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APOLLO
LUNAR SURFACE EXPERIMENTS
OPERATIONAL REQUIREMENTS

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APOLLO LUNAR SURFACE EXPERIMENTS OPERATIONAL REQUIREMENTS

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OPERATIONAL REQUIREMENTS

INTRODUCTION

The Apollo Lunar Surface Operational Requirements document delineates the operating concepts and the real-time support requirements for the Apollo Lunar Surface Experiments Package (ALSEP) program and the Early Apollo Scientific Experiments Package (EASEP) program.

ALSEP/EASEP is comprised of a group of individual experiments and supporting subsystems which will be transported to the lunar surface aboard the Lunar Module (LM). After landing on the lunar surface, the astronauts will extract the ALSEP/EASEP from the LM, deploy the instruments and subsystems, and initiate the operation of the package. The ALSEP will be self-sufficient during operation, using a radioisotopic thermoelectric generator for electrical power. The EASEP will be self-sufficient during operations using a solar cell array for electrical power. The ALSEP/EASEP data subsystems will collect, format, and transmit scientific and engineering data to the receiving sites on earth for up to 1 year (possibly 2 years). These data will be used to derive information on the composition and structure of the lunar body, magnetic field, atmosphere, and the solar wind. Command and telemetry communications will be provided by the Manned Space Flight Network (MSFN).

At present, there are three separate ALSEP Flight System Packages and one EASEP Flight System Package. The EASEP Flight System Package is comprised from the ALSEP Flight System Package 2 and is planned to be flown on the first lunar mission. The experiment complement for the flight systems are defined as follows:

ALSEP Flight System 1

Passive Seismic
Lunar Surface Magnetometer
Solar Wind Spectrometer
Suprathermal Ion Detector/Cold Cathode Gauge

ALSEP Flight System 3

Passive Seismic
Heat Flow
Cold Cathode Gauge
Charged Particle Lunar Environment

ALSEP Flight System 4

Passive Seismic
Active Seismic
Suprathermal Ion Detector/Cold Cathode Guage
Charged Particle Lunar Environment

EASEP Flight System

Passive Seismic
Laser Ranging Retro-Reflector
Solar Wind Composition

ALSEP/EASEP TELEMETRY

The data from the individual experiments will be combined into a single telemetry link by the ALSEP/EASEP data subsystem, then transmitted to MSFN sites. The downlink telemetry can have three different transmission rates: 10600, 1060, and 530 bit per second (bps). The 1060 bps will be the normal transmission rate to all MSFN sites with the 530 bps as a backup mode. The 10600 bps rate will be used twice during the year on flight system number 4 for a duration of approximately 1 hour when the Active Seismic Experiment is activated and when a controlled seismic disturbance is created on the lunar surface. Additionally, the 10600 bps mode will preempt the normal 1060 bps mode approximately once a week for 1-hour periods when the Active Seismic Experiment is operating in a listening mode. In the listening mode, the seismic detection system monitors natural seismic activity generated by tectonic disturbances or meteoroid impacts. The MSFN will receive, demodulate, and record continuously all ALSEP/EASEP telemetry data. Telemetry data will be processed and retransmitted for real-time analysis at the Mission Control Center (MCC).

All data will be recorded continuously on magnetic tape at the MSFN sites and sent to MSC for decommutation and reduction. Data tapes from the MSFN sites will contain up to five channels of data. One channel will contain timing information recorded at the remote sites, and the other channels will contain the respective ALSEP/EASEP data streams.

The telemetry data format for the normal mode (1060 bps) of operations will consist of 64 words per frame with 10 bits per word (reference Figures 1 and 2). Subcommutation for the individual experiments will be discussed under Specific Experiment Requirements. The telemetry format for the 530 bps mode will be the same as for the 1060 bps mode. The telemetry format for the high-bit-rate mode (10600 bps) of operation will consist of 32 words per frame with 20 bits per word. In the high-bit-rate mode, no more than 2.4 Kbps of data pertaining only to the Active Seismic Experiment will be transmitted to MCC for real-time analysis.

