Apollo 16 ALSEP ARCSAV Lunar Surface Magnetometer Raw Cleaned ASCII Data Collection (1975-092 to 1975-181) Description

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 16 site consists of cleaned (corrected) ASCII tabular files of Lunar Surface Magnetometer (LSM) raw data for the period of April 2, 1975 through June 30, 1975. These scientific 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 data for all the ALSEP instruments deployed at one of the Apollo landing sites [3]. Data from several instruments were intermeshed into ALSEP data 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-00915 consists of daily binary files of raw, intermeshed Apollo 16 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 16 daily binary files for NSSDCA data set PSPG-00919. Corrections were possible because the original ALSEP ARCSAV document is still available [3].
- NSSDCA data set PSFP-00715 consists of 90 daily files of raw binary LSM data extracted from the cleaned ARCSAV data set for Apollo 16, PSPG-00919.
- This present collection is a transformation of 90 daily LSM raw binary files in NSSDCA data set PSFP-00715 into ASCII format. The Fortran programs used by the data provider for this transformation are included, for documentation purposes only, in same document collection as this data description.

Required Reading

The user should read several publications before using this archive.

Required: [3] provides a detailed description of the contents of the ALSEP ARCSAV tapes. Relevant sections in [3] are 1.0, 2.0, 6.9, and Appendix D including pages D-16 through D-19 that explain the LSM measurements. [6] provides detailed engineering and operations information about the Apollo 16 ALSEP station (also known as Array D) and the LSM experiment. The most relevant chapters in [6] are 6 - ALSEP telemetry subsystem, and 8 - LSM operations.

Strongly Recommended: [2] provides a very detailed operational history of each individual ALSEP experiment, including operational status, anomalies, and failures by date. [9] and [10] describe the LSM experiment and report initial results, and [11] reports intermediate results. [12] is a compilation of the final scientific results.

Additional detailed engineering and operations information on the Apollo 16 ALSEP station and the LSM are provided in [7], [10], and [11]. 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 two 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: 90 daily products of rawLSM scientific and engineering measurements with filenames a16_lsm_1975DDD_l1_arcsav.tab/.xml where DDD is the day of year, and
- Command Verification: One product containing a log of LSM Command Verifications with filename a16_lsm_1975_l1_arcsav_cv.tab/.xml.

Raw Science Data Products

These products contain raw, unreduced measurements of the vector components of magnetic fields at the lunar surface and associated engineering data that were converted within the LSM experiment to digital data numbers (DN) and stored in the designated ALSEP Main Frame Words 5, 17, 19, 21, 49, 51, and 53 [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 (a16_lsm_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.

   To compute the time for a specific data measurement, add the milliseconds time offset found in this single-record table TimeOffset for the data measurement column of interest to the

recorded time stamp (earth-received time) in the first column of the RawData record containing the data measurement of interest.

These sampling-rate-adjusted delay times (offsets) were calculated specifically for this restoration using the mean duration for each daily set of ALSEP Main Frames. For example, some timing offsets in a16_lsm_1975094_l1_arcsav.tab, where the mean ALSEP Main Frame duration for day of year 94 was 603.752 milliseconds (9.43363 milliseconds/ALSEP Word), differ by one millisecond from the offsets in a16_lsm_1975119_l1_arcsav.tab, where the mean frame duration for day of year 119 was 603.741 milliseconds.

3. RawData Table: A multi-record fixed-width ASCII table where each record contains raw scientific and engineering data from one LSM cycle. Each record begins with the earth-received time for the set of data in that record followed by 130 columns of measurements, identified by LSM Measurement Numbers DM-N, in this order: 32 columns of engineering data (DM-1 to DM-24, where DM-1 to DM-8 are each repeated twice); 32 columns of magnetic field x-axis values (DM-25); 32 columns of magnetic field y-axis values (DM-26); 32 columns of magnetic field z-axis values (DM-27); and 2 final columns of engineering data (DM-28 and DM-29). A cross reference of each DM measurement number to a unique data sample ("Measurement Name") is provided on page D-19 of [3] and in Appendix B.

