Apollo 17 ALSEP ARCSAV Lunar Surface Gravimeter Raw Cleaned ASCII Data Collection (1975-092 to 1975-181)

Overview

The astronauts on the Apollo missions deployed a set of scientific instruments that were collectively known as the Apollo Lunar Surface Experiments Package (ALSEP) at each of the Apollo 12, 14, 15, 16, and 17 landing sites [1]. The ALSEP instruments operated from the time of deployment to September 1977 at each site [2]. This collection from the Apollo 17 site consists of cleaned (corrected) ASCII tabular files of Lunar Surface Gravimeter (LSG) raw data for the period of April 2, 1975 through June 30, 1975. These scientific, housekeeping, and command verification data were extracted from NASA's original ALSEP data archival tapes (also known as ARCSAV tapes) that recorded rearranged and time-edited, raw, unprocessed binary data transmitted from the Moon.

ARCSAV Processing History

From April 1973 to February 1976, approximately 5000 ALSEP ARCSAV tapes were generated at the NASA Johnson Space Center. They were 7-track, digital, open-reel magnetic tapes. One ARCSAV tape contained a 24-hour, continuous recording of the raw binary data for all the ALSEP instruments deployed at one of the Apollo landing sites [3]. Data from several instruments were intermeshed into ALSEP frames, each consisting of 64 ALSEP data words as shown in Appendix A.

In the years following the conclusion of the Apollo program, all of these tapes were lost. In the year 2010, 439 of these tapes, containing data from April 2, 1975 through July 1, 1975, were found at the Washington National Records Center [4]. Funding from the NASA Lunar Advanced Science & Exploration Research (LASER) and Planetary Data Archiving, Restoration, & Tools (PDART) programs NNH10ZDA001N-LASER and NNH14ZDA001N-PDART14 facilitated the extraction of data from ARCSAV tapes [4] and transformation to raw digital data sets of various levels of processing, some of which are archived at the NASA Space Science Data Coordinated Archive (NSSDCA) [5]:

- NSSDCA data set PSPG-00916 consists of daily binary files of raw, intermeshed Apollo 17 experiment data “as read” and extracted from those 439 ARCSAV tapes, but without corrections for obvious bit errors. These obvious bit errors and byte shifts and splits from tape reads were corrected to make cleaned, raw Apollo 17 daily binary files for NSSDCA data set PSPG-00920. Corrections were possible because the original ALSEP ARCSAV document is still available [3].
- NSSDCA data set PSPG-00923 consists of 79 daily files of raw binary LSG data extracted from the cleaned ARCSAV data set for Apollo 17, PSPG-00920.
- This present collection is a transformation of 79 daily LSG raw binary files in NSSDCA data set PSPG-00923 into ASCII format. The Fortran programs used by the data provider for transformation are included, for documentation purposes only, in same document collection as this data description file.

Required Reading

The user should read several publications before using this collection.

Required: [3] provides a detailed description of the contents of the ALSEP ARCSAV tapes. Relevant sections in [3] are 1.0, 2.0, 6.12, and Appendix E including pages E-34 through E-40 that explain the LSG measurements. [6] provides detailed engineering and operations information about the Apollo 17 ALSEP station (also known as Array E and Array 5) and the LSG experiment. The most relevant chapters in [6] are 6 - ALSEP telemetry subsystem, and 10 - LSG operations, modes and measurements.

Strongly Recommended: [2] provides a very detailed operational history of each individual ALSEP experiment, including operational status, anomalies, and failures by date. [9] describes the LSG experiment and reports initial results. [12] presents the final LSG report from the experimenters.

Additional detailed engineering and operations information on the Apollo 17 ALSEP station and the LSG are provided in [7]. For a brief description of a specific Apollo scientific experiment together with its operational history and its data content, formats, and availability during the Apollo era, see [8].

