Lunar Prospector Science Data Interface Specification

Version: 98-06-26

1.0 Introduction

This document describes the detailed format and delivery requirements for the data to be given to the LP science teams. The format of real-time data transferred between the LP MCC workstations OASIS and the science PCs is documented in a separate document.

For a detailed description of the spacecraft, subsystems, telemetry format, and command list, see Reference 1, the LP Spacecraft Handbook. An acronym list is given in Appendix A.

2.0 File Format Definitions

2.1 Attitude Data Files

2.1.1 Attitude Data File Format

The Attitude Data file shall be an ASCII file consisting of three header records followed by a chronological series of attitude records, with the most recent record at the end of the file. The format of the Attitude Data file shall conform to Figure 2.1-1.

```
Date & Time           Spin rate   Right ascension   Declination
(yy-ddd/hh:mm UTC)      (rpm)          (deg)           (deg)
------------------    ---------   ---------------   -----------
yy-ddd/hh:mm           xx.xxxx        xxx.xx          xxx.xx
      .                   .              .               .
      .                   .              .               .
      .                   .              .               .
yy-ddd/hh:mm           xx.xxxx        xxx.xx          xxx.xx
```

Figure 2.1-1 Attitude Data Format

2.1.2 Reference Frame

The right ascension and declination of the spin axis attitude shall be measured relative to the Mean-of-2000 Ecliptic reference frame, as shown in Figure 2.1-2.

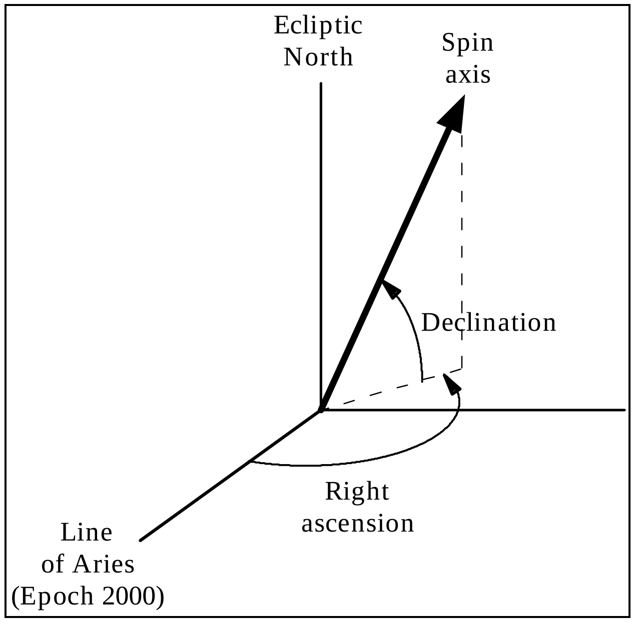

Figure 2.1-2 Attitude Data Reference Frame

2.1.3 Update Frequency

A new record shall be added to the Attitude Data file within 24 hours following each thruster maneuver sequence. Between thruster maneuver sequences the attitude shall be updated as required to maintain knowledge within 0.5°.

2.1.4 File Naming Convention

The Attitude Data file name is LP_ATTITUDE.LOG and the file is in the directory [USER.LPSCI] on the PVO computer..

2.2 Sun Pulse Data File

2.2.1 Sun Pulse File Format

The Sun Pulse Data file shall be a binary file consisting of a chronological series of sun pulse records, with the most recent record at the end of the file. The format of each record of the Sun Pulse file shall conform to Figure 2.2-1.

Sun Pulse Record (bits)

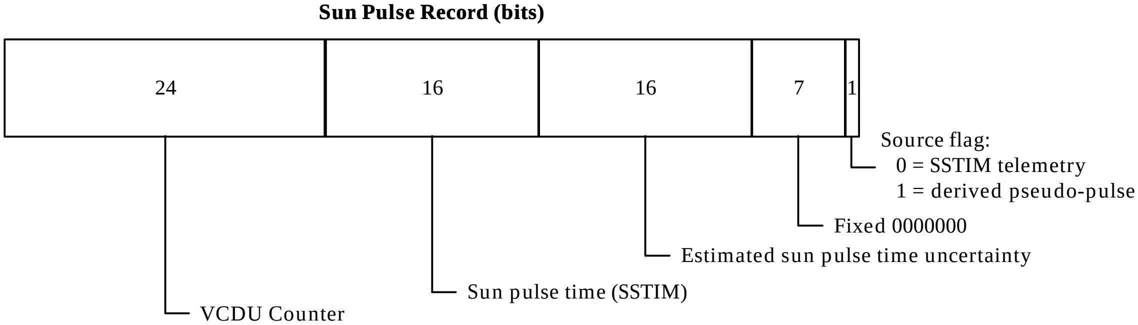

Figure 2.2-1 Sun Pulse Record Format

2.2.2 Sun Pulse Time Processing

The sun pulse time shall be calculated using the merged telemetry stream.

The sun pulse time shall be calculated only when the spacecraft is in 3600 bps telemetry mode and the sun sensor is turned on.

The sun pulse time shall be measured relative to the master (major) frame time. It is the number of counts from the first bit in the major frame header to the sun pulse. Each count is 1/1800 seconds (0.0005556 seconds.)

When the spacecraft is in sunlight, the sun pulse time shall be set equal to the sun sensor time telemetry (SSTIM).

When the spacecraft is in eclipse, the sun pulse time shall be set equal to a pseudo-sun sensor time calculated using the pre-eclipse measured spin rate, the calibrated spin change during eclipse, and/or the EMS edge time telemetry. The pseudo-sun sensor time shall be as close as reasonably achievable to the sun sensor time telemetry that would have occurred had the spacecraft not been in eclipse.

When the spacecraft is in eclipse an estimate of the uncertainty in each pseudo-sun time shall be calculated. This estimate shall define the magnitude of the range within which the true sun pulse lies (i.e. pseudo-sun time – uncertainty estimate   true sun time   pseudo-sun time + uncertainty estimate) This estimate shall have an LSB of 1/1800 seconds (0.0005556 seconds). When the spacecraft is in sunlight the estimate of the uncertainty shall be zero.

2.2.2.1 Interpretation of the sun pulse data

Figure 2.2-2 shows the mapping of a typical stream of sun pulse times to the spacecraft telemetry. SSTIM is updated once every four seconds, in the even-numbered main frames. If no sun pulse occurs in the four seconds prior to the even-numbered main frame, a <no data> value of xFADE is downlinked. Otherwise the time of the sun pulse relative to the prior major frame value is converted to counts and downlinked.

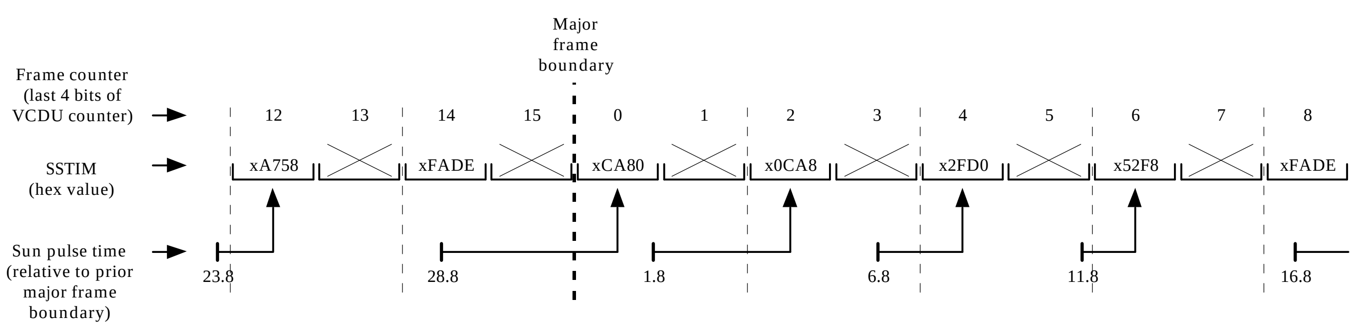

Figure 2.2-2 Mapping of Sun Pulse Times to Telemetry

2.2.3 Update Frequency

Sun Pulse Data files shall be delivered generally two to three times per week.

2.2.4 File Naming Convention

The Sun Pulse Data file naming convention is YR_DOY_H1M1_H2M2.SUNPULSE and the files are located in the [USER.LPSCI] directory on PVO. YR is the last 2 digits of the year; DOY is the day of year of the start of the file; H1M1 is the time of the start of the file (HHMM); H2M2 is the time of the end of the file. If H2M2 is less than H1M1, then the end DOY is one greater than the start DOY. In general, these files contain about 4-6 hours of data.

2.3 Command Files

Command files will be put on-line that list all commands transmitted to the spacecraft, with the transmit times associated with each one.

2.3.1 Command File Format

The command file is an ASCII file with all commands sent for a given pass. The file consists of a header and then a 2 line per entry list of commands. The header includes a title, the creation date of the file, the file name, column headers and the command list. For each command sent, the transmission time of the first bit of the command is given (‘Xmit Time’), the Command mnemonic, the Event Status, and the Station ID. The Command mnemonic includes any input parameters for the command. The Event Status shows either ‘CONFIRM’, ‘ABORT’, or ‘SKIP’. Confirm indicates all the command bits successfully were transmitted. Abort indicates that although the command began transmitted, not all the bits were sent. Skip means that the command was never sent. See the example shown in figure 2.3.1.

A complete list of commands is given in Appendix B.

```
Lunar Ops:  LP Command Confirmation Report
Tue Jan 27 01:22:44 1998
cas filename: 1998_jan_26_dss_24.cas

Xmit Time          Cmd_Mnemonic
Event Status   Station ID
_______________________________________________________________

026/16:51:50.300    'A1HTR                                    '
CONFIRM   DSS ID = 24

026/16:52:22.300    'EXEC                                     '
CONFIRM   DSS ID = 24

026/16:52:54.300    'A4HTR                                    '
CONFIRM   DSS ID = 24

026/16:53:26.300    'EXEC                                     '
CONFIRM   DSS ID = 24

026/17:00:23.400    'DELAYSUN,    1.0254                      '
CONFIRM   DSS ID = 24
```

Figure 2.3-1 Command File Format

2.3.2 Update Frequency

The command file will be put on-line at the end of any pass which had commanding activity.

2.3.3 File Naming Convention

The command file naming convention is YEAR_MON_DY_DSS_##.CAS. YEAR is the four digit year, MON is the month, DY is the day of month, and ## is the number of the Deep Space Station (DSS) which transmitted the commands. These files are located in the [USER.LPSCI] directory on the PVO computer.

2.4 Trajectory Ephemeris Files

Two types of ephemeris files will be generated for the LP project. Predicted ephemeris files containing four weeks of data will be generated once a week. Definitive ephemeris files containing the actual trajectory data for the past week will also be generated once a week. Both files will have the same format but will be distinguished by their name and location on the Flight Dynamics Division (FDD) web page.

2.4.1 Ephemeris File Format

A sample ephemeris file (the first part of it) is shown in Appendix C. The file format is defined in the following table.

Header Item #	Label	Description	Sample Valid LP Contents
1	Satellite ID	Seven Digit Satellite ID	TBD
2	Run Title	Program used to generate ephem (Header)	GTDS Ephem Program
3	Tape Identifier	Program used to generate ephem (Source ID)	GTDS
4	Date of Ephemeris Start Time	Year, month and day of month of ephemeris start time specified as YYMMDD.0000	981207.0000000000000000
5	Sec of Day of Ephemeris Start Time	Seconds of day count of ephemeris start time specified as SSSSS.SSS	0.0000000000000000
6	Date of Ephemeris End Time	Year, month and day of month of ephemeris end time specified as YYMMDD.0000	990104.0000000000000000
7	Sec of Day of Ephemeris End Time	Seconds of day count of ephemeris end time specified as SSSSS.SSS	0.0000000000000000
8	Step Size	Time interval between ephemeris points in seconds	60.0000000000000000
9	Propagator Type	Propagator used to generate ephemeris (Cowell or Brouwer)	Cowell
10	Integration Step	Output Interval Type indicator 1 = fixed step 2 = variable step	1
11	Coordinate System Indicator #1 (EBCDIC ID)	INER = True of Reference MEAN = B1950 2000 = J2000	2000
12	Coordinate System Indicator #2 (Integer ID)	2 = Mean of 1950 3 = True of Reference 4 = J2000	4
13	Ephem Creation Date	Ephem creation date specified as YYMMDD	981207.0
14	Ephem Creation Time	Ephem creation time specified as HHMMSS.SSS	073014.370
15	Epoch Date/Time of Ephem Solution	Date and epoch time of ephem solution specified as MM/DD/YY HH:MM:SS.SSS	12/07/98 0: 0: 0.0

16	Cartesian Epoch Elements	Cartesian position (km) and velocity (km/s) of epoch solution	(see Figure 3-10 of LP FDF ICD)

Header Item #	Label	Description	Sample Valid LP Contents
17	Keplerian Epoch Elements	Keplerian elements [semi-major axis (km), eccentricity, inclination (deg), right ascension of ascending node (deg), argument of perigee (deg), and mean anomaly (deg)] of epoch solution	(see Figure 3-10 of LP FDF ICD)
18	Brouwer Mean Epoch Elements	Brouwer-Lydane mean elements for epoch solution [same parameters and units as in item 17]	(elements as in Figure 3-10 of LP FDF ICD)
19	Central Body Indicator	Central body used in propagation: 1 = Earth [during transfer orbit] 2 = Moon [during mapping orbit]	1 (during transfer orbit) 2 (during mapping orbit)
20	Drag Perturbation Indicator	Atmospheric drag perturbation modeling indicator: 0 = modeled 1 = not modeled	1.0
21	Solar Radiation Perturbation Indicator	Solar radiation perturbation modeling indicator: 0 = modeled 1 = not modeled	0.0
22	Sun Point Mass Perturbation Indicator	Sun gravitation perturbation modeling indicator: 0 = modeled 1 = not modeled	0.0
23	Moon Point Mass Perturbation Indicator	Moon gravitation perturbation modeling indicator: 0 = modeled 1 = not modeled	0.0
24	Spacecraft Area	Cross-Sectional area of spacecraft in square meters	1.75
25	Spacecraft Mass	Mass of spacecraft in kilograms	299
26	Drag Coefficient	Drag Coefficient, C_{DZ}	2.0
27	Solar Reflectivity Coefficient	Spacecraft solar reflectivity coefficient, C_R	1.2
28	Atmospheric Density Model	Type of atmospheric density model used: HAR-PRIE = Harris-Priester	blank

		JACCHIA = Jachhia blank = none used	
29	RHO1	Variation in drag coefficient	0.0
30	RHO2	Time variation in atmospheric density	0.0

Header Item #	Label	Description	Sample Valid LP Contents
31	RHO3	Diurnal variation in atmospheric density	0.0
32	RHO4	Angle between the sun-line and the apex of the diurnal atmospheric bulge	0.5 [0.0]
33	Eccentric Anomaly at Epoch	Eccentric anomaly in degrees of epoch solution	value as in Figure 3-10 of LP FDF ICD
34	True Anomaly at Epoch	True anomaly in degrees of epoch solution	value as in Figure 3-10 of LP FDF ICD
35	Anomalistic Period at Epoch	Anomalistic period in minutes of epoch solution	value as in Figure 3-10 of LP FDF ICD
36	Greenwich Hour Angle at Epoch	Greenwich hour angle in radians of epoch solution	value as in Figure 3-10 of LP FDF ICD
37	Initial Greenwich Hour Angle	Greenwich hour angle in radians at ephem start time	value as in Figure 3-10 of LP FDF ICD
38	Final Greenwich Hour Angle	Greenwich hour angle in radians at ephem end time	value as in Figure 3-10 of LP FDF ICD
39	Geocentric Sun Position at Epoch	Sun Cartesian position in kilometers at solution epoch	value as in Figure 3-10 of LP FDF ICD
40	Date of Earliest Measurement	Date of earliest tracking data span used in OD solution (YYMMDD.0)	value as in Figure 3-10 of LP FDF ICD
41	Time of Earliest Measurement	Time of earliest tracking data span used in OD solution (HHMMSS.SSS)	value as in Figure 3-10 of LP FDF ICD
42	Date of Latest Measurement	Date of last tracking data span used in OD solution (YYMMDD.0)	value as in Figure 3-10 of LP FDF ICD
43	Time of Latest Measurement	Time of last tracking data span used in OD solution (HHMMSS.SSS)	value as in Figure 3-10 of LP FDF ICD
44	Leap Second Indicator	Indicator for leap second occurrence within ephemeris span: 1 = no leap second occurred 2 = leap second occurred	1 or 2
45	Ephemeris	State vectors consisting of:	

	State Vectors	• Time from Epoch in seconds • Cartesian spacecraft position vector in kilometers • Cartesian spacecraft velocity vector in kilometers / sec	(see Figure 3-10 of LP FDF ICD)

2.4.2 Update Frequency

Ephemeris files will be updated every week - both the four week predicted file, and the last week definitive file.