   These raw measurements are provided in the RawData table as decimal integers 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. 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 containing the sequence of data measurements within the RawData record 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 user should refer to Table 6-X of [6], shown in Appendix B, to understand the LSM measurement values. The tables shows scientific magnetic field measurements DM-25, DM-26, and DM-27 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 engineering measurements are interpreted as follows:

     - DM-1 to DM-8 are each a 7-bit word without a polarity bit, and therefore the raw integer values range from 0 to +127 DN.

- Each of DM-12 to DM-15, DM-20, DM-22, DM-23, and DM-28 shares the two status bits (B1 and B2 in Table 6-X) in a frame with another measurement, resulting in an integer value of 0-1 that should be used to lookup the exact status in Table 6-X.
- Each of DM-9 to DM-11, DM-16, DM-21, and DM-24 uses the two status bits B1 and B2 from a single frame, resulting in an integer value of 0-3 that should be used to lookup the exact status in Table 6-X.
- Each of DM-17, DM-18, DM-19, and DM-29 uses two status bits B1 and B2 from a frame and one status bit (either B1 or B2) from another, resulting in an integer value of 0-6. For DM-17, DM-18, and DM-19, 0 = +75% offset, 1 = +50%, 2 = +25%, 3 = 0%, 4 = -25%, 5 = -50%, and 6 = -75%.

Table 6-X in Appendix B also gives the sensor range for magnetic field measurements DM-25, DM-26, and DM-27 and sensor range and status explanation for engineering measurements DM-1 to DM-24 and DM-28 to DM-30. Please note these range values are given in physical units, not DN.

- A raw DM value of integer -999 (negative 999) indicates a missing value.
- Each DM data column 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 the measurement could still contain an error.
- To facilitate plotting, 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.

Command Verification Data Product

This product provides a time-ordered log of commands specific to LSM operations that were received by Apollo 16 ALSEP and acted upon. These Command Verifications (CV) are stored in ALSEP Word 46 as Measurement Numbers DA-5 and DA-6 [3] for relay to Earth.

The ASCII CV file (a16_lsm_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 LSM 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 D-8 of [3]. Each record contains an earth-

received time, a time status field, the command counter code as an octal integer and its MAP for one CV message. The CV values for LSM operations are listed in Appendix C.

- 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 (+425 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 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 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.

Raw Data vs. Reduced Data

This collection contains only raw, unreduced data in units of DN (digital counts). Exact information about how to transform the raw DN to physical quantities and calibrate the data was not available when this archive was being prepared, and the effort of reducing these raw data was beyond the scope of this restoration.

For example according to Table 6-X of [6] shown in Appendix B, the raw data values of -511 to +511 DN for scientific measurements DM-25, DM-26, and DM-27 could be translated into ranges of magnetic field of ±50, ±100 or ±200 gamma (nT) depending on the values of status bits

B1 and B2 in engineering range measurement DM-16. It is likely that Table 6-X of [6] provides design values and not the real calibration values. Additionally Table 1 on page 2928 of [11] lists some parameters similar to the ones presented in [6], but these values appear to be design values. Many LSM-related papers by Palmer Dyal refer to [10], but that publication contains essentially the same information on the magnetometer characteristics as [6] and [11].

Although the design values may be sufficient for some analyses, one should look for the real calibration information to properly reduce the raw data. One possibility is to inquire at the National Archives and Records Administration, Fort Worth, Texas, where many documents from the Apollo era are stored. Another possibility is to query the principal investigator, Palmer Dyal, on whether the exact calibration information if still available.

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 archive. The user needs to aware of these errors and know that these could, if necessary, be corrected, 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 such as 397 for day of year. These cases are likely caused by bit errors. Since this type of problem is always present in the ALSEP data, the 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.