Overview of Data Products

This collection contains three types of data products, where each type consists of a file of time-ordered, ASCII data in fixed-width tabular format (.tab) and a detached PDS label (.xml) that defines the format and contents of the data file:

- Raw Science Data: 79 daily products of raw LSG scientific measurements with filenames a17_lsg_1975DDD_l1_arcsav.tab/.xml, where DDD is the day of year,
- Raw Housekeeping: One product of raw analog LSG Housekeeping (Engineering) data with filename a17_lsg_1975_l1_arcsav_hk.tab/.xml, and
- Command Verification: One product containing a log of LSG Command Verifications with filename a17_lsg_1975_l1_arcsav_cv.tab/.xml.

All data in this collection were acquired while the LSG experiment was operating in normal science data mode (not in shaft-encoder mode).

Raw Science Data Products

These products contain raw, unreduced, seismic, tidal, free mode and temperature measurements and associated operational status and encoded command counter information that were converted within the LSG experiment to digital data numbers (DN) and stored in 36 designated ALSEP Main Frame Words [3, 6] at the proper demand time in serial form for relay to Earth. ALSEP Main Frame Words are also known as ALSEP data words or simply as ALSEP words.

Each daily ASCII file (a17_lsg_1975DDD_l1_arcsav.tab) consists of one header record followed by two tables in this order:

1. Header: A single record that identifies the columns (fields) in the TimeOffsets and RawData tables.

2. TimeOffsets Table: A one-record fixed-width ASCII table that provides a derived sampling-rate-adjusted delay time as an offset in milliseconds for computing the time for each data measurement in each RawData Table record.

   The sampling-rate-adjusted delay times (offsets) were calculated using an ALSEP frame duration time of 603.77 milliseconds per frame, or 9.4339 milliseconds per ALSEP data word. (There are 64 words per ALSEP frame). This frame duration time was computed by taking the average of the minimum and maximum of the daily mean sampling rates for the ALSEP frames for the time span of this data collection.

3. RawData Table: A multi-record fixed-width ASCII table where each record contains the scientific measurements from one ALSEP frame. Each record begins with the earth-received time in UTC for the set of data in that record followed by 34 raw scientific measurements identified by their LSG Measurement Number, DG-n: 31 seismic (DG-1); 1 tidal (DG-2); 1 free mode (DG-3); and 1 temperature (DG-4); and 9 experiment status and encoded command counter fields (DG-11 through DG-19 from two ALSEP Words). A cross reference of each DG measurement number to a unique data sample ("Measurement Name") is provided on page E-34 and E-35 of [3] and in Table 6-XV of [6], shown in Appendix C below.

   These raw measurements are provided in the RawData table as decimal integers, or base 2 integers (DG-11 and DG-19 only), with units of data number (DN) which is another name for digital unit (DU), the term typically used in ALSEP documentation. DN or DU, also known as digital count or instrument count, is the unit of measure for the raw digital number output by the experiment analog-to-digital converter. The label specifies units of DN which is the PDS convention.

   The PDS data label defines for layout of this table and describes the contents of each column and if applicable its range of values and their meanings, except for DG-19 values that are decoded in Appendix B. Additional explanation of the contents is provided here:

   - Records are ordered by the earth-received time in the first column. The format is YYYY-DDDTHH:MM:SS.sss, where DDD is day of year.

     This earth-received time is the time when the first word of the ALSEP frame was received on earth, referenced to the standard time signal received at the Manned Space Flight Network station. When the operators had a problem reading the time signal, they substituted it with a computer-generated time, which they called the "software clock".

     The earth-received time is followed by a quality flag which is set to an asterisk "*" if the time value is from the software clock; if there is a suspected transmission, data synchronization or tape read error in the value; or if the time value is clearly outside the expected range for this restoration effort. A negative sign "-" indicates this value is the earth-received time, and the value does not have a suspected read or transmission error or that it is unknown if there was an error and therefore could still contain an error.

   - The status column, which follows the earth-received time, contains four 1-byte flags copied from the ARCSAV tapes. Each byte is one of the four 3-bit sync status flags for the ALSEP frame. The one-byte flags from left to right are: 1) unedited time sync status; 2) unedited data sync status; 3) edited time sync status; and 4) edited data sync status. The time sync status can be any value between 0 and 7, while the data sync status can only be 0, 4, 5, or 7 [3]. Although Section 2 of [3] explains the status values, it does not define the difference between unedited and edited status flags nor does ALSEP literature that was searched.