2.4.3 Ephemeris File Retrieval and File Naming Conventions

Ephemeris files are located on the World Wide Web at address:
http://fdd.gsfc.nasa.gov/lp
Please note that at this time, the web page is still under construction and there may be changes to the format in the near future as it becomes finalized. Predicted ephemeris files are located under weekly products. These files contain four weeks of predictions are are 7.5 MB in size. Definitive ephemeris are on a separate page and will contain data for one week. Both files will have the same format. Note also, that at this time there are no definitive sample files.

2.4.4 File Naming Conventions

These files will have default names on the web page, which can be selectively changed as they transfer to a given computer.

2.5 Telemetry Data Files

Although all raw telemetry is archived at the LP MCC, the telemetry files delivered to the science teams will be merged files. The raw telemetry blocks contain real-time data alternating with delayed data (data 50 minutes old) to cover any outages that occur due to occultations. Merged files will have only one data set per spacecraft clock interval.

2.5.1 Telemetry Data File Format

The Merge software shall merge the delayed and prior data packets into a time ordered format and store them into binary files. The format of the merged files is shown in figure 2.5.1-1. Only 3600 bps data is in the merge files.

The data is packaged by the PVO VAX into physical records of 512 bytes, so the start of each data frame is not usually at the start of a physical record.

The Merge software shall perform a bit-by-bit comparison of the same time stamped data to identify bad data.

When mismatches occur between the two data streams, the data stream with the highest signal to noise ratio (SNR) shall be chosen to be stored in the file. When there are no mismatches, the prior (real-time) data stream shall be chosen by default. When miscompares occur between the two data streams, and the SNR is the same, the prior (real-time) data stream shall be chosen by default. When there is only one data stream for a given time, that stream shall be stored.

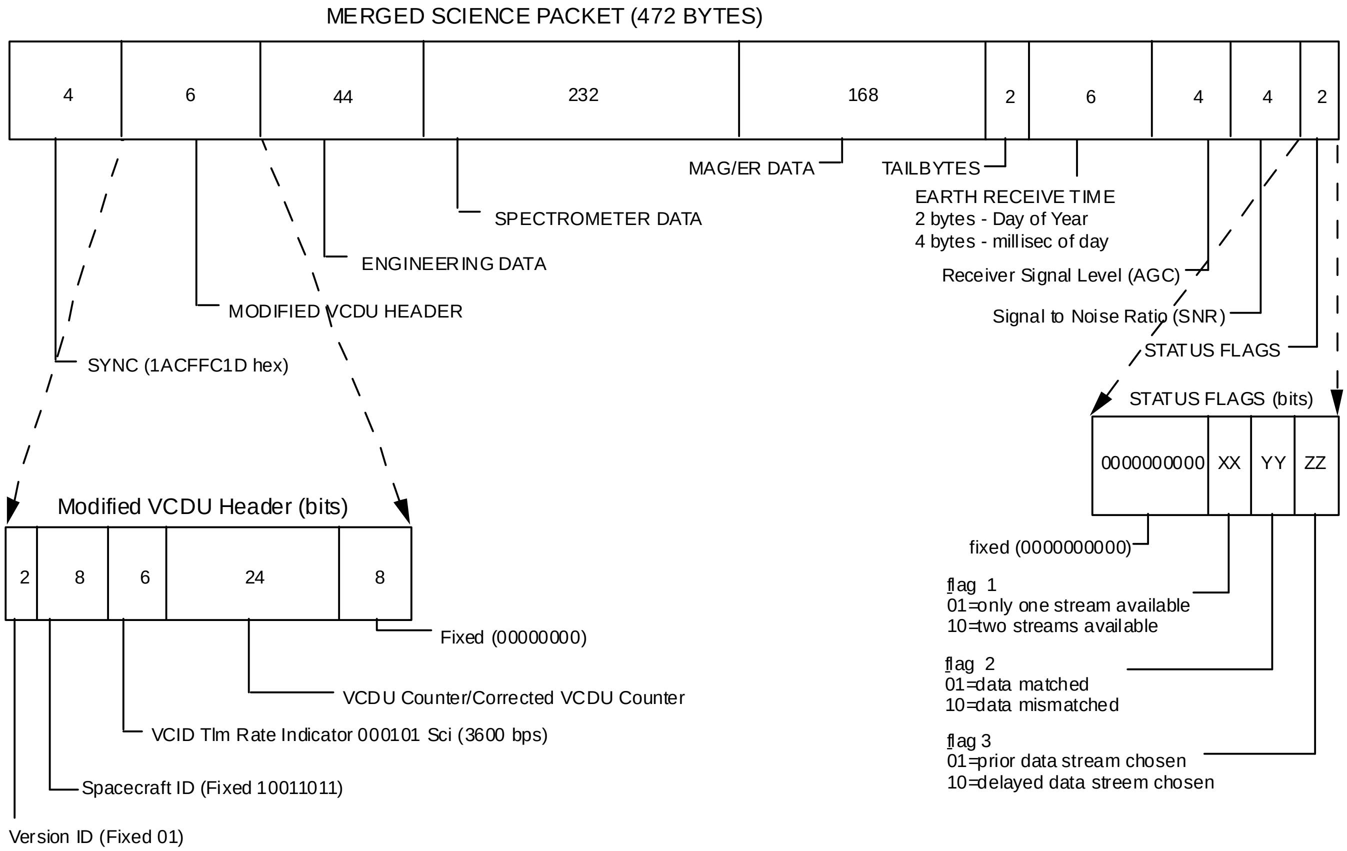

Figure 2.5.1-1 Archived Merged Science Data Format

When the delayed data set is selected for the merge files, the VCDU (spacecraft clock) and ERT are corrected. The VCDU is corrected to be the spacecraft clock when the data were taken, and the ERT is corrected to the time that the data would have been received on the ground real-time (3200 seconds is subtracted from the time.)

The Merge software shall append three flags to each frame of data. The flags are defined as follows:

flag 1 = number of data sets for a given spacecraft clock (1 = only one stream available, 2=2 streams available for comparison)

flag 2 = whether the data matched or mismatched (0 = only one stream, 1 = compared, 2 = miscompared)

flag 3 = which stream was chosen (1 = prior, 2 = delay)

Table 2.5.2-2 shows bit by bit definitions of the merged telemetry block. Note that we count words from 1-472 and bits from 1-8, with bit 1 being the leftmost (most significant) bit in the word. Each word is 8 bits (one byte).

2.5.2 Selection Process

The data is merged by spacecraft clock count (VCDU). As much of the real-time data will not be available (due to occulations), there will often be only one data set for a given clock value. Flag 1 indicates whether or not both real-time and delayed data were returned for a given clock value. Whevever there are two sets, they are compared to see if they match and the result is indicated in flag 2. Since with two data sets, it is not possible to determine the best data set by the data alone, whenever there are two data sets to select from for a given spacecraft clock, the data set with the highest signal-to-noise (SNR) is selected. If SNR is not available for any reason, the real-time data is selected. The set selected is shown in flag 3.

The engineering parameters tailbyte1 and tailbyte2 are only available in the real-time data and if there is real-time data available, it is placed in the merged record despite the SNR. Thus, even if flag 3 indicates that delayed data was selected, if flag 1 indicates that there were two streams, then the tailbytes are valid and from the real-time stream.

2.5.3 Update Frequency

A new telemetry merge file will be generated at the end of every DSN pass - approximately once every 8 hours. The file will be transferred to the PVO computer at Ames, for remote access and ftp by each member of the science and outreach teams.

Name	Word	Bits	Definition (binary unless otherwise stated)
SYNC	1-4	all	1ACFFC1D hex
Version ID	5	1-2	01 (fixed)
Spacecraft ID	5	3-8	
	6	1-2	10011011 (fixed)
VCID	6	3-8	telemetry rate (000101 = 3600 bps)
Corrected VCDU counter	7-9	all	spacecraft clock (corrected to be time of storage)
Fixed	10	all	00000000
Engineering Data	11-54	all	see table Appendices D and E
Spectrometer Data	55-286	all	see table Appendix F
Mag/ER Data	287-454	all	see table Appendix G
Tailbytes	455-456	all	Commandable Engineering words
ERT	457-462	all	Earth Receive Time of the first bit in the telemetry stream (the first bit of the sync pattern), UTC, recorded at the station wds 457-458 = Day of Year (2 bytes) wds 459-462 = millisecond of day (4 bytes)
AGC	463-466	all	Automatic Gain Control - received signal level 32 bit IEEE floating point format
SNR	467-470	all	Signal to Noise Ratio 32 bit IEEE floating point format
Filler	471	all	00 (fixed hex)
Filler	472	1-2	00 (fixed binary)
Status Flag 1	472	3-4	Number of streams for comparison: 01: only 1 stream 10: two streams available
Status Flag 2	472	5-6	00: only 1 stream 01: data matched 10: data mismatched
Status Flag 3	472	7-8	01: prior (real-time) data stream selected 10: delayed data stream selected

Table 2.5.1-2 Bit definitions of MERGE file

2.5.4 File Naming Convention

The file will be named YR_DOY_H1M1_H2M2.MERGE, located in the [USER.LPSCI] directory on PVO. YR is the last 2 digits of the year; DOY is the day of year of the start of the file; H1M1 is the time of the start of the file (HHMM); H2M2 is the time of the end of the file. If H2M2 is less than H1M1, then the end DOY is one greater than the start DOY. In general, these files contain about 4-6 hours of data.

ACS	Attitude Control System
ADC	Analog / Digital Converter
AGC	Automatic Gain Control (DSS measured parameter of downlink signal level)
APS	Alpha Particle Spectrometer Instrument
CDH	Command and Data Handling Subsystem
COM	Communications Subsystem
DOY	Day of Year
DPU	??
DSC	Digital Subcom data in the MAG / ER data set
DSN	Deep Space Network
DSS	Deep Space Station
EMS	Earth Moon Limb Sensor
ER	Electron Reflectometer Instrument
ERT	Earth Receive Time
FDF	Flight Dynamics Facility
FIFO	First In First Out
FOV	Field of View
GRS	Gamma Ray Spectrometer Instrument
GTDS	??
HV	High Voltage
ICD	Interface Control Document
ID	Identification
ISB	Intermediately Significant Byte
LMMS	Lockheed Martin Missiles and Space
LP	Lunar Prospector
LSB	Least Significant Bit or Byte
Mag	Magnetometer Instrument
MCC	Mission Control Center
MCP	??
MER	Magnetometer and Electron Reflectometer Electronics
MF	Minor Frame Number
MSB	Most Signicant Bit or Byte
NS	Neutron Spectrometer Instrument
OASIS	Name of real-time telemetry software
PA	Pitch Angle
PC	Personal Computer
PC	Power Converter of MAG / ER
PLN	Propulsion Subsystem
PPA	ER Pulse Position Analyzer
PWR	Power Subsystem
SES	Spectrometer Electronics
SIS	Science Interface Specification
SNR	Signal to Noise Ratio (DSS measured parameter of downlink quality)
SS	Subsystem
SSTIM	Sun Sensor Time (telemetry word)

TBD	To Be Determined
TML	Thermal Subsystem
VCDU	Virtual Channel Data Unit (spacecraft clock counter)
VCID	Virtual Channel Identification
x	Hex

COMMAND MNEMONIC	COMMAND NAME	Input Parameters	Min Value	Max Value	Step Size
A1	Thruster A1-Mode1				
A1234REOR	"Th A1&A3+A2&A4-Mode3				
A12LOI	"Thrus A1+A2-Mode6				
A14REOR	Thrus A1+A4-Mode2 (Re-orient)				
A1DETON	"1 APS Detector ON, Other 4 OFF"	Sensor	0	31	1
A1HTR	Thruster A1 Cat Bed Htrs				
A2	Thruster A2-Mode1				
A23REOR	"Thrus A2+A3-Mode2				
A2HTR	Thruster A2 Cat Bed Htrs				
A3	Thruster A3-Mode1				
A34VEC	Thrus A3+A4-Mode6 (Long Burn)				
A3HTR	Thruster A3 Cat Bed Htrs				
A4	Thruster A4-Mode1				
A4HTR	Thruster A4 Cat Bed Htrs				
ALOENGY	Set APS Low Energy Threshold	Low Threshold	0	255	1
AON	APS Sensor On				
CATSOFF	All Cat Bed Heaters Off				
CHANOFF	PCM Channel Select Off				
CHANSEL	PCM Channel Select	Header (hex)	00	FF	1
CLRERR	Clr Uplink Header/Thruster Errors				
COHEROFF	Coherent Mode Off				
COHERON	Coherent Mode On				
DELAYNUM	Thruster Parameters 16-bit writes	Delay Time (min)	0.0	63.75	0.25
		No. of Times (N)	1	255	1
DELAYSUN	Thruster Parameters 16-bit writes	When relative to Sun (sec)	0.0	36.408	0.556 ms
EMOFF	Earth/Moon Sensor Off				
EMON	Earth/Moon Sensor On				
EMSTHR	EMS Sensor Threshold	Threshold Setting (V)	0	0.51	0.002
ENCODOFF	Convolutional Encoder Off				
ENCODON	Convolutional Encoder On				
ERCOV	Mag/Er-ER Cover Open				
EXEC	EXECUTE				
GACSHI	Set GRS ACS Det High Energy	High Threshold	0	255	1
GACSLO	Set GRS ACS Det Low Energy	Low Threshold	0	255	1
GAIN2	PCM Gain 2	Gain2 (hex)	00	FF	1
GBGOHI	Set GRS BGO Det High Energy	High Threshold	0	255	1
GBGOLO	Set GRS BGO Det Low Energy	Low Threshold	0	255	1
GEARLYHI	Set GRS Early Time High Thresh.	High Threshold	0	255	1
GEARLYLO	Set GRS Early Time Low Thresh.	Low Threshold	0	255	1
COMMAND MNEMONIC	COMMAND NAME	Input Parameters	Min Value	Max Value	Step Size

GHV1LEV	Set GRS High Voltage 1 Level	HV Level	0	255	1
GHV1OFF	GRS High Voltage 1 Off				
GHV1ON	GRS High Voltage 1 On				
GHV2LEV	Set GRS High Voltage 2 Level	HV Level	0	255	1
GHV2OFF	GRS High Voltage 2 Off				
GHV2ON	GRS High Voltage 2 On				
GLATEHI	Set GRS Late Time High Thresh.	High Threshold	0	255	1
GLATELO	Set GRS Late Time Low Thresh.	Low Threshold	0	255	1
GON	GRS Sensor On				
HALFREV	Thruster Parameters 16-bit writes	Half Rev Value (sec)	0.0	36.408	0.556 ms
LONGDUR	Thruster Parameters 16-bit writes	Burn Duration (sec)	0.0	6553.5	0.1
MAGBOOM	Release Mag/Er: Wire cutters A&B				
MBBYTE	Load Data Byte into Load Buffer	Data	0	255	1
MBCOMMIT	Commit Load Buffer to Memory	Sum of Data Bytes	0	255	1
		# of Bytes Loaded	0	255	1
MBPROM	Set to Run PROM on Next Reset				
MBWORD	Load Data Word into Load Buffer	Data	0	65535	1
MDADDR	Set Memory Dump Address	Address	0	65535	1
MDBYTE	Load Data Byte at Address	Data	0	255	1
MDUMP	Dump Memory	# of Bytes	0	65535	1
MDUMPR	Dump Memory Repeatedly	# of Bytes	0	65535	1
MDWORD	Load Data Word at Address	Data	0	65535	1
MEECKSM	Update EEProm Checksum				
MEEPROM	Set to Run EEPROM on Next Reset				
MEEWEOFF	EEPROM write enable OFF				
MEEWEON	EEPROM write enable ON				
MERABOFF	Mag/Er-Power Both Off				
MERAON	Mag/Er-Power A On/B Off				
MERBON	Mag/Er-Power B On/A Off				
MERHTROFF	Mag/Er-Heater Power Off				
MERHTRON	Mag/Er-Heater Power On				
MERLVOFF	ER Low Voltage Off				
MERLVON	ER Low Voltage On				
MEXEC	Jump to Address				
MGA	Xmtr to MGA				
MLADDR	Set Load Address	Address	0	65535	1
MRESET	Reset MAG/ER Processor				
MRRST	Master Reset all circuitry				