- In the science data products, the magnetic field z-axis (Bz) measurements (DM-27) mostly remain at a value of -496 DN (raw digital counts, not nT). This is not an artifact of the restoration. Most Bz values are -496 DN because the z-axis sensor failed to function properly. For this scenario, the instrument range (DM-16) is usually set to 3 which means error but there are cases where DM-16 is set to 0-2. Page 4-1, item 13 in [2] gives this status remark for Apollo 16 LSM: "On Mar. 3, 1975, the z-axis-sensor science data had become intermittently static and the temperature had reduced to off scale low during the lunar night. Flip calibrations of the sensor heads have been discontinued, at the principal investigator's request, during the lunar night operation as a result of the low temperatures of the z-axis sensor."

- There a few spikes in the magnetic field data (DM-25, DM-26, and DM-27) where the data quality flag is not set to "*" which would indicate a suspected problem. Spikes like these are

quite common in the ALSEP data and are mostly caused by a bit error in data transmission. During restoration if there was no other indication that these were errors, then the quality flag was set to a negative sign "-" which indicates the data value does not have a suspected read or transmission error or that it is unknown if there was an error. It does not mean that there was no error.

- The CV file excludes entries where both a CV and its associated time stamp were determined to be poor quality, mainly originating from tape read errors that caused both quality flags to be turned on (set to an asterisk "*").

References

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Appendix A

The Apollo 16 ALSEP main frame word assignments from page 6-9 of [6].

*

ALSEP 3
BASIC

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

Legend	Number of Words Per Frame	
x - Control	3	
X - Passive Seismic - Short Period	29	43
- - Passive Seismic - Long Period Seismic	12	
• - Passive Seismic - Long Period Tidal and One Temperature	2	
0 - Magnetometer	7	
HF - Heat Flow	1	
CV - Command Verification (upon command, otherwise all zeros)	1	
H - Housekeeping	1	
- Not Used	8	
Total	64	

Each box contains one 10 bit word
Total bits per frame - 10 x 64 = 640 bits

Figure 6-2.- ALSEP word assignment for array D.

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Appendix B

Descriptions of the LSM science and engineering DM measurements from pages 6-16 to 6-17 in [6].

TABLE 6-X.- LSM MEASUREMENTS

Scientific Measurements

Symbol	Location/Measurement	ALSEP Word	Frame	Range
DM-25	LSM X-Axis Field	17,49	Every	±50,±100,±200 gamma
DM-26	LSM Y-Axis Field	19,51	Every	±50,±100,±200 gamma
DM-27	LSM Z-Axis Field	21,53	Every	±50,±100,±200 gamma

These data are in Words 17, 19, 21, 49, 51, 53 and have the following format:

2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
*Polarity Bit	Science Data								

*0 = Plus 1, 1 = Minus

Engineering Measurements

Housekeeping is located in ALSEP Word 5 which is subcommutated over 16 frames as follows:

Bit in Word 5	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Meaning	F	A1	A2	A3	A4	A5	A6	A7	B1 Status Bits	B2
		Engineering Data								

Where B1, B2 are bistable status data
A1, ..., A7 are bits derived from analog measurements
F locates the subcommutation start, F = 1 is Frame 1 of the subcommutation and F = 0 elsewhere.