- The “tsd” column, which follows the status column, contains three 1-byte flags set during reading and processing of the ARCSAV tapes. The left-most byte is set to 1 if a tape read or transmission error is indicated for the earth-received time. The middle byte is set to 1 if a tape read or transmission error is indicated for the data sync value. The right-most byte is set to 1 if a tape read or transmission error is indicated for any of the data values.
- The user should refer to the required reading sections in [3] and [6] to understand the raw measurement values. These publications show the scientific measurements DG-1 to DG-4 are each a 9-bit word plus a polarity bit, and thus the range of integer values in the RawData table is -511 to +511 DN. The nine experiment status and command counter measurements are interpreted as follows:
    - DG-11 is a 6-bit base 2 integer that contains one bit for each of the 6 temperature relays. Table 6-XV of [6] defines the meaning of bit values 0 and 1.
    - Each of DG-12 and DG-14 to DG-18 is a 1-bit experiment status indicator resulting in a decimal integer value of 0 or 1. Table 6-XV of [6] defines the meaning these values for each measurement.
    - DG-13 is a 2-bit experiment status indicator resulting in a decimal integer value ranging from 0 to 3. Table 6-XV of [6] defines the meaning these values.
    - DG-19 is a 6-bit encoded command counter represented as a base 2 integer. Appendix B decodes the counter values to command functions.
- Table 6-XV of [6], shown in Appendix C, specifies the sensor accuracy and dynamic range for scientific measurements DG-1 through DG-4. Please note these values are given in physical units, not DN.
- Each DG data value is followed by a quality flag which is set to an asterisk “*” if that data value has a suspected transmission, data synchronization or tape read error. A negative sign “-” indicates this data measurement does not have a suspected read or transmission error or that it is unknown if there was an error and therefore could still contain an error.
- To compute the time for a specific data measurement, add the milliseconds time offset, which is found in the single-record table TimeOffsets for the data measurement column of interest, to the time stamp (earth-received time) in the first column of the RawData record containing the data measurement of interest.
- The earth-received times can be reformatted from YYYY-DDDTHH:MM:SS.sss to decimal day by extracting the day of year (DDD), hour (HH), minute (MM), and seconds (SS.sss) strings from the timestamp, converting them to floating point, then performing this calculation:

    decimal day = DDD + (HH*3600. + MM+60. + SS.sss) / 86400.0

    where 86400.0 is the number of seconds in a day. Pay careful attention to the number of digits the computer carries. For example, to preserve the millisecond-resolution of the timestamps 11 decimal digits (or 35 binary digits) need be kept, and therefore the variables DDD, HH, MM, and SS.sss may need to be defined as double-precision floating point. Using single-precision floating-point variables to reformat the timestamps would reduce the resolution to about a second.

Raw Housekeeping Data Product

This product contains raw LSG Housekeeping (HK) measurements, identified by Measurement Numbers AG-n, from analog sensors that indicate the condition of the LSG experiment. Housekeeping measurements were stored in ALSEP Word 33 for relay to Earth.

The ASCII HK file (a17_lsg_1975_l1_arcsav_hk.tab) consists of one header record followed by two tables in this order:

1. Header: A single record that identifies the columns (fields) in the TimeOffsets and RawHK tables.
2. TimeOffsets Table: A one-record fixed-width ASCII table that provides a derived sampling-rate-adjusted delay time as an offset in milliseconds for computing the time for each data measurement in each RawHK Table record.

   The sampling-rate-adjusted delay times (offsets) were calculated using the same ALSEP frame duration time as the Raw Science Data Product: 603.77 milliseconds per frame, or 9.4339 milliseconds per ALSEP data word.
3. RawHK Table: A multi-record fixed-width ASCII table containing raw analog LSG Housekeeping data, where one record contains the housekeeping measurements from multiple ALSEP frames. Each record begins with the earth-received time in UTC for the set of data in that record followed by 10 raw analog measurements identified by their LSG Measurement Number, AG-n: 1 seismic (AG-1); 1 tidal (AG-2); 1 free mode (AG-3); and 7 additional housekeeping parameters (AG-4 through AG-10) indicating the condition of the LSG.