COMMAND MNEMONIC	COMMAND NAME	Input Parameters	Min Value	Max Value	Step Size
MTADDR	Set Table Address	Table	0	7	1
		Address	0	65535	1
MTDUMP	Dump Table	Table	0	7	1
		# of Bytes	0	255	1
MTDUMPR	Dump Table Repeatedly	Table	0	7	1
MTDUMPR		# of Bytes	0	255	1
MTLOADB	Load Table by Byte	Table	0	7	1
		Byte Number	0	255	1
		Data	0	255	1
MTLOADW	Load Table by Word	Table	0	7	1
		Word #	0	15	1
		Data	0	65535	1
NCDHI	Set NS Cd Detector High Level	High Level	0	255	1
NCDLO	Set NS Cd Detector Low Level	Low Level	0	255	1
NHV1LEV	Set NS High Voltage 1 Level	HV Level	0	255	1
NHV1OFF	NS High Voltage 1 Off				
NHV1ON	NS High Voltage 1 On				
NHV2LEV	Set NS High Voltage 2 Level	HV Level	0	255	1
NHV2OFF	NS High Voltage 2 Off				
NHV2ON	NS High Voltage 2 On				
NON	NS Sensor On				
NOOP1	No Op 1				
NOOP2	No Op 2				
NSNHI	Set NS Sn Detector High Level	High Level	0	255	1
NSNLO	Set NS Sn Detector Low Level	Low Level	0	255	1
OMNI	Xmtr to Omni				
OSGAIN1	PCM Offset/Gain 1	Offset (hex)	00	FF	1
		Gain1 (hex)	0	F	1
PIVCLOSE	Propellant Isolation Valve Closed				
PIVOPEN	Propellant Isolation Valve Open				
PRESSOFF	Pressure XDCR Power Off				
PRESSON	Pressure XDCR Power On				
PRIHTROFF	Pri Heater Bus Off				
PRIHTRON	Pri Heater Bus On				
PWRSM	Mini Safe Mode				
RANGOFF	Ranging Off				
RANGON	Ranging On				
RELBOOMS	Release Booms: Paraffins A & B	Activation Time	0.0	6553.5	0.1
COMMAND MNEMONIC	COMMAND NAME	Input Parameters	Min Value	Max Value	Step Size

SEBYTE12	SES Data Byte (1/2)	Date Byte 1	0	255	1
		Data Byte 2	0	255	1
SECHECK	SES Checksum @ End of Load	Checksum	0	65535	1
SECHTROFF	Red Heater Bus Off				
SECHTRON	Red Heater Bus On				
SECLRERR	SES Clear Error Status				
SECMDEXEC	SES Execute Command				
SEDATCMD	SES Data Command	# of Data Bytes	0	255	1
SEDMPADDR	SES Dump Beginning Address	Address	0	65535	1
SEEXEADDR	Load Execute Address	Address	0	65535	1
SEOFF	Power to Spectrometers-Off				
SEON	Power to Spectrometers-On				
SESTADDR	SES Data Load Starting Address	Address	0	65535	1
SETCMDREG	Reset Thruster-Parameter registers				
SETTIM	Reset 32-sec vehicle timer				
SEWDOGOFF	SES Watchdog Off				
SEWDOGON	SES Watchdog On				
SHORTDUR	Thruster Parameters 16-bit writes	Burn Duration (sec)	0.0	36.408	0.556 ms
SHOWBYTE	Display bytes shown in Tail Bytes	Table High Byte (hex)	00	FF	1
		Table Low Byte (hex)	00	FF	1
SHVDIS	Disable all Hi Volt Pwr Supplies				
SPECSOFF	All Sensors Off				
STOPFIRE	Reset Thruster Execution				
SUBOFF	Sub-Carrier Oscillator Off				
SUBON	Sub-Carrier Oscillator On				
SUNOFF	Sun Sensor Off				
SUNON	Sun Sensor On				
T12VEC	Thrs T1+T2-Mode4 (Vector Burn)				
T1D	Thruster T1-Mode5 (Spin Control)				
T1HTR	Thruster T1 Cat Bed Htrs				
T2HTR	Thruster T2 Cat Bed Htrs				
T2UP	"Thruster T2-Mode5				
T300	TLM to Engrg only format-300bps				
T3600	TLM to Science format-3600bps				
TAILBYTE	Display Tail Bytes				
TIMOFF	Stop TIME FILLING				
TIMON	Start TIME FILLING				
TLMOFF	Reset TLM circuitry-Relay open				
TLMON	Reset TLM circuitry-Relay closed				
COMMAND MNEMONIC	COMMAND NAME	Input Parameters	Min Value	Max Value	Step Size
VT1	Charge Control V/T #1				
VT2	Charge Control V/T #2				

VT3	Charge Control V/T #3				
VT4	Charge Control V/T #4				
XMTOFF	Transmitter Off				
XMTON	Transmitter On				

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EPHEMERIS FILE INFORMATION:
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SATELLITE ID NUMBER =   1234567
RUN TITLE =                  GTDS  EPHEM    PROGRAM
TAPE IDENTIFIER = GTDS
EPHEMERIS START TIME (YYMMDD.)    =    971001.0000000000000000
EPHEMERIS START TIME (SEC OF DAY) =     68400.0000000000000000
EPHEMERIS END TIME (YYMMDD.)      =    971105.0000000000000000
EPHEMERIS END TIME (SEC OF DAY)   =         0.0000000000000000
EPHEMERIS DELTA-T (SECONDS)       =        60.0000000000000000
ORBIT THEORY (COWELL OR BROUWER)  = COWELL
INTEGRATION STEP (2=FIXED)        =    1
COORDINATE SYSTEM           = 2000
COORD. SYSTEM INDICATOR     =    4
YYMMDD OF FILE CREATION     = 970729.0
HHMMSS.SSS OF FILE CREATION = 170029.000


INITIAL CONDITION INFORMATION:
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ELEMENT EPOCH (MM/DD/YY  HH:MM:SS.SSS) =  10/ 1/97  19:24:10.900
INITIAL CARTESIAN ELEMENTS :    X (KM) =       379.0744441200000
                                Y (KM) =       1733.215286400000
                                Z (KM) =       482.5047599000001
                           VX (KM/SEC) =     -0.4283441620000002E-01
                           VY (KM/SEC) =      0.4457554223200002
                           VZ (KM/SEC) =      -1.570331761000001
INITIAL KEPLERIAN ELEMENTS :    A (KM) =       1838.569120653306
                                    E  =      0.4473230583905760E-03
                               I (DEG) =       85.35347220144050
                            RAAN (DEG) =       258.9295510928905
                              AP (DEG) =       258.6866495663495
                              MA (DEG) =       266.0989881340095
INITIAL BROUWER MEAN ELEMENTS : A (KM) =       1838.110189834120
                                    E  =      0.2522146594156849E-01
                               I (DEG) =       85.34987232299338
                            RAAN (DEG) =       258.9299134739323
                              AP (DEG) =       90.05673014062709
                              MA (DEG) =       74.73444237474380
CENTRAL BODY INDICATOR (1=EARTH)          =     2.0
DRAG PERTURBATION (0=YES,1=NO)            =     1.0
SOLAR RADIATION PERTURBATION (0=YES,1=NO) =     0.0
SUN POINT MASS PERTURBATION (0=YES,1=NO)  =     0.0
MOON POINT MASS PERTURBATION (0=YES,1=NO) =     0.0
SPACECRAFT AREA (M**2)          =       2.130000000000000
SPACECRAFT MASS (KG)            =       189.6000000000000
DRAG COEFFICIENT                =       2.000000000000000
SOLAR REFLECTIVITY COEFFICIENT  =       1.200000000000000
ATMOSPHERIC DENSITY MODEL       =
RHO1  =      0.0000000000000000E+00
RHO2  =      0.0000000000000000E+00
RHO3  =      0.0000000000000000E+00
RHO4  =      0.5235987755983001


OTHER INFORMATION:
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ECCENTRIC ANOMALY AT EPOCH (DEG)     =       266.0734185734579
TRUE ANOMALY AT EPOCH (DEG)          =       266.0478494036846
ANOMALISTIC PERIOD (MINUTES)         =       117.9034619146939
GREENWICH HOUR ANGLE AT EPOCH (RAD)  =      0.1704551659421227
INITIAL GREENWICH HOUR ANGLE (RAD)   =       5.158261801832923
FINAL GREENWICH HOUR ANGLE (RAD)     =      0.7725412132307312
GEOCENTRIC SUN POSITION AT EPOCH (KM):  X  =      -147629792.8467065
                                        Y  =      -20678268.70067792
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```
                                          Z  =       -8979267.932055345
  YYMMDD OF EARLIEST MEASUREMENT       =       0.0
  HHMMSS.SSS OF EARLIEST MEASUREMENT   =       0.000
  YYMMDD OF LATEST MEASUREMENT         =       0.0
  HHMMSS.SSS OF LATEST MEASUREMENT     =       0.000
  LEAP SECOND DURING EPHEM (2=YES)     =     1