Symbol	Location/Measurement		ALSEP Word	Frame	Sensor Range		
DM-1	Sensor X Temp	Eng. Data	5	1,9	-30°C to +65°C		
DM-2	Sensor Y Temp		5	2,10	-30°C to +65°C		
DM-3	Sensor Z Temp		5	3,11	-30°C to +65°C		
DM-4	Base Temp		5	4,12	-30°C to +65°C		
DM-5	Internal Temp		5	5,13	-30°C to +65°C		
DM-6	Level Sensor 1		5	6,14	-15° to +15° (arc)		
DM-7	Level Sensor 2		5	7,15	-15° to +15° (arc)		
DM-8	Supply Voltage		5	8,16	0 to +6.25Vdc		
DM-9	X Flip Position		5	1	Discrete		2 status bits
DM-10	Y Flip Position		5	2	Discrete		2 status bits
DM-11	Z Flip Position		5	3	Discrete		2 status bits
DM-12	X Gimbal Position		5	4	Discrete		1 status bit
DM-13	Y Gimbal Position		5	4	Discrete		1 status bit
DM-14	Z Gimbal Position		5	5	Discrete		1 status bit
DM-15	Thermal Control State		5	5	Discrete		1 status bit
DM-16	Measurement Range		5	7	Discrete		2 status bits
DM-17	X Offset Field		5	9,10	Discrete		3 status bits
DM-18	Y Offset Field		5	10,11	Discrete	See Table 6-XI	3 status bits
DM-19	Z Offset Field		5	12,13	Discrete	(LSM) Page 6-17	3 status bits
DM-20	Scientific/Calibrate Mode		5	13	Discrete		1 status bit
DM-21	Offset Axis Address		5	14	Discrete		2 status bits
DM-22	Filter ON/OFF Status		5	15	Discrete		1 status bit
DM-23	Flip/Cal Inhibit Status		5	15	Discrete		1 status bit
DM-24	Filler Bits		5	16	Discrete		2 status bits
DM-28	Heater ON/OFF		5	6	Discrete		1 status bit
DM-29	Filler Bits		5	8	Discrete		3 status bits
DM-30	Frame Number		5	(Derived from F in Frame 1)			

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* Table 6-XI.- LSM 16 POINT ENGINEERING SUBCOMMUTATION FORMAT AND ENGINEERING STATUS BIT STRUCTURE LOCATED IN ALSEP MAIN FRAME, WORD 5