1 *	2 *	3 *	4 X	5 0	6 X	7 S	8 X
9 —	10 X	11 —	12 X	13 —	14 X	15 I	16 X
17 0	18 X	19 0	20 X	21 0	22 X	23 S	24 X
25 —	26 X	27 —	28 X	29 —	30 X	31 I	32 X
33 H	34 X	35 o	36 X	37 o	38 X	39 S	40 X
41 —	42 X	43 —	44 X	45 —	46 CV	47 I	48 X
49 0	50 X	51 0	52 X	53 0	54 X	55 S	56 I
57 —	58 X	59 —	60 X	61 —	62 X	63 I	64 X

(a) Flight systems 1

1 *	2 *	3 *	4 X	5 CV	6 X	7 CP	8 X
9 —	10 X	11 —	12 X	13 —	14 X	15 CG	16 X
17 CP	18 X	19 CP	20 X	21 HF	22 X	23 CP	24 X
25 —	26 X	27 —	28 X	29 —	30 X	31 CG	32 X
33 H	34 X	35 o	36 X	37 o	38 X	39 CP	40 X
41 —	42 X	43 —	44 X	45 —	46 X	47 CG	48 X
49 NA	50 X	51 NA	52 X	53 NA	54 X	55 CP	56 CG
57 —	58 X	59 —	60 X	61 —	62 X	63 CG	64 X

(b) Flight system 3.

1 *	2 *	3 *	4 X	5 CV	6 X	7 CP	8 X
9 —	10 X	11 —	12 X	13 —	14 X	15 I	16 X
17 CP	18 X	19 CP	20 X	21 NA	22 X	23 CP	24 X
25 —	26 X	27 —	28 X	29 —	30 X	31 I	32 X
33 H	34 X	35 o	36 X	37 o	38 X	39 CP	40 X
41 —	42 X	43 —	44 X	45 —	46 X	47 I	48 X
49 NA	50 X	51 NA	52 X	53 NA	54 X	55 CP	56 I
57 —	58 X	59 —	60 X	61 —	62 X	63 I	64 X

(c) Flight system 4.

Legend

		Number of words per frame		
		1	3	4
*	Control	3	3	3
X	Passive Seismic, short period	29	30	30
—	Passive Seismic, long period seismic	12	12	12
o	Passive Seismic, long period tidal and one temperature	2	2	2
0	Magnetometer	7		
S	Solar Wind	4		
I	Suprathermal Ion Detector	5		5
HF	Heat Flow		1	
CP	Charged Particle		6	6
CV	Command verification (upon command; otherwise, all zeros)	1	1	1
H	Housekeeping	1	1	1
NA	Not assigned (all zeros will be transmitted)		3	4
CG	Cold Cathode Gage Experiment (MSC)		5	
	Total	64	64	64

Note: Each box contains one 10-bit word. Total bits per frame, 10 x 64 = 640 bits for 530 bps and 1060 bps.

Figure 1.- ALSEP Telemetry Word Formats

1 *	2 *	3 *	4 X	5 NA	6 X	7 NA	8 X
9 -	10 X	11 -	12 X	13 -	14 X	15 NA	16 X
17 NA	18 X	19 NA	20 X	21 NA	22 X	23 NA	24 X
25 -	26 X	27 -	28 X	29 -	30 X	31 NA	32 X
33 H	34 X	35 .	36 X	37 .	38 X	39 NA	40 X
41 -	42 X	43 -	44 X	45 -	46 CV	47 NA	48 X
49 NA	50 X	51 NA	52 X	53 NA	54 X	55 NA	56 NA
57 -	58 X	59 -	60 X	61 -	62 X	63 NA	64 X

Legend:

		Number of Words Per Frame
*	Control	3
X	Passive Seismic - Short Period	29
-	Passive Seismic - Long Period Seismic	12
.	Passive Seismic - Long Period Tidal and One Temperature	2
CV	Command Verification (upon command, otherwise all zeros)	1
H	Housekeeping	1
NA	Not Assigned	16
	TOTAL	64

Note: Each box contains one 10-bit word
Total bits per frame - 10 x 64 = 640 bits
for 530 and 1060 bps.

Figure 2 - EASEP Telemetry Word Format

REAL-TIME SUPPORT

The real-time support at MCC must be continuous coverage for the first 45 days (which includes one full lunar temperature cycle) of operation on each ALSEP and at least 2 hours per day thereafter until the end of the mission. Also, real-time support is required during sunrise and sunset on the lunar surface.

The real-time support at MCC for EASEP must be continuous coverage during the lunar day periods of the first 45 days of operations when the solar panels are providing operational power and at least 2 hours per day thereafter during each lunar day period until the end of the mission. Also, real-time support is required during sunrise and sunset on the lunar surface.