  EPHEMERIS:
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 TIME FROM EPOCH (SEC)        X (KM)                 Y (KM)               Z (KM)
XDOT (KM/S)           YDOT (KM/S)           ZDOT (KM/S)
 --------------------- --------------------- --------------------- --------------------- --
------------------- --------------------- ---------------------
  0.00000000000000E+00  0.15217594010148E+03  0.11302778576390E+01  0.18331709381885E+04
0.31095118706519E+00  0.16018375335430E+01 -0.27093161057397E+01
  0.60000000000000E+02  0.17060919889658E+03  0.97193720872622E+02  0.18289487641678E+04
0.30334555628069E+00  0.15995218571070E+01 -0.11361302341123E+00
  0.12000000000000E+03  0.18856019854248E+03  0.19298236279069E+03  0.18195437423366E+04
0.29487957713803E+00  0.15926796640570E+01 -0.19981458046087E+00
  0.18000000000000E+03  0.20597800361333E+03  0.28822511457986E+03  0.18049821891574E+04
0.28557644681879E+00  0.15813295514208E+01 -0.28545744766744E+00
  0.24000000000000E+03  0.22281313582310E+03  0.38265233903644E+03  0.17853048063055E+04
0.27546158541037E+00  0.15655013198922E+01 -0.37030247810923E+00
```

Word	MF	Bit	Mnemonic	SS	Description
1	all	all	FRM_SEQ_NUM	CDH	Frame Sequence Number
2	all	all	LASTCMD (MSB)	CDH	Last command to S/C
3	all	all	LASTCMD (ISB)	CDH	Last command to S/C
4	all	all	LASTCMD (LSB)	CDH	Last command to S/C
5	all	all	VCID	CDH	Virtual channel ID
6	0,4,8,12	all	FIREDELAY	PLN	Burn initiation delay
6	1,5,9,13	all	DELAYSUN (MSB)	PLN	Delay after sun crossing
6	2,6,10,14	all	BURNDUR (MSB)	PLN	Burn duration
6	3,7,11,15	all	HALFREV (MSB)	PLN	Half revolution value
7	0,4,8,12	all	NUMTIM	PLN	Number of firings
7	1,5,9,13	all	DELAYSUN (LSB)	PLN	Delay after sun crossing
7	2,6,10,14	all	BURNDUR (LSB)	PLN	Burn duration
7	3,7,11,15	all	HALFREV (LSB)	PLN	Half revolution value
8	0	all	ER28V	ER	+28v
8	1	all	MAGHTRPWR	MAG	Heater power
8	2	all	ERHVCUR	ER	MicroChannel plate hi voltage line current
8	3	all	MAGTMP	MAG	Temperature
8	4	all	ERHVVLT	ER	MicroChannel plate hi voltage line voltage
8	5	all	ERHTRPWR	ER	Heater power
8	6	all	ERSWPCUR	ER	High voltage sweep current
8	7	all	ERTMP	ER	Temperature
8	8	all	ERSWPVLT	ER	High voltage sweep voltage
8	9	all	MER12V	MER	DPU +12v
8	10	all	ERM5V	ER	-5v
8	11	all	MER5V	MER	DPU +5v
8	12	all	ER5V	ER	+5v
8	13	all	MERHTRPWR	MER	DPU heater power
8	14	all	ER12V	ER	+12v
8	15	all	MERTMP	MER	DPU temperature
9	0,4,8,12	all	V5	CDH	+5v
9	1,5,9,13	all	VTERR	PWR	V/T error
9	2	all	CHKSUM (MSB)	CDH	Checksum Bytes
9	3,7,11,15	all	EMSTHR	ACS	EMS Threshold
9	6	0	EMST	ACS	Earth/Moon sensor on/off status
9	6	1	PCMADST	CDH	C&DH on/off status On/Off
9	6	2	ERRFLG	CDH	Error flag (Sun Sensor Timeout)
9	6	3	GTB0	CDH	Ground test bit 0
9	6	4	GTB1	CDH	Ground test bit 1
9	6	5-7	spare		
9	10	all	CDHTMP	CDH	PCMA Temperature
9	14	0-3	VMETO	CDH	VME Timeout Counter
9	14	4-6	WDOGST	CDH	Watch Dog Status
9	14	7	SERLKPRS	CDH	Serial Link bit
10	0,4,8,12	all	V15	CDH	+15v
10	1,5,9,13	all	VM15	CDH	-15v
10	2	all	CHKSUM (LSB)	CDH	Checksum Bytes
10	3,7,11,15	0-5	UPLKST1	CDH	C&DH status
10	3,7,11,15	6-7	spare		
10	6	0	SUNST	ACS	Sun sensor on/off status

10	6	1	PRESSST	PLN	Pressure transducer on / off status
10	6	2	PRIHTRST	TML	Primary heater on / off status
10	6	3	SECHTRST	TML	Secondary heater on / off status

Word	MF	Bit	Mnemonic	SS	Description
10	6	4	MERAST	MER	MAG/ER power A on/off status
10	6	5	MERBST	MER	MAG/ER power B on/off status
10	6	6	MERHTRST	TML	MAG/ER heater on/off status
10	6	7	SEST	SES	SES electronics on/off status
10	10	all	CCBTMP	PWR	Charge control board temperature
10	14	0	TLMFIEMP	CDH	Telemetry FIFO Empty bit
10	14	1	TLMFIFL	CDH	Telemetry FIFO Full bit
10	14	2	TLMFIOV	CDH	Telemetry FIFO Overflow bit
10	14	3	GSESTAT	CDH	Downlink Mode (GSE or Flight)
10	14	4-7	spare		
11	all	all	EMTIM1 (MSB)	ACS	Earth/Moon limb crossing time #1
12	all	all	EMTIM1 (LSB)	ACS	Earth/Moon limb crossing time #1
13	all	all	EMTIM2 (MSB)	ACS	Earth/Moon limb crossing time #2
14	all	all	EMTIM2 (LSB)	ACS	Earth/Moon limb crossing time #2
15	all	all	EMTIM3 (MSB)	ACS	Earth/Moon limb crossing time #3
16	all	all	EMTIM3 (LSB)	ACS	Earth/Moon limb crossing time #3
17	all	all	EMTIM4 (MSB)	ACS	Earth/Moon limb crossing time #4
18	all	all	EMTIM4 (LSB)	ACS	Earth/Moon limb crossing time #4
19	all	all	EMTIM5 (MSB)	ACS	Earth/Moon limb crossing time #5
20	all	all	EMTIM5 (LSB)	ACS	Earth/Moon limb crossing time #5
21	all	all	EMTIM6 (MSB)	ACS	Earth/Moon limb crossing time #6
22	all	all	EMTIM6 (LSB)	ACS	Earth/Moon limb crossing time #6
23	all	all	EMTHRESHLEV (MSB)	ACS	EMS Threshold Level
24	all	all	EMTHRESHLEV (LSB)	ACS	EMS Threshold Level
25	even	all	SSSINV	ACS	Sun sensor sin voltage
25	odd	all	SSBIASV	ACS	Sun sensor bias voltage
26	even	all	SSCOSV	ACS	Sun sensor cos voltage
26	odd	all	SSANG	ACS	Sun sensor coarse angle
27	even	all	SSTIM (MSB)	ACS	Sun sensor time
27	1	0,1	BATVTST	PWR	Battery V/T status
27	1	2	CARLOCK	COM	Carrier lock status
27	1	3	PIVST	PLN	PIV open/closed status
27	1	4	DEMODLOCK	COM	Demodulation lock status
27	1	5-7	spare		
27	odd 3-15	all	spare		
28	even	all	SSTIM (LSB)	ACS	Sun sensor time
28	1	0-1	spare		
28	1	2	RANGST	COM	Ranging on/off status
28	1	3	XMTST	COM	Transmitter on/off status
28	1	4	SUBST	COM	Sub-carrier oscillator on/off status
28	1	5	COHERST	COM	Coherent mode on/off status
28	1	6	ENCODST	COM	Encoder on/off status
28	1	7	spare		
28	3	0-4	spare		
28	3	5	ANTSEL	COM	Antenna selection: Omni or Med Gain
28	3	6-7	spare		
28	odd 5-15	all	spare		
29	0,8	all	SES5V	SES	+5v
29	1,9	all	GRSHV1	GRS	High voltage #1

29	2,10	all	NSHV1	NS	High voltage #1
29	3,11	all	APSM25V	APS	-25vdc
29	4,12	all	SESTMP	SES	Temperature
29	5,13	all	NSAPSTMP	APS	NS / APS Temperature
29	6,7,14,15	all	spare		

Word	MF	Bit	Mnemonic	SS	Description
30	0,8	all	SES12V	SES	+12v
30	1,9	all	GRSHV2	GRS	High voltage #2
30	2,10	all	NSHV2	NS	High voltage #2
30	3,11	all	SES28VCUR	SES	28v line current
30	4,12	all	GRSTMP	GRS	Temperature
30	5-7,13-15	all	spare		
31	0,4,8,12	all	RCVSIGSTR	COM	Receiver signal strength
31	1,5,9,13	all	XMTSECV12	COM	Transmitter secondary +12 voltage
31	2,6,10,14	all	XMTTMP	COM	Transmitter temperature
31	3,7,11,15	all	spare		
32	0,4,8,12	all	LOOPSTR	COM	Loop stress
32	1,5,9,13	all	XMTSECV20	COM	Transmitter secondary +20 voltage
32	2,6,10,14	all	spare		
32	3,7,11,15	all	spare		
33	0,4,8,12	all	RCVSECVLT	COM	Receiver secondary voltage
33	1,5,9,13	all	XMTPWROUT	COM	Transmitter power output
33	2,6,10,14	all	spare		
33	3,7,11,15	all	spare		
34	0,4,8,12	all	A1TMP	PLN	Thruster A1 cataylst bed temperature
34	1,5,9,13	all	A4TMP	PLN	Thruster A4 cataylst bed temperature
34	2,6,10,14	all	T2TMP	PLN	Thruster T2 cataylst bed temperature
34	3,11	all	TANKPRESS	PLN	Tank pressure
34	7,15	all	TANK2TMP	PLN	Tank 2 temperature (+Y)
35	0,4,8,12	all	A3TMP	PLN	Thruster A3 cataylst bed temperature
35	1,5,9,13	all	T1TMP	PLN	Thruster T1 cataylst bed temperature
35	2,6,10,14	all	A2TMP	PLN	Thruster A2 cataylst bed temperature
35	3,11	all	TANK1TMP	PLN	Tank 1 temperature (+X)
35	7,15	all	TANK3TMP	PLN	Tank 3 temperature (-Y)
36	0,8	all	LDCUR	PWR	Load current
36	1,9	all	BATCUR	PWR	Battery current
36	2,10	all	BATVLT	PWR	Battery voltage
36	3,11	all	BUSVLT	PWR	Bus voltage
36	4,12	all	SA2TMP	PWR	Solar array pannel 2 temperature (+Y)
36	6,14	all	DAMPTMP	CDH	Viscous damper temperature
36	5,7,13,15	all	spare		
37	0,8	all	SACUR	PWR	Solar array current
37	1,9	all	STRCUR	PWR	Structure current
37	2,10	all	BATTMP	PWR	Battery temperatur
37	3,11	all	SA1TMP	PWR	Solar array pannel 1 temperature (+X)
37	4,12	all	SA3TMP	PWR	Solar array pannel 3 temperature (-Y)
37	5,13	all	EMDETTMP	ACS	Earth / Moon limb detector temperature
37	6,7,14,15	all	spare		
38	all	all	spare		
39	all	all	spare		

38	all	all	spare		
39	all	all	spare		
40	all	all	spare		
41	all	all	spare		
42	all	all	spare		
43	all	all	spare		
44	all	all	spare		

Mnemonic	Units	C0	C1	C2	C3	C4	C5
A1TMP	°C	-1.30E+02	1.13E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
A2TMP	°C	-1.30E+02	1.13E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
A3TMP	°C	-1.30E+02	1.13E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
A4TMP	°C	-1.30E+02	1.13E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
APSM25V	V	0.00E+00	-1.25E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BATCUR	A	-9.57E+00	5.80E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BATTMP	°C	5.42E+01	-5.88E-01	2.33E-03	-5.68E-06	0.00E+00	0.00E+00
BATVLT	V	0.00E+00	1.40E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BATVTST	Counts	1.00E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUSVLT	V	0.00E+00	1.40E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CCBTMP	°C	7.92E+01	-7.69E-01	3.53E-03	-9.07E-06	0.00E+00	0.00E+00
CDHTMP	°C	7.92E+01	-7.69E-01	3.53E-03	-9.07E-06	0.00E+00	0.00E+00
DAMPTMP	°C	5.42E+01	-5.88E-01	2.33E-03	-5.68E-06	0.00E+00	0.00E+00
DELAYSUN	sec	0.00E+00	5.56E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EMELXTMP	°C	5.42E+01	-5.88E-01	2.33E-03	-5.68E-06	0.00E+00	0.00E+00
EMSTHR	V	0.00E+00	2.00E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EMTIM1	sec	0.00E+00	5.56E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EMTIM2	sec	0.00E+00	5.56E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EMTIM3	sec	0.00E+00	5.56E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EMTIM4	sec	0.00E+00	5.56E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EMTIM5	sec	0.00E+00	5.56E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EMTIM6	sec	0.00E+00	5.56E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ER12V	V	0.00E+00	6.40E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ER28V	V	0.00E+00	1.39E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ER5V	V	0.00E+00	2.57E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ERHTRPWR	W	0.00E+00	7.20E-03	-2.00E-05	8.00E-08	0.00E+00	0.00E+00
ERHVCUR	mA	0.00E+00	1.01E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ERHVVLT	V	8.20E+00	1.53E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ERM5V	V	0.00E+00	-2.63E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ERSWPCUR	mA	0.00E+00	6.14E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00

ERSWPVLT	V	2.20E+00	2.02E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ERTMP	°C	-4.08E+01	8.34E-01	-4.88E-03	1.38E-05	0.00E+00	0.00E+00
FIREDELAY	min	0.00E+00	2.50E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GRSHV1	V	0.00E+00	9.02E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GRSHV2	V	0.00E+00	9.02E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GRSTMP	°C	5.42E+01	-5.88E-01	2.33E-03	-5.68E-06	0.00E+00	0.00E+00
HALFREV	sec	0.00E+00	5.55E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LDCUR	A	0.00E+00	5.80E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LONGDUR	sec	0.00E+00	1.00E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LOOPSTR	kHz	-1.75E+02	2.64E+00	-1.09E-02	8.01E-05	-3.52E-07	7.01E-10
MAGHTRPWR	A	0.00E+00	2.70E-03	2.04E-05	-4.00E-08	0.00E+00	0.00E+00
MAGTMP	°C	-4.08E+01	8.34E-01	-4.88E-03	1.38E-05	0.00E+00	0.00E+00
MER12V	V	0.00E+00	6.40E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MER5V	V	0.00E+00	3.27E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MERHTRPWR	A	5.20E-01	7.20E-03	-2.00E-05	8.00E-08	0.00E+00	0.00E+00
MERTMP	°C	-4.08E+01	8.34E-01	-4.88E-03	1.38E-05	0.00E+00	0.00E+00
NSAPSTMP	°C	5.42E+01	-5.88E-01	2.33E-03	-5.68E-06	0.00E+00	0.00E+00
NSHV1	V	0.00E+00	9.05E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NSHV2	V	0.00E+00	9.02E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NUMTIM	Counts	0.00E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RCVSECVLT	V	0.00E+00	1.13E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RCVSIGSTR-A*	dBm	-1.32E+02	1.09E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RCVSIGSTR-B*	dBm	-2.38E+02	1.33E+00	-2.63E-03	2.32E-06	0.00E+00	0.00E+00
SA1TMP	°C	7.92E+01	-7.69E-01	3.53E-03	-9.07E-06	0.00E+00	0.00E+00
SA2TMP	°C	7.92E+01	-7.69E-01	3.53E-03	-9.07E-06	0.00E+00	0.00E+00
SA3TMP	°C	7.92E+01	-7.69E-01	3.53E-03	-9.07E-06	0.00E+00	0.00E+00
SACUR	A	0.00E+00	5.93E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SES12V	V	0.00E+00	6.02E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SES28VCUR	A	0.00E+00	2.54E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SES5V	V	0.00E+00	2.51E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SESTMP	°C	5.42E+01	-5.88E-01	2.33E-03	-5.68E-06	0.00E+00	0.00E+00
SHORTDUR	sec	0.00E+00	5.55E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00

SSANG	Binary	0.00E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SSBIASV	V	0.00E+00	2.00E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SSCOSV	V	0.00E+00	2.00E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SSSINV	V	0.00E+00	2.00E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SSTIM	sec	0.00E+00	5.56E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
STRCUR	A	-6.25E+00	5.00E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
T1TMP	°C	-1.30E+02	1.13E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
T2TMP	°C	-1.30E+02	1.13E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TANK1TMP	°C	5.42E+01	-5.88E-01	2.33E-03	-5.68E-06	0.00E+00	0.00E+00
TANK2TMP	°C	5.42E+01	-5.88E-01	2.33E-03	-5.68E-06	0.00E+00	0.00E+00
TANK3TMP	°C	5.42E+01	-5.88E-01	2.33E-03	-5.68E-06	0.00E+00	0.00E+00
TANKPRESS	psi	1.80E+01	1.80E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
V15	V	0.00E+00	7.00E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
V5	V	0.00E+00	2.30E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
VM15	V	-2.77E+01	5.34E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
VTERR	??	0.00E+00	6.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
XMTPWROUT	dBm	2.95E+01	7.08E-02	-1.95E-04	-3.12E-07	5.96E-09	-1.53E-11
XMTSECV12	V	0.00E+00	9.90E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
XMTSECV20	V	0.00E+00	9.90E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
XMTTMP	°C	5.42E+01	-5.88E-01	2.33E-03	-5.68E-06	0.00E+00	0.00E+00

Words not converted:

CHKSUM	Hex
EMTHRSLEV	Binary
FRM_ID	Counts
FRMSEQNUM	Counts
LASTCMD	Hex
TAILBYTE1	Hex
TAILBYTE2	Hex
VCID	Counts
VCDU	Counts
WDOGST	Counts

Status Words	bit=0	bit=1
ANTSEL	OMNI	MGA
CARLOCK	NOLOCK	LOCK
COHERST	OFF	ON
DEMODLOCK	NOLOCK	LOCK
EMST	OFF	ON
ENCODST	OFF	ON
ERRFLG	OK	ERROR
GSESTAT	FLIGHT	GSE PRES
GTBO	OFF	ON
GTB1	OFF	ON
MERAST	OFF	ON
MERBST	OFF	ON
MERHTRST	OFF	ON
PCMADST	OFF	ON
PVIST	OPEN	CLOSED
PRESSST	OFF	ON
PRIHTRST	OFF	ON
RANGST	OFF	ON
SECHTRST	OFF	ON
SERLKPRS	JUMP	NO_JUMP
SEST	OFF	ON
SUBST	OFF	ON
SUNST	OFF	ON
XMTST	OFF	ON
TLMFIEMP	FALSE	TRUE
TLMFIFL	FALSE	TRUE
TLMFIOV	FALSE	TRUE

UPLNKST Table

From DSN (NOT SPACECRAFT TELEMETRY)

AGC dBm

SNR dB

Mnemonic	Description	State Value = Text	Location					
			Main Frame #	Word #	Master Frame Word #	Start Bit	# Bits	SES Hardware Address
SFRMCNT0	Frame Count 0x0		0	0	0	0	4	S/W
SCMDEX	SES Command Executed (32 sec)	0=NO 1=YES	0	0	0	4	1	S/W
SCMDREC	SES Command Received Flag	0=NO 1=YES	0	0	0	5	1	S/W
SCMDERR	SES Command Error Status	0=OK 1=ERR	0	0	0	6	1	S/W
SCMDCHK	SES Command Checksum Error	0=OK 1=ERR	0	0	0	7	1	S/W
SCMDRBK1	Command Readback - Function Code		0	1	1	0	8	S/W
SCMDRBK2	Command Readback - Data Field		0	2	2	0	8	S/W
SDPSYNC1	Data Product Sync 0xB8		0	3	3	0	8	S/W - Fixed
SDPID1	Data Product I.D. 1		0	4	4	0	2	S/W - Fixed
SGRSRLY	GRS Relay State	0=OFF 1=ON	0	4	4	2	1	20008 - Bit 2
SGH1CTL	GRS HV 1 Control	0=DIS 1=EN	0	4	4	3	1	20004 - Bit 5
SGH2CTL	GRS HV 2 Control	0=DIS 1=EN	0	4	4	4	1	20004 - Bit 4
SWTCHDG	SES Watchdog Status	0=DIS 1=EN	0	4	4	5	1	S/W
SSWCHKERR	Software Checksum Error	0=OK 1=ERR	0	4	4	6	1	S/W
SSWMEMER	Software Memory Test Error	0=OK 1=ERR	0	4	4	7	1	S/W
SGH1LVL	GRS HV 1 Level		0	5	5	0	8	20018
SGH2LVL	GRS HV 2 Level		0	6	6	0	8	2001A
SBGOWL	GRS BGO Window Low Energy Threshold		0	7	7	0	8	20C00
SBGOWH	GRS BGO Window High Energy Threshold		0	8	8	0	8	20C02
SBC454WL	GRS BC454 Window Low Energy Threshold		0	9	9	0	8	20C04
SBC454WH	GRS BC454 Window High Energy Threshold		0	10	10	0	8	20C06
SETL	GRS Early Time Low TTSP Threshold		0	11	11	0	8	20C08