Frame Mark Bit	Engineering Parameter	Status Parameter	Subcommutation Frame	B_1	B_2	Status
1	Sensor X Temp	X-axis Flip Position	1	0	0	Not at 0°, 90°, or 180° position
		X-axis Flip Position	1	0	1	0° position
		X-axis Flip Position	1	1	0	90° position
		X-axis Flip Position	1	1	1	180° position
0	Sensor Y Temp	Y-axis Flip Position	2	0	0	Not at 0°, 90°, or 180° position
		Y-axis Flip Position	2	0	1	0° position
		Y-axis Flip Position	2	1	0	90° position
		Y-axis Flip Position	2	1	1	180° position
0	Sensor Z Temp	Z-axis Flip Position	3	0	0	Not at 0°, 90°, or 180° position
		Z-axis Flip Position	3	0	1	0° position
		Z-axis Flip Position	3	1	0	90° position
		Z-axis Flip Position	3	1	1	180° position
0	Base Temp	X-axis Gimbal Position	4	1		Pre Site Survey Position
		X-axis Gimbal Position	4	0		Post Site Survey Position
		Y-axis Gimbal Position	4		1	Pre Site Survey Position
		Y-axis Gimbal Position	4		0	Post Site Survey Position
0	Internal Temp	Z-axis Gimbal Position	5	1		Pre Site Survey Position
		Z-axis Gimbal Position	5	0		Post Site Survey Position
		Temp Control State	5		1	X-axis Control
		Temp Control State	5		0	Y-axis Control/OFF
0	Level Sensor 1	Heater Power Status	6	1	1	Heater ON
		Heater Power Status	6	1	0	Heater OFF
0	Level Sensor 2	Measurement Range	7	0	0	50 γ Range
		Measurement Range	7	1	0	100 γ Range
		Measurement Range	7	1	1	200 γ Range
		Measurement Range	7	0	1	Error
0	Supply Voltage 1	Filler Bits	8	1	1	Not used
0	Sensor X Temp	X-axis Field Offset	9	0	1	0% offset
0	Sensor Y Temp	X-axis Field Offset	10	1		0% offset
		X-axis Field Offset	9	1	0	-25% offset
		X-axis Field Offset	10	0		-25% offset
		X-axis Field Offset	9	1	0	-50% offset
		X-axis Field Offset	10	1		-50% offset
		X-axis Field Offset	9	1	1	-75% offset
		X-axis Field Offset	10	0		-75% offset
		X-axis Field Offset	9	0	0	+75% offset
		X-axis Field Offset	10	0		+75% offset
		X-axis Field Offset	9	0	0	+50% offset
		X-axis Field Offset	10	1		+50% offset
		X-axis Field Offset	9	0	1	+25% offset
		X-axis Field Offset	10	0		+25% offset
		Y-axis Field Offset	10		0	0% offset
0	Sensor Z Temp	Y-axis Field Offset	11	1	1	0% offset
		Y-axis Field Offset	10		1	-25% offset
		Y-axis Field Offset	11	0	0	-25% offset
		Y-axis Field Offset	10		1	-50% offset
		Y-axis Field Offset	11	0	1	-50% offset
		Y-axis Field Offset	10		1	-75% offset
		Y-axis Field Offset	11	1	0	-75% offset
		Y-axis Field Offset	10		0	+75% offset
		Y-axis Field Offset	11	0	0	+75% offset
		Y-axis Field Offset	10		0	+50% offset
		Y-axis Field Offset	11	0	1	+50% offset
		Y-axis Field Offset	10		0	+25% offset
		Y-axis Field Offset	11	1	0	+25% offset
0	Base Temp	Z-axis Field Offset	12	0	1	0% offset
0	Internal Temp	Z-axis Field Offset	13	1		0% offset
		Z-axis Field Offset	12	1	0	-25% offset
		Z-axis Field Offset	13	0		-25% offset
		Z-axis Field Offset	12	1	0	-50% offset
		Z-axis Field Offset	13	1		-50% offset
		Z-axis Field Offset	12	1	1	-75% offset
		Z-axis Field Offset	13	0		-75% offset
		Z-axis Field Offset	12	0	0	+75% offset
		Z-axis Field Offset	13	0		+75% offset
		Z-axis Field Offset	12	0	0	+50% offset
		Z-axis Field Offset	13	1		+50% offset
		Z-axis Field Offset	12	0	1	+25% offset
		Z-axis Field Offset	13	0		+25% offset
		Scientific/Cal Mode	13		0	Calibrate ON
			13		1	Calibrate OFF
0	Level Sensor 1	Offset Axis Address	14	0	0	Not at X, Y, or Z
		Offset Axis Address	14	1	0	X-axis position
		Offset Axis Address	14	0	1	Y-axis position
		Offset Axis Address	14	1	1	Z-axis position
0	Level Sensor 2	Filter Status	15	1		Filter bypassed
		Filter Status	15	0		Filter not bypassed
		Flip/Cal Inhibit Status	15		1	Calibration Inhibited
		Flip/Cal Inhibit Status	15		0	Calibration not inhibited
0	Supply Voltage 1	Filler Bits	16	0	0	Not used

Appendix C

Command Verification values and their actions for the LSM instrument, excerpted from pages 5-16 to 5-18 in [6]. LSM commands are octal integers 123 to 134.

102 LVL SNSR IN/OUT EXP 1 (PSE)

Command 102 is a two-state command (IN/OUT) which activates logic that enables the coarse level sensors to control the LPX and LPY axes drive motors when an off level condition exists. The coarse level sensors are used only in the automatic leveling mode. PSE activation initializes the coarse level sensor to OUT.

103 PSE LVL MDE A/F EXP 1 (PSE)

Command 103 is a two-state command (AUTOMATIC/FORCED) which controls the leveling mode of LPX, LPY, and LPZ axes. PSE activation initializes the leveling mode to AUTOMATIC.