   These raw measurements are provided in this table as decimal integers with units of data number (DN). The user should refer to the required reading sections in [3] and [6] to understand the raw HK values and the operating ranges for the HK analog sensors. These publications indicate the value for a raw HK measurement comprises 8-bits, and thus the range of integer values in the RawHK table is 0 to +255 DN. Please note the operating ranges for AG-1 to AG-10 are given in physical units such as volts, not DN.

   AG-1, AG-2, and AG-3 measure the same physical quantities as DG-1, DG-2, and DG-3 (seismic, tide, and free mode, respectively) except that they were sampled at much lower frequencies and at lower resolutions.

   The PDS data label defines for layout of this table and describes the contents of each column and if applicable its range of values and their meanings. Additional explanation of the contents is provided here:

   - Records are ordered by the earth-received time in the first column.

     This earth-received time is the UTC time when the first word of the ALSEP frame containing the AG-2 measurement was received on earth, referenced to the standard time signal received at the Manned Space Flight Network station. When the operators had a problem reading the time signal, they substituted it with a computer-generated time, which they called the “software clock”.

     The earth-received time is followed by a quality flag which is set to an asterisk “*” if the time value is from the software clock; if there is a suspected transmission, data synchronization or tape read error in the value; or if the time value is clearly outside the expected range for this restoration effort. A negative sign “-” indicates this value is the earth-received time, and the value does not have a suspected read or transmission error or that it is unknown if there was an error and therefore could still contain an error.

- The status column, which follows the earth-received time, contains the same type of four 1-byte flags as the status column defined for and used in the Raw Science Data Product.
- A HK value of integer -9 (negative nine) indicates a missing value.
- Table 6-XV of [6], shown in Appendix C, specifies the operating ranges for the analog sensors for HK measurements AG-1 through AG-10. Please note these values are given in physical units, not DN.
- Each HK data value is followed by a quality flag which is set to an asterisk "*" if that data value has a suspected transmission, data synchronization or tape read error. A negative sign "-" indicates this data measurement does not have a suspected read or transmission error or that it is unknown if there was an error and therefore could still contain an error.
- To compute the start time for a specific Housekeeping measurement, add the milliseconds time offset, which is found in the single-record table TimeOffsets for the Housekeeping measurement column of interest, to the time stamp (earth-received time) in the first column of the RawHK record containing the Housekeeping measurement of interest.
- *Note:* The first three parameters AG-1, AG-2, and AG-3 measured physical quantities that were identical to DG-1, DG-2, and DG-3 (seismic, tide, and free mode, respectively) except that they were sampled at much lower frequencies and at lower resolutions.

Command Verification Data Product

This product provides a time-ordered log of commands specific to LSG operations that were received by Apollo 17 ALSEP and acted upon. These Command Verifications (CV) are stored in ALSEP Word 7 as Measurement Numbers DA-5 and DA-6 for relay to Earth.

The ASCII CV file (a17_lsg_1975_l1_arcsav_cv.tab) consists of one header record and one table in this order:

1. Header: A single record that identifies the columns (fields) in the CVLog table.
2. CVLog Table: A multi-record fixed-width ASCII table providing a log of time-ordered Command Verification (CV) messages for LSG operations. CV messages consist of a command counter code (the CV value) and its Message Acceptance Pulse (MAP) bit flag that reads out a "1" when the command parity error check was successful and the command was accepted and acted upon, as explained on page E-8 of [3]. Each record contains an earth-received time, the command counter code as an octal integer and its MAP for one CV message. The CV values for LSG operations are listed in Appendix D of this document.

    - Records are ordered by the earth-received time in the first column.

      The time given here is not the command time. It is the earth-received time in UTC of the first word of the ALSEP frame in which the CV was recorded, referenced to the standard time signal received at the Manned Space Flight Network station. The command was received and acted upon sometime before the CV was recorded (+57 milliseconds after the earth-received time). When the operators had a problem reading the time signal, they substituted it with a computer-generated time, which they called "software clock".