Mnemonic	Description	State Value = Text	Location					
			Main Frame #	Word #	Master Frame Word #	Start Bit	# Bits	SES Hardware Address
SETH	GRS Early Time High TTSP Threshold		0	12	12	0	8	20C0A
SLTL	GRS Late Time Low TTSP Threshold		0	13	13	0	8	20C0C
SLTH	GRS Late Time High TTSP Threshold		0	14	14	0	8	20C0E
	Cat 3/4 Scalar (10 bits wide, 8 each packed)		0	15-24	15-24	0	8	COM PORT
	GRS Cat. 3/4 Events (high, middle, low byte) 69 Events, Event # 1-69		0	25-231	25-231	0	8	82000 - Low, Mid 81000 - high
SFRMCNT1	Frame Count 0x1		1	0	232	0	4	S/W
SCMDCNT	Number of Commands Executed		1	0	232	4	4	S/W
	GRS Cat. 3/4 Events (high, middle, low byte) 77 Events, event #70-146		1	1-231	233-463	0	8	82000 - Low, Mid 81000 - high
SFRMCNT2	Frame Count 0x2		2	0	464	0	4	S/W
SMSTRCNT0	SES Master Frame Counter - Bits 0-3		2	0	464	4	4	S/W
	GRS Cat. 3/4 Events (high, middle, low byte) 77 Events, event # 147-223		2	1-231	465-695	0	8	82000 - Low, Mid 81000 - high
SFRMCNT3	Frame Count 0x3		3	0	696	0	4	S/W
SMSTRCNT1	SES Master Frame Counter - Bits 4-7		3	0	696	4	4	S/W
	GRS Cat. 3/4 Events (high, middle, low byte) 77 Events, event #224-300		3	1-231	697-927	0	8	82000 - Low, Mid 81000 - high
SFRMCNT4	Frame Count 0x4		4	0	928	0	4	S/W
SMSTRCNT2	SES Master Frame Counter - Bits 8-11		4	0	928	4	4	S/W
	GRS Cat. 3/4 Events (high, middle, low byte) 77 Events, event #301-377		4	1-231	929-1159	0	8	82000 - Low, Mid 81000 - high
SFRMCNT5	Frame Count 0x5		5	0	1160	0	4	S/W
SMSTRCNT3	SES Master Frame Counter - Bits 12-15		5	0	1160	4	4	S/W
	GRS Cat. 3/4 Events (high, middle, low byte) 35 Events, event #378-412		5	1-105	1161-1265	0	8	82000 - Low, Mid 81000 - high
	GRS Prompt BC454 ET - 16 Channels		5	106-121	1266-1281	0	8	A8040-A807C
	GRS Prompt BC454 LT - 16 Channels		5	122-137	1282-1297	0	8	A8080-A80BC

Mnemonic	Description	State Value = Text	Location					
			Main Frame #	Word #	Master Frame Word #	Start Bit	# Bits	SES Hardware Address
	GRS Delayed BC454 ET - 64 Channels		5	138-201	1298-1361	0	8	98100-981FC
	GRS Delayed BC454 LT - Channels 0-29		5	202-231	1362-1391	0	8	98200-98274
SFRMCNT6	Frame Count 0x6		6	0	1392	0	4	S/W
SMIDCMD0	Command Readback - Middle byte bits 0-3		6	0	1392	4	4	S/W
	GRS Delayed BC454 LT - Channels 30-63		6	1-34	1393-1426	0	8	98278-982FC
	GRS Delayed BGO ET - 64 Channels		6	35-98	1427-1490	0	8	A0100-A01FC
	GRS Delayed BGO LT - 64 Channels		6	99-162	1491-1554	0	8	A0200-A02FC
SDP1CHKSM	Data Product 1 Checksum		6	163	1555	0	8	S/W
SDPSYNC0	Data Product Sync 0xB8		6	164	1556	0	8	S/W - Fixed
SDPID0	Data Product I.D. 0		6	165	1557	0	2	S/W - Fixed
SMODE	SES Data Mode	0 = SCI 1 = DUMP	6	165	1557	2	1	S/W
	SPARE		6	165	1557	3	5	
	GRS Category 1 BGO PHS Channels 0-65		6	166-231	1558-1623	0	8	B8000-B8104
SFRMCNT7	Frame Count 0x7		7	0	1624	0	4	S/W
SMIDCMD1	Command Readback - Middle byte bits 4-7		7	0	1624	4	4	S/W
	GRS Category 1 BGO PHS Channels 66-296		7	1-231	1625-1855	0	8	B8108-B84A0
SFRMCNT8	Frame Count 0x8		8	0	1856	0	4	S/W
SOVLDSRL0	Scalar - Overload bits 0-3		8	0	1856	4	4	COM PORT
	GRS Category 1 BGO PHS Channels 297-511		8	1-215	1857-2071	0	8	B84A4-B87FC
	GRS Category 2 BGO PHS Channels 0-15		8	216-231	2072-2087	0	8	(B9000-B903C) + (B9800-B983C)
SFRMCNT9	Frame Count 0x9		9	0	2088	0	4	S/W

Mnemonic	Description	State Value = Text	Location					
			Main Frame #	Word #	Master Frame Word #	Start Bit	# Bits	SES Hardware Address
SOVLDSRL1	Scalar - Overload bits 4-7		9	0	2088	4	4	COM PORT
	GRS Category 2 BGO PHS Channels 16-246		9	1-231	2089-2319	0	8	(B9040-B93D8) + (B9840-B9BD8)
SFRMCNT10	Frame Count 0xA		10	0	2320	0	4	S/W
SOVLDSRL2	Scalar - Overload bits 8-11		10	0	2320	4	4	COM PORT
	GRS Category 2 BGO PHS Channels 247-477		10	1-231	2321-2551	0	8	(B93DC-B9774) + (B9BDC-B9F74)
SFRMCNT11	Frame Count 0xB		11	0	2552	0	4	S/W
SOVLDSRL3	Scalar - Overload bits 12-15		11	0	2552	4	4	COM PORT
	GRS Category 2 BGO PHS Channels 478 -511		11	1-34	2553-2586	0	8	(B9778-B97FC) + (B9F78-B9FFC)
	GRS Category 2 BGO PHS (BC454W=1) 64 Channels		11	35-98	2587-2650	0	8	B9800-B98FC
	GRS Category 2 BC454 PHS (BGOW=1) 64 Channels		11	99-162	2651-2714	0	8	B0000-B00FC
	Scalar - CAT2D (64 each)		11	163-226	2715-2778	0	8	COM PORT
SCAT12SH	Scalar - CAT1/2 high byte		11	227	2779	0	8	COM PORT
SCAT12SL	Scalar - CAT1/2 low byte		11	228	2780	0	8	COM PORT
SDTSCLRH	Scalar - Deadtime high byte		11	229	2781	0	8	COM PORT
SDTSCLRL	Scalar - Deadtime low byte		11	230	2782	0	8	COM PORT
SDP0CHKSM	Data Product 0 Checksum		11	231	2783	0	8	S/W
SFRMCNT12	Frame Count 0xC		12	0	2784	0	4	S/W
SNH1CTL	NS HV 1 Control	0=DIS 1=EN	12	0	2784	4	1	20004 - Bit 3
SNH2CTL	NS HV 2 Control	0=DIS 1=EN	12	0	2784	5	1	20004 - Bit 2
SNSRLY	NS Relay State	0=OFF 1=ON	12	0	2784	6	1	20008 - Bit 3
	SPARE		12	0	2784	7	1	
SDPSYNC2	Data Product Sync 0xB8		12	1	2785	0	8	S/W - Fixed

Mnemonic	Description	State Value = Text	Location					
			Main Frame #	Word #	Master Frame Word #	Start Bit	# Bits	SES Hardware Address
SDPID2	Data Product I.D. 2		12	2	2786	0	2	S/W - Fixed
	SPARE		12	2	2786	2	6	
SNH1LVL	NS HV 1 LEVEL (0-255)		12	3	2787	0	8	2001C
SNH2LVL	NS HV 2 LEVEL (0-255)		12	4	2788	0	8	2001E
SHECDWL	NS Low Window Tin Counter (0-255)		12	5	2789	0	8	20800 + 00
SHECDWH	NS High Window Tin Counter (0-255)		12	6	2790	0	8	20800 + 02
SHESNWL	NS Low Window Cadmium Counter (0-255)		12	7	2791	0	8	20800 + 04
SHESNWH	NS High Window Cadmium Counter (0-255)		12	8	2792	0	8	20800 + 06
SAEWL	APS Low Threshold Energy Window (0-255)		12	9	2793	0	8	20400 + 00
SAPSFACE1	APS Face 1 Sensor Status	0=DIS 1=EN	12	10	2794	0	1	20402 Bit 0
SAPSFACE2	APS Face 2 Sensor Status	0=DIS 1=EN	12	10	2794	1	1	20402 Bit 1
SAPSFACE3	APS Face 3 Sensor Status	0=DIS 1=EN	12	10	2794	2	1	20402 Bit 2
SAPSFACE4	APS Face 4 Sensor Status	0=DIS 1=EN	12	10	2794	3	1	20402 Bit 3
SAPSFACE5	APS Face 5 Sensor Status	0=DIS 1=EN	12	10	2794	4	1	20402 Bit 4
	SPARE		12	10	2794	5	3	
	NS HESN PHS - 32 Channels		12	11-42	2795-2826	0	8	70000-7007C
	NS HECD PHS - 32 Channels		12	43-74	2827-2858	0	8	78000-7807C
	NS HESN Scalars - 64 each		12	75-138	2859-2922	0	8	COM PORT
	NS HECD Scalars - 64 each		12	139-202	2987-2986	0	8	COM PORT
	APS PHS - Channels 0 - 28 (128 channels)		12	203-231	2987-3015	0	8	58000-58070
SFRMCNT13	Frame Count 0xD		13	0	3016	0	4	S/W

Mnemonic	Description	State Value = Text	Location					
			Main Frame #	Word #	Master Frame Word #	Start Bit	# Bits	SES Hardware Address
SAPSLVRLY	APS LV Relay State	0=OFF 1=ON	13	0	3016	4	1	20008 - Bit 4
SAPSHVRLY	APS HV Relay State	0=OFF 1=ON	13	0	3016	5	1	20008 - Bit 5
	SPARE		13	0	3016	6	2	
	APS PHS - Channels 29 - 127 (128 channels)		13	1-99	3017-3115	0	8	58074-581FC
	APS Events (high, low byte) 66 Events, event # 1-66		13	100-231	3116-3247	0	8	42000
SFRMCNT14	Frame Count 0xE		14	0	3248	0	4	S/W
	SPARE		14	0	3248	4	4	
	APS Events (high, low byte) 115 Events, event # 67-181, high byte event # 182		14	1-231	3249-3479	0	8	42000
SFRMCNT15	Frame Count 0xF		15	0	3480	0	4	S/W
	SPARE		15	0	3480	4	4	
	APS Events, low byte event # 182, (high, low byte) 112 events, event #183-294		15	1-225	3481-3705	0	8	42000
SAPSSCLRH	APS Scalar high byte		15	226	3706	0	8	COM PORT
SAPSSCLRL	APS Scalar low byte		15	227	3707	0	8	COM PORT
SDP2CHKSM	Data Product 2 Checksum		15	228	3708	0	8	S/W
	SPARE		15	229	3709	0	8	
	SPARE		15	230	3710	0	8	
	SPARE		15	231	3711	0	8	

Lunar Prospector MAG/ER Instrument Telemetry Format

98-2-5 D.W.Curtis

This document describes the Lunar Prospector MAG/ER instrument telemetry format. A detailed description of the instrument and its operation can be found in <***TBS***>. A brief top-level description of the instrument telemetry follows in Section 1, followed by a more detailed description in Section 2. Section 3 describes the analog housekeeping sampled by the spacecraft.

1. Top-Level Telemetry Description

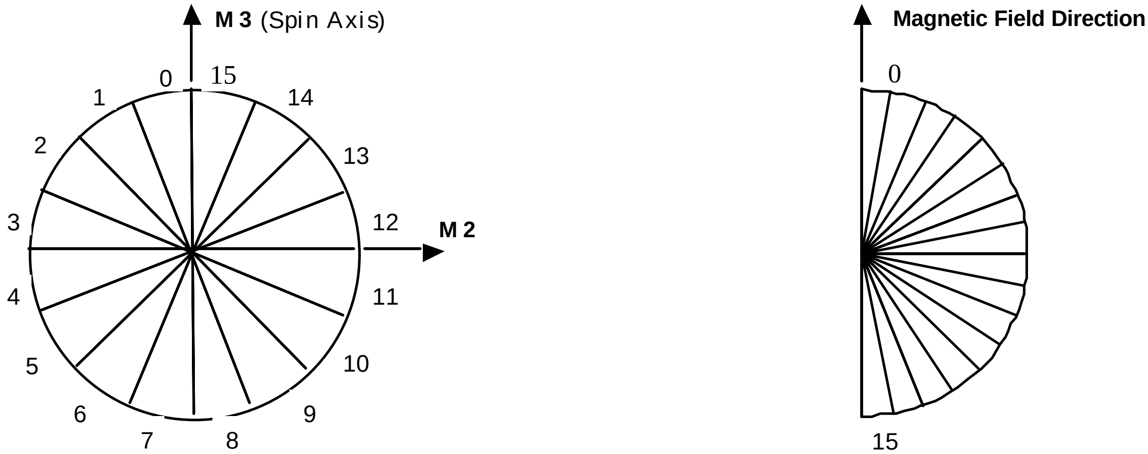
The MAG/ER instrument has a science telemetry allocation of 672 bps. This is in addition to MAG/ER analog housekeeping telemetry sampled by the spacecraft. This rate is shared approximately equally between MAG and ER science data. In addition to real-time telemetry, 'burst' telemetry will be included in the telemetry. Burst telemetry consists of enhanced time resolution data collected for a short interval. Telemetry will be formatted into two-second telemetry frames. Each 2-second frame of MAG/ER data is included in a spacecraft frame, which includes a time tag (frame counter). A group of 16 frames (starting with frame number modulo 16 equals 0) makes a 'Major Frame'.

1.1 MAG Real-Time Telemetry

MAG telemetry will consist of raw three axis magnetometer samples, digitized to 12 bits, sampled at 18 Hz and averaged to 9Hz (telemetry-synchronous). Automatic MAG range control is exercised once a frame (to select one of 8 measurement ranges), and ranging information is included once a frame.

1.2 ER Real-time Telemetry

ER telemetry is collected spin-synchronous (nominal spin rate = 12 RPM). Data is accumulated in the ER instrument in two formats simultaneously: pitch angle sorted and fixed sector sorted. Pitch angle sorted data is accumulated into a 16 α (pitch angle) by 16 energy array, while fixed sector data is accumulated into a 16 θ (anode) by 16 energy array. The fixed sector array angular bins are equally spaced over the 360° Field-of-view (FOV), giving 22.5° resolution. Pitch angle sorting is based on the magnetic field direction provided by the magnetometer, and is done 'on the fly' for each electron count to a resolution of 1.4°. The pitch angle array angular bin spacing is programmable (default is equally spaced 11.25° bins). The figure below shows the binning schemes schematically. Note that M1 and M3 in the figure refer to instrument coordinates as described in the 'Lunar Prospector Mission Spacecraft to Science Instruments Interface Control Document', (ICD), Lockheed Martin Document LMMS/P086796F.



Nominal ER Fixed Angle Bins Definition(θ) Nominal ER Pitch Angle Bins Definition (α)

Figure 1.2 ER binning schemes

The ER energy is swept 32 times per spin (for uniform phase space coverage), and data is summed over 2 energy sweeps (1/16 spin, 22.5 degrees of rotation). The ER FOV samples all look directions in spin of the spacecraft. ER fixed angle data is sampled 8 times in the spin to accumulate 3D distributions with 22.5° by 22.5° resolution. This scheme over-samples the poles of the distribution (along the spin axis), so the resulting 128 angular bins are summed into 88 bins with more uniform phase space sampling (see section 2.3.2). The processor collects and accumulates data into averaged pitch angle distributions of 16 α by 15 energies and three dimensional distributions of 88 angular bins (Ω) by 15 energies. The 16th energy step collected while the sweep supply ramps up is discarded.

ER data is collected into a fixed telemetry format, which is accumulated over 16 spins. The 16-spin accumulation is read out in 36 telemetry frames. At the nominal spin rate (12 RPM), 16 spins occur in 40 telemetry frame times. The extra telemetry frames are used to send Burst data or Fill. An index in each telemetry frame indicates which of the 36 frames of ER data is included (or of it is a Burst of Fill packet). If the spin rate is above nominal, the ER will produce an accumulation in less than 40 telemetry frames. This causes less Burst/fill data to be sent. If the spin rate exceeds 13.3 RPM, then there will be insufficient telemetry space to send the ER data with no Burst/Fill. Data frames will be dropped and an error will be indicated in this case. If the spin rate is below nominal, then more burst/fill data is read out.

Real-time 3D data is collected for spin, and read out once every 16 spins. Real-time ER pitch angle data has different time resolutions for different energies. Two selected energies are accumulated and read out every spin. The rest of the energies are accumulated and read out every 4 or 8 spins. Note that 3D data is accumulated only over spin, while Pitch Angle data is typically accumulated continuously over the sample interval.

Below a certain energy, pitch angle distributions are not as useful. The distribution is significantly non-gyrotropic in the spacecraft frame even if it is in the solar wind frame. Also, electrostatic charging effects of the spacecraft and planet distort the distribution at low energies. Accumulating the data into a pitch angle distribution under these circumstances makes the angular data unusable because it mixes unrelated regions of phase space. To accommodate this, below a programmable energy step (nominally about 100eV), 'Cut' data is sent instead of pitch angle data. Cut data is the fixed sector data at a selected spin phase, corresponding to when the magnetic field is in the field of view of the instrument. Cut data is sampled, not averaged. This provides a low angular resolution pitch angle measurement without mixing different regions of phase space. Cuts are only sent in Real-time data, not burst data (where 3D data is always available). Cut data has 22.5 degree fixed resolution since it is extracted from the fixed angle data.

The ER uses the magnetic field direction measured by the magnetometer for pitch-angle sorting the electrons on-board. The magnetic field vector is propagated in the ER hardware for spacecraft rotation, and the vector is only updated from the magnetic field data four times a spin. It is important to know on the ground what magnetic field direction is used for pitch-angle sorting (in order to know the geometric factor of each pitch angle bin). The ER uses the same field vector that is in the MAG real-time telemetry, so the only uncertainty is which of the vectors in telemetry were used. Based on the spin phase timing included in the instrument telemetry, you can determine fairly accurately which sample, but there will be cases where the MAG sample time is close enough to the start of a 1/4 spin to make the determination of which MAG sample is used ambiguous. To eliminate this ambiguity, one bit per quarter spin is telemetered to indicate the LSB of the MAG sample number that was used.

1.3 Digital Subcom

Instrument status information is included in Digital Subcom telemetry. Digital Subcom data consists of a 16-bit word read out each Frame, subcomutated by 16 using the frame number included in the spacecraft. Digital Subcom data is sampled at the time of the start of the Major Frame.

1.4 Burst Operation

The burst system will be run in one of two possible modes: 'Triggered' and 'Commanded'. In Triggered mode, the burst memory will be used to attempt to capture interesting events based on a burst criterion computed from the ER data. In Commanded mode, the burst memory will be used to study a selected region on the lunar surface with enhanced spatial resolution. Most of the time, the system will be in Triggered burst mode. Commanded bursts will be collected at selected times by ground command. After the Commanded burst is collected and transmitted, the system returns to Triggered burst mode.

1.4.1 Triggered Burst Mode

This is the normal operating mode. In this mode, high rate data is continuously put into a piece of the burst memory called a ‘preamble’. This section is continuously over-written until the burst criteria value exceeds that of the previously recorded burst. At that time, the preamble is saved, and subsequent data is saved in the ‘ending’ block, over-writing the previous ‘best’ burst. When the ending is full, the system starts searching for an even better event using a second preamble buffer. This continues while a previously collected burst is played out through telemetry. When the transmission of the burst being telemetered is complete, its preamble and ending buffers are freed, and the current best burst preamble and ending buffers are frozen for telemetry. This system collects the ‘best’ burst once every burst read-out interval. It requires 3 preamble buffers (transmitting, collecting, and best), and two ending buffers (transmitting and best). The sizes of the preamble and ending buffers are programmable, but the total of the five buffers must fit into the 1 Mbyte burst memory.