Real-time telemetry analysis at MCC is required for support in commanding the ALSEP/EASEP. The ALSEP/EASEP commands will originate from MCC. These commands will be used for turning experiments on and off and for changing modes of operation of the experiments. All of the commands used on ALSEP/EASEP are predetermined and can be loaded or programmed into the appropriate computers prior to the ALSEP/EASEP mission.

The MCC is required to process and display all ALSEP/EASEP telemetry data from two out of a possible four ALSEP/EASEP flight articles simultaneously. This requirement applies both to playback and real-time data.

Approximately 15 personnel (including scientists) are required to adequately staff the Apollo Lunar Surface Experiment Support Facility.

SPECIFIC EXPERIMENT REQUIREMENTS

ALSEP/EASEP Systems Measurements (Housekeeping)

The ALSEP/EASEP Systems Measurements utilize one word out of each main frame of data and are subcommutated over 90 frames. The capability to monitor all of the systems measurements continuously is required in real-time when data are being received at MCC. These data should be displayed in analog form or converted to engineering units and displayed on TV or a high-speed printer. Out-of-limits indications are to be provided for all systems measurements, regardless of whether the word is being currently displayed or not. In addition to the systems measurements, the command word, and command verification word are to be displayed. For more details on displays of ALSEP System Measurements refer to MSFN/MCC/ALSEP Specification No. ICD 314118.

Passive Seismic Experiment (PSE)

The PSE data occupy 43 words in each ALSEP/EASEP frame for ALSEP flight system 1 and the EASEP flight system, and 44 words in each ALSEP frame for ALSEP flight systems 3 and 4. The PSE data to be analyzed in real-time at MCC consist of four seismic outputs continuously displayed on eight drum recorders with low frequency bandpass filters, three tidal outputs and one temperature output continuously displayed on a slow-speed (Multipoint preferred) recorder with timing information, and eight channels of engineering data included in the ALSEP/EASEP system (housekeeping) data. Calibration data for the four seismic outputs will be occasionally displayed on a high-speed, rectilinear strip chart recorder (such as an 8-channel Brush recorder) with timing information. The eight drum recorders must have the capability of displaying the seismic data with or without low frequency bandpass filters. The engineering data should be displayed on the high-speed printer or on the television displays and will not be required by the Principal Investigator on a continuous basis, but would have callup capability. The PSE data words are formatted as follows:

Long period seismic data	Words
X-axis (N-S)	9, 25, 41, 57
Y-axis (E-W)	11, 27, 43, 59
Z-axis	13, 29, 45, 61
Short period seismic data	
Z-axis	Every even word except 2, 46*, 56
Long period tidal data	
X-axis (N-S)	35 on even frames
Y-axis (E-W)	37 on even frames
Z-axis	35 on odd frames
Sensor unit temperature data	37 on odd frames

* Applicable to ALSEP flight systems 1 and EASEP flight system. Word 46 is used for short period seismic data on ALSEP flight system 3 and 4.

Lunar Surface Magnetometer Experiment (LSM)

The LSM data contain seven 10-bit words in each ALSEP frame comprised of six words of scientific data and one word of engineering (housekeeping) data. Word 5 in the ALSEP frame is used for LSM engineering data and is subcommutated over 16 frames for a complete data record. The remaining words (17, 19, 21, 49, 51 and 53 in each ALSEP frame) are scientific data and are not subcommutated. Words 17 and 49 are used for the X-axis measurement. Words 19 and 51 are used for the Y-axis measurement. Words 21 and 53 are for the Z-axis measurement. The scientific data are to be displayed on either analog chart recorder and/or high-speed printer; the engineering data are to be displayed in the same manner.

Solar Wind Spectrometer Experiment (SWS)

The SWS data consist of four 10-bit words in each ALSEP frame (words 7, 23, 39, and 55). This output sequence has a cyclic repetition of 186 words (46.5 ALSEP frames) requiring 28.1 seconds of transmission time at normal 1060 bps ALSEP telemetry rates. The 186-word block is subcommutated over 16 cycles such that 2976 words (744 ALSEP frames) represents a full nonrepetitive data cycle. The SWS Experiment has only one operational mode which includes range changes or calibration cycles. A computer printout of the SWS data will be required for information purposes in either of the following two formats: (1) the normal format should be used when the computer is able to recognize SWS data sequences, and (2) the abnormal format should be used whenever SWS sequences cannot be recognized. The data to be analyzed in real-time at MCC consist of six words of scientific data and one word of engineering data. The scientific data should be displayed either on a TV display or a high-speed printer; the engineering data should be displayed either on an analog recorder or a high-speed printer.