      The earth-received time is followed by a quality flag which is set to an asterisk "*" if the time value is from the software clock; if there is a suspected transmission, data

synchronization or tape read error in the value; or if the time value is clearly outside the expected range for this restoration effort. A negative sign "-" indicates this value is the earth-received time, and the value does not have a suspected read or transmission error or that it is unknown if there was an error and therefore could still contain an error.

- The status column, which follows the earth-received time, contains the same type of four 1-byte flags as the status column defined for and used in the Raw Science Data Product.
- The command counter code and its MAP bit are followed by a quality flag which is set to an asterisk "*" if the CV and/or its MAP has a suspected read or transmission error. A negative sign "-" indicates these values do not have a suspected read or transmission error or that it is unknown if there was an error and therefore could still contain an error.

Caveats/Confidence Level

Earth-Received Time vs. Data Acquisition Time

The earth-received times in the data products are approximately 1.19 to 1.37 seconds after the time when the data were acquired on the moon. This estimate, taken from ephemerides computed by the JPL Horizons System (https://ssd.jpl.nasa.gov/?horizons), is the minimum and maximum one-way down-leg light-time from the center of the moon (radius 1737 km) to a Manned Space Flight Network station on Earth (Canberra or Goldstone) for the time span of the data products.

Data Gaps

There are no LSG data for days 104-107, 117-120, and 133-135 because the Apollo 17 ALSEP station was operating in high-bit-rate to accommodate the Lunar Seismic Profiling Experiment in listening mode [10].

Raw Data vs. Reduced Data

This collection contains only raw, unreduced data in units of DN (digital counts). Information for transforming the raw DN to physical values is not readily available, and providing this along with calibration information and transfer function of the instrument is beyond the scope our restoration effort. However, the seismic response of LSG is described by [11]. Also see [12] and [13]. Please note Table 6-XV of [6] provides design values, which may be sufficient for some analyses, and not the real calibration values.

Data Quality

The goal for this restoration was to recover as much of the original data from tape as possible without overinterpreting and overcorrecting the values. The source binary files contain data that were corrected (cleaned) to remove byte shifts caused by missing, combined, extra, and split bytes that resulted from tape-reading errors. Only the obvious errors were corrected, and thus many bit errors may still remain in the source binary files and are carried over to the ASCII products in this collection. Correcting and flagging of all possible errors were beyond the scope of this restoration. However, the user needs to be aware of these errors and know that these could be corrected, if necessary, but not always. Some known data quality issues most likely caused by a transmission, data synchronization or tape read errors are:

- Some values for earth-received time appear to be out of temporal order; may overlap with other timestamps; are outside the time range of this collection; or are an unreasonable value

for day of year such as 397. These cases are likely caused by bit errors. Since this type of problem is always present in the ALSEP data, this restoration effort attempted to flag earth-received times whenever such a problem was suspected. Since the data that follow are likely to be correct, the incorrect times can often be interpolated from correct times before and after. Some bit errors, such as a single-bit error, can be corrected if it is obvious, but correcting other types errors, such as those already existed when the ARCSAV tapes were created and thus indicated with their time-sync status flags, can require subjective judgments, which can be false. One solution would be to ignore the data when an error is suspected, but this may not be appropriate.

The user should aware that this attempt to evaluate the earth-received times was not perfect, and therefore there may be cases where the quality flag for is not turned on (not set to an asterisk "*") for a value that appears to be incorrect.

- Some values in the status column may be incorrect that most likely resulted from tape read or data synchronization errors. This is often reflected in the quality flags for the data columns, which are turned on (set to an asterisk "*") when the data are out of synchronization.
- The Command Verification file contains 20 instances where the command counter has a value of octal 73. This is not a valid code for Apollo 17 ALSEP and is most likely caused by a transmission, data synchronization or tape read error. The correct value is likely to be an octal 72 command.

References

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Appendix A

The Apollo 17 ALSEP main frame word assignments from [6], [3].

