingencies arise.)

8.3 CONTINGENCY PLANNING DATA

(This paragraph will specify criteria for selection of the specific SDO's and DE's which will be rescheduled in case of a contingency such as: failure of LRV; one-man EVA; shortened lunar stay period; no lunar landing; etc. Candidate data for inclusion include: priorities of SDO's and DE's in lunar orbit and on the lunar surface; the minimum number of crewmen required to accomplish a specific activity; time requirements for activities, etc.)

APPENDIX A

ACRONYM LIST

NOTE

This list will be revised to reflect acronyms used in this document.

ACRONYM LIST

ALSCC	Apollo Lunar Surface Close-up Camera
ALSEP	Apollo Lunar Surface Experiments Package
APS	Ascent Propulsion System
AS	Apollo Saturn
ASE	Active Seismic Experiment
BET	Best Estimate of Trajectory
CDU	Coupling Data Unit
CM	Command Module
CPLEE	Charged Particle Lunar Environment Experiment
CSM	Command and Service Module
DPS	Descent Propulsion System
DSE	Data Storage Equipment
E	East
EV	Electron Volts
EVA	Extravehicular Activity
FM	Frequency Modulation
FTO	Functional Test Objective
GET	Ground Elapsed Time
GNCS	Guidance, Navigation and Control System
HBR	High Bit Rate
HD	Highly Desirable
Hz	Hertz
IMC	Image Motion Compensation
IMU	Inertial Measurement Unit
IR	Infrared
ISS	Inertial Subsystem
KEV	Kilo Electron Volts
km	kilometer
LAC	Lunar Aeronautical Chart
LBR	Low Bit Rate
LGEC	Lunar Geological Exploration Camera
LM	Lunar Module

LRL	Lunar Receiving Laboratory
LRRR	Laser Ranging Retro-Reflector
M	Mandatory
m	meter
mm	millimeter
MCC	Mission Control Center
MESA	Modular Equipment Stowage Assembly
MET	Modular Equipment Transporter
MHz	Megahertz
MQF	Mobile Quarantine Facility
MSC	Manned Spacecraft Center
MSFN	Manned Space Flight Network
MSL	Mapping Science Laboratory
NASA	National Aeronautics and Space Administration
NM	Nautical Mile
N	North
OMSF	Office of Manned Space Flight
PCM	Pulse Code Modulation
PCMD	Pulse Code Modulation Digital
PIPA	Pulse Integrating Pendulous Accelerometer
PLSS	Portable Life Support System
PRN	Pseudo-Random Noise
RCS	Reaction Control Subsystem
RTCC	Real Time Computation Center
RTG	Radioisotope Thermoelectric Generator
S	South
SA	Saturn Apollo
SLA	Spacecraft/LM Adapter
SM	Service Module
SPS	Service Propulsion System
S-IC	Saturn IC
S-II	Saturn II
S-IVB	Saturn IVB
T	Time (of lift-off)
TBD	To Be Determined

TEI	Transearth Injection
TM	Telemetry
TV	Television
U	Unclassified
UV	Ultraviolet
ΔV	Delta Velocity
W	West

APPENDIX B

REFERENCE DOCUMENT LIST

NOTE

List will be revised to reflect the documents referenced in the MSRD.

REFERENCE DOCUMENTS

1. Apollo Flight Mission Assignments (U), OMSF Document M-D MA 500-11, SE 010-000-1, 17 October 1969, and amendments.

2. Apollo Spacecraft Program Configuration Management Manual SB07-C-001, 15 December 1967.

3. Apollo Spacecraft Configuration, Weight and Performance Summary, D2-118078, the Boeing Company - Space Division.

4. MSC unnumbered document Apollo Stowage List, Mission AS 511 CM 112/LM-10.

APPENDIX C

DISTRIBUTION LIST

NOTE

This list will be revised to reflect applicable distribution for Apollo Mission J-1.