Suprathermal Ion Detector Experiment/Cold Cathode Gauge Experiment (SIDE/CCGE)

The SIDE data which include the CCGE data, contain five 10-bit words in each ALSEP frame (words 15, 31, 47, 56, 63) and use a word sequence which cycles 128 times before repeating. The data are subcommutated over 256 frames for a data record. In addition, there is a supercommutation that repeats every 6144 frames or every 24 cycles of the subcommutated 256 frame cycle. The data to be analyzed in real-time at MCC consist of the five scientific data words in each frame and the two channels of engineering data included in the ALSEP systems (Housekeeping) data word. The scientific data should be displayed in engineering units with provisions for comparison of accumulated data on either a TV display or a high-speed printer. The engineering data may be displayed on a TV in engineering units or on an analog chart recorder.

Heat Flow Experiment (HFE)

The HFE utilizes one 10-bit word in each ALSEP frame (ALSEP word 21). The scientific data are subcommutated over 721 frames for a complete data record. The seven channels of engineering data are subcommutated with other ALSEP engineering and housekeeping data in word 33 of the ALSEP telemetry frame. The data to be analyzed in real-time at MCC consist of the sixteen scientific data measurements and the seven channels of engineering data. The HFE measurements should be displayed in engineering units intermittently on a TV display or printout. It is preferable for 5 selected scientific data words (to be determined) to be displayed on a slow-speed recorder (Multipoint recorder preferred); however, a TV display or a computer printout is acceptable.

Cold Cathode Gauge Experiment (CCGE)

The CCGE, an independent experiment without the SIDE, utilizes five 10-bit data words in each ALSEP frame (words 15, 31, 47, 56 and 63). These scientific data, utilizing the same words as the SIDE, will require a different telemetry data format through the central station and should be displayed intermittently on either a TV display or a high-speed printer.

Charged Particle Lunar Environment Experiment (CPLEE)

The CPLEE data utilize six 10-bit words in each ALSEP frame (words 7, 17, 19, 23, 39 and 55). Two frames are required for a complete data record. The data to be analyzed in real-time at MCC consist of the six scientific data words in each frame and the six channels of engineering data included in the ALSEP system data word. The scientific data are to be displayed in engineering units either on TV or printed out with provision for displaying 32 frames of data simultaneously in two different modes. One mode will be with the data continuously updated and the other mode will be with the data updated when the value changes 10% from the previously displayed data. The engineering and scientific data are to be displayed on a TV display or high-speed printer.

Active Seismic Experiment (ASE)

The ASE uses the high-bit-rate (10600 bps) telemetry format. Only the ASE data and some ALSEP housekeeping data will be transmitted in the high-bit-rate mode. For further format details, refer to MSFN/MCC/ALSEP specifications No. ICD 314118. The data to be analyzed in real-time at MCC consist of scientific data from the geophones and engineering systems measurements. Due to the 2.4 Kbps limitation on data transmission from an MSFN site to MCC, a uniform sampling of the 10.6 Kbps should be made (that is, approximately one out of every four or five data points from each geophone plus the engineering data should be transmitted to MCC). The scientific data from each geophone should be displayed separately in analog form on a chart recorder. The engineering data should be displayed in engineering units on a high-speed printer or on a TV display. All 3 channels of geophone data are to be displayed separately in analog form on a chart recorder. The explosive shot break instant (an event) should be stripped out and displayed on the same chart recorder as the geophone data. Specific ALSEP systems data will require display on a high-speed printer during display of ASE.

Laser Ranging Retro-Reflector Experiment (LRRR)

The LRRR is a passive experiment consisting of an array of precise optical corner reflectors assembled into an adjustable support structure and attached to an ALSEP pallet. No telemetry data is transmitted on the ALSEP data stream.

Solar Wind Composition Experiment (SWC)

The SWC Experiment, an independent passive experiment and not a part of the EASEP package, consists of a panel of very thin aluminum foil rolled and assembled into a combination handling and deployment container. No data analysis will be required at MCC.

General Requirements

Data format selection capability from the Science and Applications Directorate Console positions is required for all displayed ALSEP/EASEP experiment data (including housekeeping) that is being transmitted to MCC from MSFN.