The burst criterion is based on changes in the ER count rate in a programmable energy range. The counts over the selected interval are summed and log-compressed once each spin. A simple filter is used to compute the baseline value for this measurement (in log counts). The absolute value of the difference between the current value and the baseline value is the burst criteria. If the burst criterion is better that the criteria for the current ‘best’ burst, then a new ‘best’ burst is saved. Note that the criterion for a ‘best’ burst is the maximum value of the criterion taken over the whole burst.

Burst telemetry shall include MAG samples at 18 Hz, and both fixed angle (88 Ω by 15 E) and pitch angle (16 α by 15 E) ER data sampled typically every 1/2 spin (the sample rate is programmable). With some additional context data, this produces 5997 bps. At this rate the burst memory can hold a total of 23 minutes of data (divided amongst the 3 preamble and 2 ending buffers).

The nominal telemetry allocation is:

MAG Science: ....328.0 bps
ER Science:.....................302.8 bps (at 12 RPM)
Digital Subcom:................ 8.0 bps
Burst Playback: .... 33.2 bps (at 12 RPM)

Total: ....672.0 bps

At this rate, 6 minutes of burst data (at about 6Kbps collect rate) will play out in about 18 hours.

1.4.2 Commanded Burst Mode

Commanded burst mode is initiated by command. At a selected time, the burst memory contents are erased (the current Triggered bursts are lost), and the burst memory is filled with burst data. When the selected burst buffer size has been reached, all data collection is suspended, and the full telemetry stream is used to play out the burst memory contents.

When the memory playback is complete, the system returns to normal (Triggered burst) mode and real-time data. A series of periodic Commanded bursts may be set up, for example once per orbit as the spacecraft passes over the desired location on the planet (or perhaps every second orbit so that some context data is collected at the normal rate).

Commanded bursts contain the same data as triggered bursts. Since the playback rate is considerably higher (about 20x), the playback time is shorter. If we limit the playback time to one orbit (118 minutes), the burst size is 580 Kbytes, and the record time is about 13 minutes (at 6 Kbps collect rate).

1.5 Timing

Instrument timing is tied to the frame and major frame pulses received by the instrument. These pulses are generated by the spacecraft at the beginning of each frame and major frame. The time of these frame pulses can be reconstructed on the ground based on Earth receive time, minus light time, and minus known delays in the data through the spacecraft data system (2 seconds for regular data, 3200 seconds for ‘delayed’ data).

ER data is collected spin-synchronous, based on a sun pulse provided by the spacecraft which drives a phase-locked loop in the ER. When there is no sun pulse, the ER continues to ‘fly-wheel’ using the last measured spin period. The timing of the ER data accumulation relative to the Major Frame time can be reconstructed from the Mag/ER telemetry (see section 2.3.5).

2. Detailed Telemetry Format

MAG/ER has 672bps*2s/8bits = 168 bytes per 2 second telemetry frame. The first 3 bytes of every frame is the same in all modes:

Byte	Contents
0	Frame Code (see section 2.1)
1,2	Digital Subcom (see section 2.5)

The format of the remaining bytes depends on the Frame Code as described in section 2.1 below.

2.1 Frame Code

The Frame Code indicates the format of the remaining data in the frame. The 6 LSB of the Frame Code are the Frame Type, with the two MSB containing ancillary information, depending on the Frame Type.

2.1.1 Real-time Frames (Frame Type 0-35)

These frames contain real-time MAG and ER data. The Frame Type indicates which of the 36 ER packets making up a 16-spin sample are included (see section 2.3). For these frames, the 2 MSBs of the Frame Code are used for ancillary ER data (see Section 2.3.3). The frame format is:

Byte	Contents
3-84	Real-time Mag data (Section 2.2)
85-167	Real-time ER data (Section 2.3)

2.1.2 Half Burst Frames (Frame Type 36-62, with Frame Code MSB = 0)

These frames contain real-time MAG data, plus burst playback data. The MSB of the Frame Code for these frames are zero. The Frame Type number indicates which of the 22 Burst packet types is included (see section 2.4). This format is typically used for Triggered burst playback data.

Byte	Contents
3-84	Real-time Mag data (Section 2.2)
85	Burst playback frame counter (Section 2.4)
86-167	82 byte burst Playback record (Section 2.4)

2.1.3 Full Burst Frames (Frame Code 36-62 with Frame Type MSB =1)

These frames contain no real-time data, but two packets of Burst playback data. The MSB is set to distinguish these packets from Half Burst frames. The Frame Type indicates the type for the first burst packet. The type of the second packet is indicated in byte 85. This format is typically used for Commanded bursts.

Byte	Contents
3-84	82 byte burst playback record #1 (Section 2.4)
85	Record #2 Frame Code (Section 2.4)
86-167	82 byte burst Playback record #2 (Section 2.4)

2.1.4 Memory Dump Frames (Frame Type 63)

These frames include real-time MAG data and memory dump data. These packets may be selected by command, or they are produced automatically if no ER or Burst data is available. The 2 MSB of the Frame Code are set to 11.

Byte	Contents
3-84	Real-time Mag data
85-86	Memory dump address (LS Byte first)
86-167	81 bytes of memory data starting at Memory dump address.

2.2 Mag Data Format

Both real-time Mag data (type 0-35) and Burst Mag data (type 56 – see section 2.4) use the same format. They include a MAG range / frame number byte plus 18 MAG samples (81 bytes). The format is:

Byte #	Contents
0	MAG Status: F.F.F.F.CAL.R.R.R (FFFF = Frame #,RRR=Range)
1-9	MAG sample 0 and 1
10-18	MAG sample 2 and 3
19-27	MAG sample 4 and 5
28-36	MAG sample 6 and 7
37-45	MAG sample 8 and 9
46-54	MAG sample 10 and 11
55-63	MAG sample 12 and 13
64-72	MAG sample 14 and 15
73-81	MAG sample 16 and 17

In this table, Byte # is relative to the start of the 82 byte MAG data block. CAL is a bit indicating the MAG is in calibration mode (1 = calibration mode, 0 = nominal mode). Calibration data is diagnostic, and should be ignored for science analysis. The Range code tells the gain of the instrument (see section 2.2.3).

A pair of MAG samples (2samples * 3 axis * 12bits) fills 9 bytes:

Byte #	Bits	Contents
0,1	0-11	MAG sample 0, x axis (12 bits)
1,2	12-23	MAG sample 0, y axis (12 bits)
3,4	24-35	MAG sample 0, z axis (12 bits)
4,5	36-47	MAG sample 1, x axis (12 bits)
6,7	48-59	MAG sample 1, y axis (12 bits)
7,8	60-71	MAG sample 1, z axis (12 bits)

In this table, Byte # is relative to the start of the 2 MAG sample block. Bit numbers start at zero for the LSB of the first byte of the MAG sample block.

The Frame Number included in the Mag status is redundant with that included in the spacecraft header for real-time data (it can be used as a consistency check). For Burst data (Frame Type 56), it tells how long since the most recent Major Frame marker block time this data was collected (Major Frame marker blocks are described in section 2.4). Since Burst data is collected at a rate of two frames per 2-second frame time, another bit of timing information is needed to tell which of the two samples is included. Bit 6 from the Frame Code byte serves this function for Frame Type 56. It is zero for the sample taken during the one second interval following the start of the frame, and one for the second sample.

2.2.1 MAG Sample Timing

The MAG is sampled 36 times per 2 second frame, synchronous with the telemetry clock. The first sample is taken at the time of the Frame pulse. Real-time data consists of averaged sample pairs. The first sample is the vector sum of the sample measured at the frame pulse time, and the sample taken 1/18 second later, divided by 2.

The spin-phase of the spacecraft at the time of the MAG sample can also be computed with the aid of data in the Digital Sub-Com (see section 2.5). For the N^{th} raw MAG sample taken after the Major Frame pulse (with N=0 for the sample taken at the time of the Major Frame pulse), the spin phase (in degrees) is:

360. * (Phase/4096. + N/(18.*Period*.001024))

‘Phase’ and ‘Period’ are in the Digital Sub-Com.

The real-time data consists of averages of two consecutive Mag samples. The average of the two sample times for the N^{th} real-time MAG sample is:

360. * (Phase/4096. + (N +   )/(9.*Period*.001024))

2.2.2 MAG Data Calibration

In the deployed configuration, the nominal MAG orientation is has its Z-axis along the spacecraft spin axis (M3), its X-axis radially outwards from the spacecraft (M1), and its Y-axis pointing tangentially to the spacecraft in a right-handed coordinate system (M2). Once the booms are deployed, there may be a small rotational offset in this orientation which will be determined by the MAG team based on their data.

The MAG vector samples are telemetered as three 12-bit numbers coded excess-2048. The raw, signed measurement is computed as the telemetered value minus 2048. An offset in the measurement must be subtracted to account for instrument offsets and spacecraft field. This offset is different for each range, and may vary with time with spacecraft configuration. The MAG team will determine these offsets from their data. Once the offsets are subtracted, the measurement must be multiplied by a gain value which is a function of the Gain setting. The nominal gain factors (to convert to nT) are:

Range	Gain
0	1/512
1	1/128
2	1/32
3	1/8
4	1/2
5	2

6	8
7	32

These values are only nominal. The actual values are TBD.

2.3 Real-Time ER Frame Format

The 36 Real-time ER frame types together contain 16 spins of ER data. At the nominal spin rate, these are collected every 40 frames. When the next frame of ER data is not yet ready then the next Triggered Burst data or Memory Dump block is sent instead. ER frames will be read out sequentially, interrupted by occasional Burst or Memory Dump frames.

Each Real-time ER frame contains 83 bytes of ER data. These bytes contain from two to five 16-angle pitch angle samples. The remaining data is filled with the 3D (88 angle by 15 energy) data. The pitch angle data is sent out as close as possible to the end of the accumulation time to minimize latency through the system.

All ER counter data is log compressed to 8 bits of telemetry per sample (see section 2.6 below for a description of the compression scheme). Some accumulations are pre-scaled to avoid saturating the dynamic range of the compression scheme.

A 16-angle pitch angle sample is labeled by its energy bin number (0-14). Energy bin 0 is the highest energy. Energy bins 6 and 9 (in telemetry format 1) are transmitted every spin. Energy bins 0-5 are sent every 8 spins, and energy bins 7, 8 and 10-14 every 4 spins.

Energy bins 10-14 are 'Cuts' rather than Pitch Angle data (in Telemetry format 1). Cuts are taken from the fixed-sectored data (22.5 degree fixed resolution) when the magnetic field vector is in the FOV of the detector. Cuts are sampled over 22.5 degrees of spin, not an averaged over multiple half-spins. The magnetic field vector used to determine the sector number in the cut is the first of the two samples for the half-spin of the cut used by the pitch-angle sorting system. The correspondence between energy bin number and energy level is a function of programmable parameters. The nominal values are shown in section 2.3.4 below.

Pitch angle data (not Cuts) may be pre-scaled to avoid saturating the compression scheme dynamic range. Pre-scaling may be done automatically based on the count rates measured in the previous 16-spin accumulation, or statically by command. Pre-scaling is done separately in 8 energy bands. In automatic pre-scaling mode, if any pitch-angle sample in a band is saturated (counts greater than 524,287), then all values in that band will be divided by a factor of 8 before compression on the following 16 spin accumulations. The band will continue to be pre-scaled until all samples in the band are at least a factor of 2 below saturation without the pre-scale for a whole 16 spin accumulation. The pre-scale can also be forced on or off for any band by command. The pre-scale state is included in the ER header (see section 2.3.1).

The following table describes the contents of the ER real-time frames for each Frame Type.

ER Real-Time Telemetry Frames Contents

Format 1

Frame Type	ER Data Contents					
0	E0S0,	E1S0,	E2S0,	E3S0,	E4S0,	Header bytes 0-2
1	E5S0,	E6S0,	E7S0,	E8S0,	E9S0,	Header byte 3, 3D bytes 0-1
2	E10S0,	E11S0,	E12S0,	E13S0,	E14S0,	3D bytes 2-4
3	E6S1,	E9S1,	E6S2,	E9S2,		3D bytes 5-23
4	E6S3,	E9S3,				3D bytes 24-74
5	E6S4,	E9S4,				3D bytes 75-125
6	E6S5,	E9S5,				3D bytes 126-176
7	E6S6,	E9S6,				3D bytes 177-227
8	E6S7,	E9S7,				3D bytes 228-278
9	E6S8,	E7S1,	E8S1,	E9S8,	E10S1,	3D bytes 279-281
10	E11S1,	E12S1,	E13S1,	E14S1,		3D bytes 282-300
11	E6S9,	E9S9,				3D bytes 301-351
12	E6S10,	E9S10,				3D bytes 352-402
13	E6S11,	E9S11,				3D bytes 403-453
14	E6S12,	E9S12,				3D bytes 454-504
15	E6S13,	E9S13,				3D bytes 505-555
16	E6S14,	E9S14,				3D bytes 556-606
17	E6S15,	E9S15,				3D bytes 607-657
18	E0S1,	E1S1,	E2S1,	E3S1,	E4S1,	3D bytes 658-660
19	E5S1,	E6S16,	E7S2,	E8S2,	E9S16,	3D bytes 661-663
20	E10S2,	E11S2,	E12S2,	E13S2,	E14S2,	3D bytes 664-666
21	E6S17,	E9S17,	E6S18,	E9S18,		3D bytes 667-685
22	E6S19,	E9S19,				3D bytes 686-736
23	E6S20,	E9S20,				3D bytes 737-787
24	E6S21,	E9S21,				3D bytes 788-838
25	E6S22,	E9S22,				3D bytes 839-889
26	E6S23,	E9S23,				3D bytes 890-940
27	E6S24,	E7S3,	E8S3,	E9S24,	E10S3,	3D bytes 941-943
28	E11S3,	E12S3,	E13S3,	E14S3,		3D bytes 944-962
29	E6S25,	E9S25,				3D bytes 963-1013
30	E6S26,	E9S26,				3D bytes 1014-1064
31	E6S27,	E9S27,				3D bytes 1065-1115
32	E6S28,	E9S28,				3D bytes 1116-1166
33	E6S29,	E9S29,				3D bytes 1167-1217
34	E6S30,	E9S30,				3D bytes 1218-1268
35	E6S31,	E9S31,				3D bytes 1269-1319

The code E6S23 in the above table, for example, corresponds to the 24^{th} sample of energy 6 of the pitch angle/cut data. Data is put into the frame starting with the item on the left, progressing through the last item on the right in the above table. Each pitch angle data sample includes 16 pitch angle bins installed in the frame in pitch-angle bin number order, while Cut data includes 16 fixed angle bins installed in the frame in fixed angle bin number order (see the figures in section 1.2). Header data is described in section 2.3.1, and 3D data in section 2.3.2.

2.3.0 Telemetery Format 2

The above format for ER real-time data is the format corresponding to the original default configuration of the ER. This format was modified early in the mission to change the energies of the high time resolution pitch angle samples, and to lower the energy at which Cuts are made. Data in the original format is indicated by the Version code in the DSC data being one. The Version number changed to two for this new format, called Telemetry Format 2. For the new format the high time resolution energy channels are 9 and 11 instead of 6 and 9, and the Cuts start with energy 12 instead of 10. The new format is described in the table below:

ER Real-Time Telemetry Frames Contents

Format 2

Frame Type	ER Data Contents					
0	E0S0,	E1S0,	E2S0,	E3S0,	E4S0,	Header bytes 0-2
1	E5S0,	E6S0,	E7S0,	E8S0,	E9S0,	Header byte 3, 3D bytes 0-1
2	E10S0,	E11S0,	E12S0,	E13S0,	E14S0,	3D bytes 2-4
3	E9S1,	E11S1,	E9S2,	E11S2,		3D bytes 5-23
4	E9S3,	E11S3,				3D bytes 24-74
5	E9S4,	E11S4,				3D bytes 75-125
6	E9S5,	E11S5,				3D bytes 126-176
7	E9S6,	E11S6,				3D bytes 177-227
8	E9S7,	E11S7,				3D bytes 228-278