ALSEP word assignment for array E

ALSEP 5
BASIC

1 SYNC	2 SYNC	3 SYNC & ID	4 LSG	5 LMS	6 LSG	7 COMMAND VERIFI-CATION	8 LSG
9 N/A	10 LSG	11 N/A	12 LSG	13 N/A	14 LSG	15 N/A	16 LSG
17 LMS	18 LSG	19 LMS	20 LSG	21 LMS	22 LSG	23 HF	24 LSG
25 LSG	26 LSG	27 LSG	28 LSG	29 LSG	30 LSG	31 LEAM	32 LSG
33 HOUSE-KEEPING	34 LSG	35 LSG	36 LSG	37 LSG	38 LSG	39 LEAM	40 LSG
41 N/A	42 LSG	43 N/A	44 LSG	45 N/A	46 LSG	47 N/A	48 LSG
49 N/A	50 LSG	51 N/A	52 LSG	53 N/A	54 LSG	55 N/A	56 LSG
57 N/A	58 LSG	59 N/A	60 LSG	61 N/A	62 LSG	63 RESERVE POWER	64 LSG

Each square represents 1 10-bit word. Total matrix = 10 x 64 = 640 bits/frame
N/A = not assigned

	Number of words per main frame
Control words (sync)	3
Lunar Mass Spectrometer Experiment	4
Command verification (8 bits upon command, otherwise all zeros)	1
Lunar Surface Gravimeter Experiment	36
Heat Flow Experiment	1
Lunar Ejecta and Meteorite Experiment	2
Housekeeping	1
Reserve power	1
Words not used (zeros are sent for each empty word)	15
Total	64

Figure 6-1.- Main frame format.

6-5

Appendix B

The command functions indicated by the 6-bit command counter, which is LSG Measurement Number DG-19 in the Raw Science Data Products:

Base2 Count*	Octal Count	Function
100000	40	Counter Clear
100001	41	Read Shaft Encoder
100010	42	Mass Change Motor ON
100011	43	Bias In
100100	44	Bias Out
100101	45	Integrator, Normal Mode
100110	46	Integrator, Short Mode
100111	47	Seismic Low Gain
101000	50	Seismic High Gain
101001	51	Sensor Beam Caged
101010	52	Sensor Beam Uncaged
101011	53	Coarse Screw Servo ON
101100	54	Tilt, Mass Change, Screw Servos and Pressure Transducer OFF
101101	55	Pressure Transducer ON
101110	56	Mass Change Increment
101111	57	Gross Slew Up/Tilt Increment Up
110000	60	Gross Slew Down/Tilt Increment Down
110001	61	Vernier Slew Up
110010	62	Vernier Slew Down
110011	63	Fine Screw Servo ON
110100	64	North/South Tilt Servo ON
110101	65	East/West Tilt Servo ON
110110	66	Temperature Increment Relay #1
110111	67	Temperature Increment Relay #2
111000	70	Temperature Increment Relay #3
111001	71	Temperature Increment Relay #4
111010	72	Temperature Increment Relay #5
111011	73	Temperature Increment Relay #6
111100	74	Temperature Reset
111101	75	Post Amp. Gain Increment
111110	76	Post Amp. Gain Reset
111111	77	Unassigned

* The most-significant (left-most) bit is always set to 1.

This information was excerpted from [3] and pages 5-24 to 5-30 in [6]. Detailed descriptions of the DG-19 command counter functions, also known as "LSG Encoded Commands", can be found in Chapter 3 of [7].

Appendix C

Description of the LSG scientific, operational status, and housekeeping measurements from pages 6-34 to 6-37 in [6].

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ALSEP 5
BASIC/PCN-1

TABLE 6-XV.- LSG MEASUREMENTS
(36-WORD LSG MAIN FRAME)

Scientific Measurements:

Symbol	Measurement	ALSEP Word	Frame	Dynamic Range	Sensor Accuracy	Words/ Frame
DG-1	Seismic	Even No.*	Every	0.0001 to 0.1 Micron	±0.0001 Micron	31
DG-2	Tide	25	Every	0 to 2000μ gals	±2.0μ gals	1
DG-3	Free Mode	27	Every	0.004 to 4μ gals	±0.004μ gal(rms)	1
DG-4	Sensor Temperature	29	Every	50° C ± 2° C	±0.002° C	1

P-1

*Every even-numbered word except #2.