DISTRIBUTION

1 AB/C. C. Kraft
2 BM6/Technical Library
14 BM86/Mission Data Package
- 1 PA/J. A. McDivitt
- 1 PA/K. S. Kleinknecht/ S. H. Limpkinson
- 1 PA/O. G. Morris
- 1 PD/C. H. Perrine
- 1 PD7/D. R. Segna
- 1 PE/D. M. Corcoran
- 1 PF/A. Cohen
- 1 PF2/G. A. Coultas
- 1 PF2/J. S. Lowe
- 3 PP3/H. L. Tash (for SPAN room)
- 1 PSK/A. E. Morse
- 1 TRW/M. J. Barone

1 CA/D. T. Gregory
1 CA/D. K. Slayton
3 CB/Astronaut Office
1 CB/E. A. Cernan
1 CB/P. K. Chapman
1 CB/A. W. England
1 CB/J. H. Engle
1 CB/R. E. Evans
1 CB/W. R. Fullerton
1 CB/F. W. Haise
1 CB/J. A. Lovell
1 CB/T. K. Mattingly
1 CB/B. McCandless
1 CB/E. D. Mitchell
1 CB/W. R. Pogue
1 CB/S. A. Roosa
1 CB/H. H. Schmitt
1 CB/A. B. Shepherd
6 CB/T. P. Stafford
1 CF/W. J. North
1 CF14/J. Bilodeau
1 CF15/C. H. Woodling
1 CF21/M. E. Dement
1 CF31/M. J. Howley
1 CF41/P. C. Kramer
1 CF51/D. C. Schultz
1 CF61/T. R. Lindsey
1 CF61/J. Radcliff
1 CF61/J. V. Rivers
1 CF61/T. W. Holloway
1 CF61/J. W. O'Neill
1 CF61/C. L. Stough
1 CF71/H. A. Kuehnel
1 CF71/R. G. Zedekar
1 CF71/W. J. Wood
1 CF71/J. W. McKee
1 CF71/A. C. Holt
1 CF81/S. Faber
1 CF131/D. F. Grimm
1 CF131/G. C. Franklin
1 CF131/C. D. Perner
1 DA/C. A. Berry, M.D.
1 DA/H. R. Hair
1 DC5/W. R. Carpentier, M.D.
1 DD/W. R. Hawkins
1 EA/M. A. Faget
1 EA2/J. B. Lee
1 EA5/P. M. Deans
1 EB/H. C. Kyle
1 EB2/R. W. Moorehead
2 EB3/M. R. Franklin

DISTRIBUTION (Continued)

2	EB5/G. D. Marlow	1	ES12/W. G. McMullen
1	EC3/R. J. Gillen	1	ES12/S. P. Weiss
1	EC3/P. F. Hurt	1	ES12/W. F. Rogers
1	EC3/F. A. McAllister	1	ES16/J. A. Smith
1	EC3/E. M. Tucker	1	EW31/G. C. Miller
1	EC9/J. L. Gibson	1	FA/R. G. Rose
1	EC9/R. L. Span	1	FA/S. A. Sjoberg
1	EC9/H. L. Stutesman	1	FC/J. W. Roach
1	ED3/M. T. Cunningham	3	FC/E. F. Kranz
1	EE/R. S. Sawyer	1	FC/L. W. Blair
1	EE2/P. P. Coan	1	FC/C. A. Beers
1	EE3/D. S. Eggers	1	FC/M. F. Brooks
5	EE12/E. E. Lattier	1	FC/L. Pavlow
1	EE12/R. H. Dietz	1	FC/L. W. Aaron
1	EE12/R. G. Irvin	1	FC/M. L. Windler
1	EG2/D. C. Cheatham	1	FC/M. P. Frank
1	EG7/C. F. Wasson	1	FC/J. H. Temple
1	EG7/J. F. Hanaway	3	FC2/C. S. Harlan
1	EG8/R. E. Wilson	3	FC3/A. D. Aldrich
1	EG23/K. J. Cox	1	FC3/L. S. Canin
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