9	E6S8,	E7S1,	E8S1,	E9S8,	E10S1,	3D bytes 279-281
10	E11S1,	E12S1,	E13S1,	E14S1,		3D bytes 282-300
11	E9S9,	E11S9,				3D bytes 301-351
12	E9S10,	E11S10,				3D bytes 352-402
13	E9S11,	E11S11,				3D bytes 403-453
14	E9S12,	E11S12,				3D bytes 454-504
15	E9S13,	E11S13,				3D bytes 505-555
16	E9S14,	E11S14,				3D bytes 556-606
17	E9S15,	E11S15,				3D bytes 607-657
18	E0S1,	E1S1,	E2S1,	E3S1,	E4S1,	3D bytes 658-660
19	E5S1,	E6S16,	E7S2,	E8S2,	E9S16,	3D bytes 661-663
20	E10S2,	E11S2,	E12S2,	E13S2,	E14S2,	3D bytes 664-666
21	E9S17,	E11S17,	E9S18,	E11S18,		3D bytes 667-685
22	E9S19,	E11S19,				3D bytes 686-736
23	E9S20,	E11S20,				3D bytes 737-787
24	E9S21,	E11S21,				3D bytes 788-838
25	E9S22,	E11S22,				3D bytes 839-889
26	E9S23,	E11S23,				3D bytes 890-940
27	E6S24,	E7S3,	E8S3,	E9S24,	E10S3,	3D bytes 941-943
28	E11S3,	E12S3,	E13S3,	E14S3,		3D bytes 944-962
29	E9S25,	E11S25,				3D bytes 963-1013
30	E9S26,	E11S26,				3D bytes 1014-1064
31	E9S27,	E11S27,				3D bytes 1065-1115
32	E9S28,	E11S28,				3D bytes 1116-1166
33	E9S29,	E11S29,				3D bytes 1167-1217
34	E9S30,	E11S30,				3D bytes 1218-1268
35	E9S31,	E11S31,				3D bytes 1269-1319

2.3.1 ER Header Format

The 5 LSB of the first byte of the ER header contain the number of half-spins since the start of the Major Frame that the 16-spin accumulation started (see section 2.3.5 on accumulation timing). The 3 MSB of the first byte of the ER header is a version number for the pitch angle boundaries map. This number is set by command (PABBVersion in Table 4 - see "Lunar prospector MAG / ER Commanding" document). The default value is zero, corresponding to equally spaced (11.25 degree) pitch angle bins. If the spacing of the bins is changed by command, this number should also be changed so that ground software can correctly interpret the data. This code may also be used to identify other important changes in the ER data format, such as a change in the 'cut' energy limit, which may be changed by command but are not otherwise indicated in the telemetry.

The second header byte contains the 'Pre-scale' state for the real-time pitch angle accumulations. The longer pitch angle accumulations (all except energies 6 and 9 and cut data) may be pre-scaled to avoid saturation of the compression scheme. Pre-scaling involves dividing the count values by 8. Pitch angle data is divided into 8 energy bands: all counters in an energy band are either pre-scaled or not together. The 8 bits in the second ER header byte correspond to the pre-scale state of the 8 energy bands (0=not pre-scaled, 1=pre-scaled), (Bit 0 is the LSB):

Bit Number	Energy Steps
0	0,1
1	2,3
2	4,5
3	6, 7
4	8,9
5	10,11
6	12,13
7	14

Note that high time resolution and Cut data is not prescaled.

The third byte of the ER header contains the compressed, 'Total Counts'. Total Counts is the sum of all counts for all angles and energies (including the 'retrace' energy step not included in other telemetry) over the first half-spin of the ER accumulation. It is the sum of all events processed by the ER Pulse Position Analyzer, excluding those masked by the Anode masks, and any lost by FIFO over-run between the PPA and event processor (the event processor handles an event every microsecond, and the FIFO is 4 events deep). The total counts are divided by 16 before being compressed to avoid saturation of the compression scheme.

The fourth byte contains the 'Rate Counter' accumulated for first half spin of the ER accumulation (corresponding to the same time interval as the Total counts in byte 3). The Rate counter should be the same as the total counter except for events eliminated by one of the following: Pulse height above the upper level discriminator, Pulse occurred during PPA dead time (about 300ns per analyzed event), Pulse lost in event processor FIFO, or pulse rejected by anode masks. The Rate counter is prescaled by 2 in the hardware, and by another factor of 8 in software before being compressed.

The relative counts in Total and Rate, assuming the anode masks are all off and the event rate is not too high, should tell how many events are too large for the PPA, indicating that the MCP setting may be too high.

2.3.2 ER 3D Format

The 3D data consists of 88 angles (Ω) by 15 energies. The 1320 bytes (88*15) of 3D data are scattered over the 36 ER frames as indicated in the table in Section 2.3. The data is ordered as 15 groups of 88 angles, read out in ascending energy step number order. The phase space map below identifies the 88 phase space samples and their readout order. Bins covering more than one spin phase bin include the sum of the counts in all the covered bins. The figure in section 1.2 describes the anode bin numbering (fixed angle bins). The spin phase bin number corresponds to the time since the start of the half-spin that the data was collected, in units of 22.5°; Spin Phase bin 0, for example, is accumulated from 0 to 22.5° from the start of the half-spin.

<table>
<tr><th rowspan="2">Anode Bin #</th><th colspan="8">Spin Phase Bin # (22.5° per Bin)</th></tr>
<tr><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td>0</td><td colspan="4">0</td><td colspan="4">1</td></tr>
<tr><td>1</td><td colspan="2">2</td><td colspan="2">3</td><td colspan="2">4</td><td colspan="2">5</td></tr>
<tr><td>2</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td></tr>
<tr><td>3</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td></tr>
<tr><td>4</td><td>22</td><td>23</td><td>24</td><td>25</td><td>26</td><td>27</td><td>28</td><td>29</td></tr>
<tr><td>5</td><td>30</td><td>31</td><td>32</td><td>33</td><td>34</td><td>35</td><td>36</td><td>37</td></tr>
<tr><td>6</td><td colspan="2">38</td><td colspan="2">39</td><td colspan="2">40</td><td colspan="2">41</td></tr>
<tr><td>7</td><td colspan="4">42</td><td colspan="4">43</td></tr>
<tr><td>8</td><td colspan="4">44</td><td colspan="4">45</td></tr>
<tr><td>9</td><td colspan="2">46</td><td colspan="2">47</td><td colspan="2">48</td><td colspan="2">49</td></tr>
<tr><td>10</td><td>50</td><td>51</td><td>52</td><td>53</td><td>54</td><td>55</td><td>56</td><td>57</td></tr>
<tr><td>11</td><td>58</td><td>59</td><td>60</td><td>61</td><td>62</td><td>63</td><td>64</td><td>65</td></tr>
<tr><td>12</td><td>66</td><td>67</td><td>68</td><td>69</td><td>70</td><td>71</td><td>72</td><td>73</td></tr>
<tr><td>13</td><td>74</td><td>75</td><td>76</td><td>77</td><td>78</td><td>79</td><td>80</td><td>81</td></tr>
<tr><td>14</td><td colspan="2">82</td><td colspan="2">83</td><td colspan="2">84</td><td colspan="2">85</td></tr>
<tr><td>15</td><td colspan="4">86</td><td colspan="4">87</td></tr>
</table>

2.3.3 Real-Time ER 'Bits'

For real-time ER frames, the 2 MSB of the frame type code for the 36 frames are collected together into 72 bits (9 bytes) per 16-spin accumulation. The first 8 bits contain the 8 MSB of the ER test pulser command setting (parameter TestP in Table 1, see 'Lunar Prospector MAG/ER Commanding' document). The remaining 64 bits contain the MAG sample information discussed in section 1.2 above. To determine which MAG sample is used for each 1/4 spin, first compute the MAG sample closest to the start of each 1/4 spin based on the spin phase timing in the Digital Sub-Com (see section 2.2.1). To resolve any ambiguity when the MAG sample time is close to the start of a 1/4 spin, the bit for that 1/4 spin indicates if the MAG sample was odd or even (with the first MAG sample in a frame being even).

2.3.4 ER Energy Bins

The ER sweep waveform is programmable, parameterized by two values; the top value and the sweep rate. The sweep starts out at the top value at the beginning of the sweep, and steps at a rate of 128 steps per sweep (8 steps per energy accumulation) to provide a fairly smooth sampling of energy. Energy step N+1 is computed from energy step N by:

$$E[N+1] = E[N] - F*E[N]/512$$

F is a parameter that controls the sweep rate, and can be set to any value between 0 and 47. Note that F=0 gives a constant value. The top energy step is set with a 16 bit number (the sweep is controlled by a 16 bit DAC), with the maximum value (65535) corresponding to the maximum sweep supply voltage (4835V), which corresponds to about 27KeV (assuming an analyzer constant of 5.65). The values of F and the sweep maximum are contained in the Digital Sub-Com (see section 2.5).

Note that the first 1/16th sweep is held fixed at the maximum value while the supply charges up. The data from this period is discarded.

With the default settings of sweep maximum set to 48000 (20KeV), and sweep rate F=34 (Telemetry Format 1), the energy bins are as follows:

Telemetry Format 1

Step	Energy (K=5.65)	Default Accumulation
14	6 - 10 eV	Cut every 4 spins plus 3D every 16 spins
13	10 - 17 eV	Cut every 4 spins plus 3D every 16 spins
12	17 - 29 eV	Cut every 4 spins plus 3D every 16 spins
11	29 - 51 eV	Cut every 4 spins plus 3D every 16 spins
10	51 - 88 eV	Cut every 4 spins plus 3D every 16 spins
9	88 - 152 eV	PAD every 1/2 spin plus 3D every 16 spins
8	152 - 263 eV	PAD every 4 spins plus 3D every 16 spins
7	263 - 466 eV	PAD every 4 spins plus 3D every 16 spins
6	466 - 791 eV	PAD every 1/2 spin plus 3D every 16 spins
5	791 - 1,371 eV	PAD every 8 spins plus 3D every 16 spins
4	1.37 - 2.38 keV	PAD every 8 spins plus 3D every 16 spins
3	2.38 - 4.12 keV	PAD every 8 spins plus 3D every 16 spins
2	4.12 - 7.14 keV	PAD every 8 spins plus 3D every 16 spins
1	7.14 - 12.4 keV	PAD every 8 spins plus 3D every 16 spins
0	12.4-20.0 keV	PAD every 8 spins plus 3D every 16 spins

For Telemetry Format 2, with F=27 and Sweep Max = 48000:

Telemetry Format 2

Step	Energy (K=5.65)	Default Accumulation
14	32 - 49 eV	Cut every 4 spins plus 3D every 16 spins
13	49 - 75 eV	Cut every 4 spins plus 3D every 16 spins
12	75 - 116 eV	Cut every 4 spins plus 3D every 16 spins
11	116 - 180 eV	PAD every 1/2 spin plus 3D every 16 spins
10	180 - 277 eV	PAD every 4 spins plus 3D every 16 spins
9	277 - 427 eV	PAD every 1/2 spin plus 3D every 16 spins
8	427 - 659 eV	PAD every 4 spins plus 3D every 16 spins
7	659 – 1,016 eV	PAD every 4 spins plus 3D every 16 spins
6	1.02 – 1.57 keV	PAD every 4 spins plus 3D every 16 spins
5	1.57 – 2.42 keV	PAD every 8 spins plus 3D every 16 spins
4	2.42 – 3.73 keV	PAD every 8 spins plus 3D every 16 spins
3	3.73 – 5.75 keV	PAD every 8 spins plus 3D every 16 spins
2	5.75 – 8.87 keV	PAD every 8 spins plus 3D every 16 spins
1	8.87 – 13.7 keV	PAD every 8 spins plus 3D every 16 spins
0	13.7-20.0 keV	PAD every 8 spins plus 3D every 16 spins

2.3.5 ER Real-Time Data Timing

The base time for the real-time ER data is taken from the most recent Major Frame time. The Digital Sub-Com contains the spin phase at the time of the Major Frame pulse, and the spin period. With these values, the time of the start of a reference spin can be computed, the spin that started just before the Major Frame pulse. The ER header contains the last bit of information needed, the number of half-spins between the Major Frame pulse and the start of the 16-spin ER accumulation. The 16-spin ER accumulation time, T_{Acc}, can be computed as:

$$T_{Acc} = T_{MF} + 2.4\text{ms} - T_{Phase} + T_{NHS}$$

Where:

T_{MF} Is the time of the Major Frame pulse (see section 1.5). The 2.4ms is a fixed delay in the Frame pulse timing in the instrument.

T_{Phase} Is the time interval between the Major Frame pulse and the start of the preceding half-spin. This can be computed from the data in the Digital Sub-com as:

T_{Phase} = (Phase modulo 2048)*Period*0.00025 (sec)

'Phase' and 'Period' are the values in the Digital Sub Com.

T_{NHS} Is the time interval from the half-spin preceding the Master Frame pulse to the start of the ER 16-spin accumulation. This is equal to the half-spin period times the number of half-spins (NHS) indicated in the ER header, plus 1 (section 2.3.1).

T_{NHS} = ((NHS+1) modulo 32) *Period*.000512 (sec)

'Period' is the value in the Digital Sub Com.

It is possible that the ER 16-spin accumulation started before the Major Frame that contains the first frame of the data for that accumulation. This is indicated by the computed T_{Acc} being greater than the frame time of the first frame of data of the 16-spin ER accumulation. In that case, the T_{MF} and T_{Phase} in the above computations should be taken from the previous Major Frame.

T_{Acc} is the end-time of the first accumulation of each type. 3D data is sampled during the half spin just preceding T_{Acc} (i.e. T_{Acc} – spin to T_{Acc}). The N^th^ sample of pitch angle data is accumulated from T_{Acc} + (N-1)*A to T_{Acc} + N*A (A is the accumulation time, spin, 4 spins, or 8 spins, and N=0 for the first sample). Cut data is sampled from the last spin of the 4-spin accumulation interval: for the Nth cut sample, the accumulation time is: T_{Acc} + N*A – spin to T_{Acc} + N*A (A is the accumulation time, 4 spins, and N=0 for the first sample).

2.3.6 ER Calibration

The ER full instrument geometric factor, G, is approximately 0.07 E (KeV) cm2 ster KeV. This sensitivity is divided amongst 256 effective look directions (anodes), each with nominally 1/256 of the geometric factor. In fact there is significant variation in the geometric factor from anode to anode due to differential non-linearity in the Analog-to-Digital converter that does the binning, and due to variations in the gain of the micro-channel plate detector. A table of anode efficiency factors, F, is TBS.

The basic integration time is given by the spin period divided by 256. The 3D data and cuts are accumulated for this interval (except the 3D polar bins which are summed over 2 or 4 accumulations – see section 2.3.2). Pitch Angle accumulations are multiples of this basic integration time – see below.

The fixed-anode distribution geometric factors can be computed from G and F by summing over the 16 anodes in each fixed bin. Computing the pitch-angle data geometric factors is more complex. Pitch angle binning is computed for each event when it occurs. The magnetic field vector used to compute pitch angles is sampled 4 times a spin, and then rotated into the detector coordinates, updated 256 times a spin. To determine the effective geometric factor of a pitch angle bin, first sum the geometric factors of each of the 256 anode bins that are mapped into this pitch angle bin by the rotated magnetic field vector in a given $1/256^{th}$ of a spin. Then sum these factors over the time that the bin is accumulated. The energy sweep must be taken into account; data is accumulated into a given pitch angle/energy bin only $1/16^{th}$ of an energy sweep, and energy sweeps repeat 32 times a spin. To perform these calculations accurately, the arithmetic must match that of the on-board process in terms of accuracy, rounding, etc. A detailed description of this arithmetic is included in Reference TBS.

2.4 Burst Frame Format

Burst packets consist of 82 bytes of data plus a type code. Either one or two burst packets can be transmitted per frame. When there are two burst packets per frame (Full Burst Packets – see section 2.1.3), the Frame Type of the second burst packet is contained in byte 85 of the frame. Mag burst data (Frame Type 56) is the same format as for real-time MAG data, described in section 2.2 above. One burst Mag packet is generated each second. ER data, consisting of a 1/2 spin snapshot of both 3D and pitch angle data, plus ancillary data, is collected nominally each 1/2 spin, and fills 20 packets (Frame Types 36-55). Type 57 is a Major Frame marker packet, generated at the start of each Major Frame during burst collection. This packet includes timing information and ancillary data (see section 2.4.2). A Major Frame marker is jammed in at the start of a burst (before the preamble). It is a copy of the last Major Frame marker packet before the start of the burst. It is identified by bit 6 of the Frame Code being set to 1 (to indicate that a new burst read-out is starting). In special cases the first packet of a burst might be a fill packet (Frame Type 62) instead of a Major Frame marker. If so, it will still have bit 6 set in the type code to indicate the start of a burst. As just indicated, Frame Type 62 packets are fill. They are rarely if ever generated, and contain no useful data. Frame Types 58-61 are undefined.