LSG Data Format for DG-1 through DG-4

Bit Position	1	2	3	4	5	6	7	8	9	10
Binary	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Transmitted Data	(MSB)	Ten Bits of Scientific Data								(LSB)

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TABLE 6-XV.- LSG MEASUREMENTS - Continued

LSG Experiment Operate Status

ALSEP Word No. 35

Meas. No.	Measurement	Meaning When Bit is 1	Meaning When Bit is 0
DG-11	Temperature Relay #1 (Bit 1)	Selected	Not Selected
	Temperature Relay #2 (Bit 2)	Selected	Not Selected
	Temperature Relay #3 (Bit 3)	Selected	Not Selected
	Temperature Relay #4 (Bit 4)	Selected	Not Selected
	Temperature Relay #5 (Bit 5)	Selected	Not Selected
	Temperature Relay #6 (Bit 6)	Selected	Not Selected
DG-12	Mass Change Motor	ON	OFF
DG-13	Coarse/Fine Screw Servo Motor Status*		
DG-14	Tilt Servo Motor	ON	OFF

* DG-13

Bit I	Bit 2	Function
0	0	OFF
0	1	OFF
1	0	NOT SLEWING
1	1	SLEWING

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LSG Command Register Status

ALSEP Word No. 37

Meas. No.	Measurement	Meaning When Bit is 1	Meaning When Bit is 0
DG-15	Command Decoder Power	ON	OFF
DG-16	Instrument Housing Heater Power	ON	OFF
DG-17	Pressure Transducer Monitor	ON	OFF
DG-18	Seismic High Gain Mode	High	Low
DG-19	Not Used - Spare (Bit 1)	Filler Bit	
	Command Counter, 2^4 Bit* (Bit 2)	ON	OFF
	Command Counter, 2^3 Bit (Bit 3)	ON	OFF
	Command Counter, 2^2 Bit (Bit 4)	ON	OFF
	Command Counter, 2^1 Bit (Bit 5)	ON	OFF
	Command Counter, 2^0 Bit (Bit 6)	ON	OFF

*The 5-Stage Command Counter Bits refer to the set of 30 LSG commands obtained via the UP, DOWN, and EXECUTE Commands (Octal commands 72, 74, and 67 respectively). When the LSG Command Decoder is powered OFF, these five bits are indeterminate (but probably all 1's).

TABLE 6-XV.- LSG MEASUREMENTS - Concluded

Engineering Measurements:

ALSEP Word No. 33

Symbol	Measurement	ALSEP Channel	Operating Range
AG-01	LSG Seismic Signal	39	± 10 Volts
AG-02	LSG Tide Signal	10	± 1000 μgals
AG-03	LSG Free Mode Oscillation Signal	23	± 10 Volts
AG-04	LSG Sensor Temperature	68	50.0° C ± 2° C
AG-05	LSG Instrument Housing Pressure	89	0.5 to 30 torr
AG-06	LSG Mass Position Signal	54	2.3 to 3.9 Volts
AG-07	LSG Oscillator Amplitude	24	15 ± 1.0 Volts (p-p)
AG-08	LSG Power Converter (+15V)	38	+15 ± .75 Volts
AG-09	LSG Power Converter (-15V)	53	-15 ± .75 Volts
AG-10	LSG Power Converter (+5V)	69	+5 ± .25 Volts

Bit Allocations for ALSEP Word 35 and 37:

Word \ Bit	1	2	3	4	5	6	7	8	9	10
35	DG-11						DG-12	DG-13		DG-14
	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6		Bit 1	Bit 2	
37	DG-15	DG-16	DG-17	DG-18	DG-19					
					Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6

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Appendix D

Command Verification values and their actions for the LSG instrument, excerpted from pages 5-24 to 5-30 in [6]. LSG commands are octal integers 52 to 57, 60, 62 to 64, 67, 70 to 72, and 74.