NOTE

Only one axis motor is to be on at a time.

123 LSM RANGE STEPS EXP 3 (LSM)

Command 123 is a three-state command that determines the range of the X-, Y-, and Z-axes sensors of the LSM. LSM activation initializes the range to ±200 gamma. Repeated application of this command sequences the range through ±50, ±100, ±200 gamma. The selected range is common to all three sensors.

124 LSM FLD O/S CH EXP 3 (LSM)

Command 124 is a seven-state command that controls field offset of the X-, Y-, and Z-axes. LSM activation initializes the offset to 0 percent. Repeated application of this command sequences the offset through +25, +50, +75, -75, -50, -25, and 0 percent of the range selected by Command 123. Example: With Command 123 set to ±100 gamma and Command 124 set to +25 percent, the effective range of the addressed sensor would be +125 to -75 gamma (sensor heads in 0° or 90° position).

125 LSM O/S ADD CH EXP 3 (LSM)

Command 125 is a four-state command used to address the X-, Y-, and Z-axes for offsetting. LSM activation initializes the offset address to neutral. Neutral is defined as no axis addressed. Repeated application of this command sequences the offset address from X to Y to Z to neutral. Example: With this command set to the X-axis, Command 124 controls the offset of the X-axis only, with Y- and Z-axes unaffected.

127 FLIP/CAL INHIB EXP 3 (LSM)

Command 127 is a two-state command (IN/OUT) used to inhibit the flip/calibrate sequence of the LSM. LSM activation initializes the logic to inhibit IN.

NOTE

SINCE THIS COMMAND WILL INHIBIT THE FLIP/CAL COMMAND FROM THE AUTOMATIC DELAYED-COMMAND SEQUENCER (SEE COMMAND 033) AND GROUND COMMAND 131, THIS COMMAND MUST BE CONSIDERED CRITICAL BECAUSE OF A POSSIBILITY OF UPLINK FAILURE.

131 FLIP/CAL GO EXP 3 (LSM)

Command 131 is a one-state command that initiates the flip/calibration cycle. Execution of this command activates the flip/cal sequencer, and upon completion of the sequence, the LSM is returned to the normal operating mode and places the sequencer in OFF.

NOTE

THERE MUST BE EXACTLY FOUR FLIP/CALIBRATE CYCLES BEFORE PERFORMING A SITE SURVEY. In addition to ground Command 131, the flip/calibrate delayed-command sequencer (see Command 033) will generate flip/cal commands.

132 LSM FILT IN/OUT EXP 3 (LSM)

Command 132 is a two-state command (IN/OUT). LSM activation initializes the filter to IN. Application of the command to OUT will cause a major portion of the digital filter to be bypassed.

133 SITE SURVEY XYZ EXP 3 (LSM)

Command 133 is a one-state command that activates the site survey sequence generator. The first application of this command will initiate the sequence to survey the X-axis. Upon completion of the X-axis survey, the LSM instrument will return to the normal scientific mode. The second and third application of this command will initiate the sequence generator to survey the Y- and Z-axes, respectively, returning the LSM to the normal mode of operation upon completion of the respective axis survey.

NOTE

THE SITE SURVEY MUST BE PERFORMED
ONLY AFTER FOUR FLIP/CALIBRATE CYCLES
HAVE BEEN COMPLETED.

134 LSM T CTL XYO EXP 3 (LSM)

Command 134 is a three-state command (X, Y, OFF) which is used to select the X- or Y-axis sensor heater thermostat or to deactivate all LSM heater power. LSM activation initializes the temperature control to the X-axis thermostat. Repeated application of this command sequences the temperature control through Y-axis thermostat, off, and X-axis thermostat. The selected axis thermostat (X or Y) controls heater power to all LSM heaters. In the off position, all LSM heater power is removed. Note that there is no thermostat in the Z-axis sensor.