2.4.1 Burst ER Format

The 20 Burst ER packets contain:

ER Burst Packet Contents

Packet Type	Contents
36	ER Header (4 bytes), 3D data bytes 0-77
37	3D data bytes 78-159
38	3D data bytes 160-241
39	3D data bytes 242-323
40	3D data bytes 324-405
41	3D data bytes 406-487
42	3D data bytes 488-569
43	3D data bytes 570-651
44	3D data bytes 652-733
45	3D data bytes 734-815
46	3D data bytes 816-897
47	3D data bytes 898-979
48	3D data bytes 980-1061
49	3D data bytes 1062-1143
50	3D data bytes 1044-1225
51	3D data bytes 1226-1307
52	3D data bytes 1308-1319, PA data bytes 0-69
53	PA data bytes 70-151
54	PA data bytes 152-233
55	PA data bytes 234-239, MagAngles (4 bytes), ER Table (72 bytes)

The ER Header is in the same format described in section 2.3.1 above (note that the burst pitch angle data is not pre-scaled, and the pre-scale bits are not useful). The 1320 bytes of 3D data are in the same format as described in section 2.3.2 above. The 240 bytes of Pitch Angle (PA) data consist of 16 pitch angle samples for each of 15 energies, in ascending energy step number order. The data is Pitch Angle for all 15 energies - no ‘cuts’. The accumulation time for both 3D and pitch angle data is 1/2 spin.

The MagAngles includes 2 samples of the computed magnetic field angles as sent to the ER on the two 1/4 spin intervals during this 1/2 spin accumulation. This is in place of the Mag sample number bits used in real-time data, and avoids having to find the MAG sample corresponding to the 1/4 spin interval, and computing the angles from the 3 components. MagPhi is the spin phase of the MAG vector (in de-spun coordinates, with zero at the sun pulse time). MagTh is the elevation angle, with zero along the spin vector. Both are coded in degrees*256/360.

MagAngles

Byte	Contents
0	MagTh #0
1	MagPhi #0
2	MagTh #1
3	MagPhi #1

The ER Table contains the current ER control parameters, as described in the 'Lunar Prospector MAG / ER Commanding' document, under Table 1.

2.4.2 Burst Major Frame Marker Packet

This packet is generated at the start of each Major Frame (32 seconds) during burst collection. It contains timing information needed to determine when the burst data was collected, as well as some instrument status information. All the information is current as of the collect time, except the second entry (Major Frame count at transmit time). The Byte number is relative to the start of the Burst packet.

Byte	Contents
0,1	The Major Frame count at the time this frame was collected (16 bits, LSByte first)
2,3	The Major Frame count at the time this frame is transmitted (16 bits, LSByte first)
4	The Burst number (increments by one for each transmitted burst)
5-11	Burst status information (see below)
12-23	Spin Phase-Locked Loop control table (see Commanding document)
24-33	Magnetometer control table (see Commanding document)
34-49	Burst control table (see Commanding document)
50-81	Digital Subcom data (all 32 bytes - see section 2.5)

The Burst Status information contains (Byte number relative to start of Burst Status):

Byte	Contents
0	Best Available Flag (1 if there is a 'best' burst ready to transmit, else 0)
1	Burst Read State (0 if nothing to read, 1 if reading preamble, 2 if reading ending)
2	Burst Record State (0=recording preamble, 1=over-writing preamble while waiting for a new 'best' burst, 2=recording ending)
3	Best Trigger: trigger criteria of current 'best' burst
4	Read Trigger: trigger criteria of burst being read out
5-6	Filtered criteria: baseline trigger criteria level (*256)

2.4.3 Burst Timing

Burst data may reside in the burst memory for quite a while. Data in the Major Frame marker packets can be used to determine when the data was collected. The difference between the Major Frame count at the time the packet is transmitted and the Major Frame count at the time it was collected (modulo 2^{16} = NF) is the number of frames that the Major frame marker packet was in the burst memory. The Major Frame marker packet was collected at the time of Major Frame in which it is transmitted, minus 32 seconds times NF (call this T_{MFM}).

The first MAG burst packet following a Major Frame marker packet was collected starting at T_{MFM}, with subsequent MAG burst packets collected on 1-second intervals. The Frame Counter and a bit in the Frame code can be used to compute the offset from T_{MFM} that a MAG burst packet was collected – see section 2.2.

The ER burst accumulation timing is computed similarly to the real-time ER data (see section 2.3.5), using T_{MFM} instead of T_{MF}, and taking ‘Phase’ and ‘Period’ from the Major Frame Marker packet rather than the current Digital Sub-Com. The 3D and Pitch Angle data accumulation intervals are from T_{Acc} – spin to T_{Acc}.

2.5 Digital Subcom Format

The digital subcom is sampled at the start of each Master frame (32 seconds), and transmitted in the second and third byte of each frame, for a total of 2*16=32 bytes of data. The Frame number used to decomutate the data can be extracted from either the spacecraft telemetry or from the real-time Mag data if present.

Digital Sub-Com Definition

<table>
<tr><th rowspan="3">Frame #</th><th colspan="8">Byte #1</th><th colspan="8">Byte #2</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>MSB
LSB</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>MSB
LSB</td></tr>
<tr><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>0</td><td colspan="8">Cmd 0</td><td colspan="8">Cmd 1</td></tr>
<tr><td>1</td><td colspan="8">Cmd 2</td><td colspan="8">Cmd Cnt</td></tr>
<tr><td>2</td><td colspan="8">Error</td><td colspan="4">RCnt</td><td colspan="4">ECnt</td></tr>
<tr><td>3</td><td colspan="4">Ver</td><td>D</td><td>E</td><td>S</td><td>B</td><td colspan="8">IMon 0</td></tr>
<tr><td>4</td><td colspan="4">SW 0</td><td colspan="4">IMon 1</td><td colspan="8">SW 1</td></tr>
<tr><td>5</td><td colspan="8">PC Temp</td><td colspan="8">Mag +12V</td></tr>
<tr><td>6</td><td colspan="8">Mag Temp</td><td colspan="8">Mag –12V</td></tr>
<tr><td>7</td><td colspan="8">Mag +5V</td><td colspan="8">ER MCPI</td></tr>
<tr><td>8</td><td colspan="8">ER MCPV</td><td colspan="8">ER SWPI</td></tr>
<tr><td>9</td><td colspan="8">ER –5V</td><td colspan="8">ER +5V</td></tr>
<tr><td>10</td><td colspan="8">ER +12V</td><td colspan="8">ER +28V</td></tr>
<tr><td>11</td><td colspan="8">Phase 0</td><td>P</td><td>C</td><td>A</td><td>M</td><td colspan="4">Phase 1</td></tr>
<tr><td>12</td><td colspan="8">Period 0</td><td colspan="2">L</td><td colspan="6">Period 1</td></tr>
<tr><td>13</td><td colspan="8">SW Max 0</td><td colspan="8">SW Max 1</td></tr>
<tr><td>14</td><td>ER</td><td>R</td><td colspan="6">SW Rate</td><td colspan="8">MCP Set</td></tr>
<tr><td>15</td><td colspan="8">Best</td><td>BE</td><td>Q</td><td colspan="2">W</td><td colspan="4">BRF</td></tr>
</table>

Name	Description

Cmd 0	8 LSB of the most recently received MAG/ER command
Cmd 1	8 middle bits of the most recently received command
Cmd 2	8 MSB of the most recently received command
Cmd Cnt	number of commands (modulo 256) since instrument reset
Error	an 8 bit code indicating the most recent error type
ECnt	number of errors (modulo 16) that have occurred since instrument reset
RCnt	number of processor resets (modulo 16) since instrument power-up
Ver	software version number (0 for PROM code)
D	Mag 1m boom deploy status
E	EEPROM Write Enable (1=Enabled)
S	Mag electronics side currently operating
B	Boot mode for next reset (1=PROM, 0 = EEPROM)
IMon 0	Instrument current monitor 8 LSB (IMON has a 2048 offset)
IMon 1	Instrument current monitor, 4 MSB
SW 0	* ER Sweep HV supply voltage monitor, 4 LSB (SW has a 2048 offset)
SW 1	* ER Sweep HV supply voltage monitor, 8 MSB
PC Temp	Power Converter temperature (128 offset)
Mag +12V	Mag/ER DPU +12V supply voltage monitor (absolute value)
Mag Temp	Magnetometer temperature (128 offset)
Mag -12V	Mag/ER DPU -12V supply voltage monitor (absolute value)
Mag +5V	Mag/ER DPU +5V supply voltage monitor (absolute value)
ER MCPI	* ER MCP High Voltage supply current monitor (absolute value)
ER MCPV	* ER MCP High Voltage supply voltage monitor (absolute value)
ER SWPI	* ER Sweep High Voltage supply, current monitor (absolute value)
ER -5V	* ER -5V supply voltage monitor (absolute value)
ER +5V	* ER +5V supply voltage monitor (absolute value)
ER +12V	* ER +12V supply voltage monitor (absolute value)
ER +28V	* ER +28V supply voltage monitor (absolute value)
Phase 0	* 8 LSB of the Spin Phase at the time of the Master Frame pulse (plus a small TBD time offset (approx. 2-3msec). The phase is a value from 0 to 4095, in units of spin period/4096, indicating the time interval between the last Sun pulse from the spacecraft and the Master Frame pulse of the start of this DSC block
Phase 1	* 4 MSB of the Spin Phase at the time of the Master Frame pulse
P	* ER HV Enable Plug state; 1 = in/enabled, 0 = out/disabled
C	* ER internal cover status; 1 = Closed, 0 = Open
A	* ER Sweep HV Enable; 1 = enable, 0 = disable
M	* ER MCP HV Enable (1=enable, 0=disable)
Period 0	* 8 LSB of current spacecraft Spin Period setting, units are 1.024 ms

Period 1	* 6 MSB of current spacecraft Spin Period setting
L	Spin Period Phase Locked Loop status: ❋ 00 = Unlocked (no sun pulse) ❋ 10 = Locked ❋ 11 = ReSynced (the PLL has achieved Lock in the last Major Frame interval)
SW Max 0	* 8 LSB of ER Sweep HV Maximum level
SW Max 1	* 8 MSB of ER Sweep HV Maximum level
ER	ER Power status: 1 = On, 0 = Off
R	Mag Autoranging mode: 1 = autorange, 0 = manual
SW Rate	* ER Sweep HV supply sweep rate code
MCP Set	* ER MCP High Voltage Setting
Best	Current Best burst trigger evaluation (excluding the burst being read out)
BE	Burst readout enable: 1=enabled
Q	Burst Readout state: 0 = preamble, 1 = ending
W	Burst Record state: ❋ 00 = preamble ❋ 01='Wait' (over-writing preamble waiting for a better burst that 'best' ❋ 10=ending.
BRF	Burst Read Fraction: Indicates how far through the burst the readout is (in 16ths of the burst size)

Items marked with a * are only valid when the ER is on (ER is 1)

The analog housekeeping is converted by a 12 bit bipolar ADC, which converts with a 2048 code offset, so that zero volts is converted as 2048, positive voltages are greater that 2048, and negative voltages are less than 2048. The IMon and SW values are transmitted with the full 12 bits just as sampled by the ADC. For the other analog samples, only 8 bits is transmitted. The temperatures (PC Temp and Mag Temp) are bipolar values, so the 8 MSB are sent. This gives a value which has a 128 step offset. The other values are either always positive or always negative, so the absolute value is taken of the ADC value minus 2048, and then the 8 MSB of the remaining 11 bit value is sent.

Analog Monitor values can be converted using the following nominal coefficients. The conversion process involves first subtracting the B value, then multiplying by the A value.

DSC Housekeeping Nominal Calibration Coefficients

Value	Bits	A	B	Units
Imon	12	0.0724	2006.6	mA
SW	12	2.475	2047.1	V
PCTemp	8	—	—	C *
Mag +12V	8	0.0640	0	V

Mag Temp	8	—	—	C *
Mag -12V	8	-0.0640	0	V
Mag +5V	8	0.032	0	V
ERMCPI	8	0.0988	0	mA
ERMCPV	8	15.02	-0.5	V
ERSWPI	8	0.060	0	mA
ER -5V	8	-0.0258	0	V
ER +5V	8	0.0252	0	V
ER +12V	8	0.0627	0	V
ER +28V	8	0.137	0	V

*- Temperatures are converted with a polynominals:
V = Value-128 (Value is the value in the Digital Sub-Com, 0-255)
Temp = a + b*V + c*V^2 + d*V^3

Temperature Conversion Coefficients

Value	a	b	c	d
PC Temp	32.33	0.413	1.84E-3	1.00E-5
MAG Temp	9.46	0.332	5.98E-5	4.40E-6

2.6 ER Counter Data Compression Scheme

The ER accumulations are log-compressed to 8 bits. The compression scheme is a 4 bit exponent with 4 bit mantissa (hidden bit) unsigned format with a dynamic range of 1 to 500,000. Un-transmitted bits of the mantissa are truncated, not rounded, so the decompressed values shown in the table below are the minimum value the counter must have had for that code. The counter value above or equal to this value, but below the value for the next highest code. Note that pre-scaled data is also not rounded but truncated.

ER Counter Compression Scheme

Code (Hex)

	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F
00	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
10	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
20	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62
30	64	68	72	76	80	84	88	92	96	100	104	108	112	116	120	124
40	128	136	144	152	160	168	176	184	192	200	208	216	224	232	240	248
50	256	272	288	304	320	336	352	368	384	400	416	432	448	464	480	496
60	512	544	576	608	640	672	704	736	768	800	832	864	896	928	960	992
70	1024	1088	1152	1216	1280	1344	1408	1472	1536	1600	1664	1728	1792	1856	1920	1984
80	2048	2176	2304	2432	2560	2688	2816	2944	3072	3200	3328	3456	3584	3712	3840	3968
90	4096	4352	4608	4864	5120	5376	5632	5888	6144	6400	6656	6912	7168	7424	7680	7936
A0	8192	8704	9216	9728	10240	10752	11264	11776	12288	12800	13312	13824	14336	14848	15360	15872
B0	16384	17408	18432	19456	20480	21504	22528	23552	24576	25600	26624	27648	28672	29696	30720	31744
C0	32768	34816	36864	38912	40960	43008	45056	47104	49152	51200	53248	55296	57344	59392	61440	63488
D0	65536	69632	73728	77824	81920	86016	90112	94208	98304	102400	106496	110592	114688	118784	122880	126976
E0	131072	139264	147456	155648	163840	172032	180224	188416	196608	204800	212992	221184	229376	237568	245760	253952
F0	262144	278528	294912	311296	327680	344064	360448	376832	393216	409600	425984	442368	458752	475136	491520	507904

3. Analog Housekeeping

The MAG/ER instrument provides the spacecraft with a single analog line onto-which the instrument multiplexes one of 16 analog housekeeping values. The values are changed at the start of each frame, and the cycle is synchronized to the Major Frame pulse. The multiplexing circuit is powered by the instrument heater bus, so that the measurement is only valid when the instrument heater circuit is on. Half of the values are related to the heater circuit operation, and are valid even if the rest of the instrument is off. The other half are monitors of the ER instrument, and are only valid when the instrument power bus is on and the ER is on. The ER monitors are redundant with values in the Digital Sub-Com (see section 2.5). They are included as monitors of the ER high voltage when the spacecraft is in low telemetry rate mode (300bps), when the science data is not transmitted.

The following table describes the analog housekeeping values, sub-commutation, and calibration. The calibration uses a third order polynomial to convert the counts value in the housekeeping (0-255) to the engineering value in the indicated units:

$$\text{Value} = C0 + C1{*}\text{Counts} + C2{*}\text{Counts}^2 + C3{*}\text{Counts}^3$$

Analog Housekeeping Calibration Table

Frame #	**Value**	**C0**	**C1**	**C2**	**C3**	**Units**
0	ER +28V Monitor	0.0	1.395E-1	0.0	0.0	Volts
1	MAG Heater Power	0.0	2.700E-3	2.04E-5	4.00E-8	Watts
2	ER MCP HV Current	0.0	1.010E-1	0.0	0.0	mA
3	MAG Temperature	-4.08E1	8.340E-1	-4.876E-3	1.384E-5	°C
4	ER MCP HV Voltage	8.20E0	1.533E1	0.0	0.0	Volts
5	ER Heater Power	0.0	7.20E-3	-2.00E-5	8.00E-8	Watts
6	ER Sweep HV Current	0.0	6.138E-2	0.0	0.0	mA
7	ER Temperature	-4.08E1	8.340E-1	-4.876E-3	1.384E-5	°C
8	ER Sweep HV Voltage	2.20E0	2.022E1	0.0	0.0	Volts
9	Heater +12V Monitor	0.0	6.40E-2	0.0	0.0	Volts
10	ER –5V Monitor	0.0	-2.631E-2	0.0	0.0	Volts
11	Heater +5V Monitor	0.0	3.268E-2	0.0	0.0	Volts
12	ER +5V Monitor	0.0	2.570E-2	0.0	0.0	Volts
13	DPU Heater Power	5.20E-1	7.20E-3	-2.00E-5	8.00E-8	Watts
14	ER +12V Monitor	0.0	6.401E-2	0.0	0.0	Volts
15	DPU Temperature	-4.08E1	8.340E-1	-4.876E-3	1.384E-5	°C