052 LSG ON POWER DISTRIBUTION UNIT
Command 052 actuates relays K1 and K2, in both PDU's, to the position that applies +29 Vdc to the operating line of the LSG.

053 LSG STBY POWER DISTRIBUTION UNIT
Command 053 actuates relays K1, in both PDU's, to the position that removes +29 Vdc operational power from the LSG if it is in the operate mode and applies +29 Vdc to the standby line. In the OFF mode, Command 053 has no effect.

054 LSG OFF POWER DISTRIBUTION UNIT
Command 054 actuates relays K1 and K2, in both PDU's, to the position that removes all +29 Vdc power from the LSG. LSG OFF is the lunar surface initial condition.

*

055 LSP ON POWER DISTRIBUTION UNIT

Command 055 actuates relays K1 and K2, in both PDU's, to the position that applies +29 Vdc to the operating line of the LSP. Astronaut switch 2 is in this line and telemetry will indicate LSP operational mode regardless of the state of switch 2.

056 LSP STBY POWER DISTRIBUTION UNIT

Command 056 actuates relay K1, in both PDU's, to the position that removes +29 Vdc operational power from the LSP, if it is in the operate mode and applies +29 Vdc to the standby line. The LSP has no standby mode and this line is not connected to the experiment. However, telemetry will show the standby mode. In the OFF mode, Command 056 has no effect. LSP STBY is the lunar surface initial condition.

*

057 LSP OFF — POWER DISTRIBUTION UNIT

Command 057 actuates relays K1 and K2, in both PDU's, to the position that removes all +29 Vdc power from the LSP.

060 PCU 1 SEL — POWER CONDITIONING UNIT

Command 060 actuates relay K1, in the PCU, to the position that applies +16 Vdc from the RTG to PCU 1 and disconnects PCU 2 from the RTG. In this configuration, PCU 1 provides power for the ALSEP system via PDU 1. PCU 1 is preset to be energized at initial lunar activation.

062 PCU 2 SEL — POWER CONDITIONING UNIT

Command 062 actuates relay K1, in the PCU, to the position that applies +16 Vdc from the RTG to PCU 2 and disconnects PCU 1 from the RTG. In this configuration, PCU 2 provides power for the ALSEP system via PDU 2.

063 LSG HTR ON EXP 4 (LGS)

Command 063 turns the slave heater ON. The slave heater must remain on at all times except during tilt motor or mass change motor operation. | P-1

064 LSG HTR OFF EXP 4 (LGS)

Command 064 turns the slave heater OFF. Prior to driving a tilt or mass change servo motor, CMD 064 must be transmitted in order to minimize the thermal disturbance by minimizing the peak power dissipation within the LSG. | P-1

067 LSG CMD EX EXP 4 (LSG)

Command 067 executes the command currently in the command counter. The command counter is incremented and decremented by CMD 072 and CMD 074 respectively. Execution does not clear the command counter.

070 LSG DECODER ON EXP 4 (LSG)

Command 070 applies operating power to the LSG command decoder and resets the command counter to the "00000" state.

071 LSG DECODER OFF EXP 4 (LSG)

Command 071 removes operating power from the LSG command decoder.

072 LSG STEP UP EXP 4 (LSG)

Command 072 increments the command counter one step each successful execution.

074 LSG STEP DOWN EXP 4 (LSG)

Command 074 decrements the command counter one step each successful execution.

NOTE

LSG Command Counter and Commands:

An expanded command capability is accomplished in the LSG experiment by decoding a 5-Stage, "Up-Down" command counter. Thirty of the possible thirty-two states of the counter are used to generate command functions. State of the counter is read out through the telemetry link. P-1

Three command lines are used to step the command counter (up or down), CMD 072 and CMD 074, and to generate a command execute function, CMD 067.

Following is a list of all LSG experiment command counter states and the associated functional command assignments:

Command Symbol	Binary Count	Command Function
CG-8	00001	Read shaft encoder
CG-9	00010	Mass change motor ON
CG-10	00011	Bias in
CG-11	00100	Bias out
CG-12	00101	Integrator, normal mode
CG-13	00110	Integrator, short mode