MARS GLOBAL SURVEYOR

Mars Orbiter Laser Altimeter

MOLA PRECISION EXPERIMENT DATA RECORD
SOFTWARE INTERFACE SPECIFICATION
(MOLA PEDR SIS)

MGS-M-MOLA-3-PEDR-L1B-V1.0

Version 2.4,
March 24, 1998

NASA
Goddard Space Flight Center
Greenbelt MD 20771

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Document and Change Control Log			
Date	**Version**	**Section**	**Status**
04/01/97	1.0	all	Released for MGS
07/23/97	1.1	Section 4.3.2 Table 1 Table 2 Appendix C	Updated for PEDR format changes
07/23/97	1.1	Appendix C	Incorrect start bytes and descriptions were corrected in the format files (unmarked)
01/30/98	2.0	all	revised for contingency science

1.0 Introduction

The MOLA Science Team is required to create validate, and archive the MOLA standard data products. To define each standard data product, the MOLA Science Team is required to provide a Software Interface Specification (SIS). The SIS shall describe the data product contents and define the record and data format. The Planetary Data System's (PDS) Geosciences Node has agreed to archive the MOLA standard data products. The MOLA archive volume shall be described in a separate SIS. The MOLA standard science data products are the Aggregated Experiment Data Record—all MOLA raw data aggregated by orbit; Precision Experiment Data Record—MOLA science data processed into profiles with precision orbit locations added; Any Experiment Gridded Data Record—MOLA gridded data in 2 different densities. This SIS shall define the Precision Experiment Data Record (PEDR) Data Product.

1.1 Purpose

This document describes the format and contents of the PEDR Data Product. This includes a description of the required SFDU format and the record description and contents of the PEDR File.

1.2 Scope

This SIS defines the format of the SFDU labels and headers and the Precision Experiment Data Record down to the bit level. Also, the PEDR Data Product software, hardware, and human interfaces shall be mentioned in order to describe the interface; the actual software, hardware, or human node on the other side of the interface shall be described in detail in its own interface or other reference document.

1.3 Applicable Documents

1. `MOLA-672-PL-89.354` *Operations Facility Configuration and Control Plan*, Version 1.0, NASA Goddard Space Flight Center Wallops Flight Facility, January 5, 1990
2. `MOLA-972-SP-91.163` *Mars Orbiter Laser Altimeter Aggregated Experiment Data Record Product Software Interface Specification Document*, Version 1.0, NASA Goddard Space Flight Center Wallops Flight Facility, March 31, 1997
3. `SFOC-0088-00-07-02` *Space Flight Operations Center User's Guide for Work Station End Users, Volume 2: Working with File Data*, Version 17.0, Draft, Jet Propulsion Laboratory, January 1992
4. `MO-642-3-PDB-UG-01` *Mars Observer Project Database (MO PDB) User Overview*, Strawman, Jet Propulsion Laboratory, February 7, 1990
5. `MOSO0099-04-00` *Planetary Science Data Dictionary Document*, PDS Version 3.0, Jet Propulsion Laboratory, November 20,1992, JPL D-7116, Rev C
6. `MOLA-972-SP-92-232` *Mars Orbiter Laser Altimeter Any-Experiment Gridded Data Product Software Interface Specification*, Version 1.0, NASA Goddard Space Flight Center Wallops Flight Facility, March 31, 1997
7. `MOLA-972-SP-92.213` *MOLA CD-ROM Standard Product Archive Collection Software Interface Specification*, Version 1.0, S. Slavney, R. E. Arvidson, Washington University, August 11, 1993

1.4 Functional Description

1.4.1 Data Content Summary

The PEDR data product contains the along-track, time series collection of the MOLA instrument's science mode data in engineering and physical units. Precision orbit data describing the instrument's position and location has been added to each record. The precision orbit data is supplied by the MOLA Science Team.

Using the precision orbit data, the accuracy of the MOLA footprint is 30 meters radially; 30 meters along track; 30 meters across track.

1.4.2 Source and Transfer Method

The PEDR Data Product is created on the MOLA operations computer system. The PEDR Data Product is created by reading the Aggregated Experiment Data Record (AEDR) Data Product record by record, computing the applicable science parameters (as described in Section 4.0), appending the precision orbit data, and wrapping the whole file with SFDU headers and labels. This SIS will detail the format of the PEDR Data Product. The AEDR Data Product is described in Applicable Document #2. After creation and verification, the PEDR Data Product shall be transferred to the MOLA SOPC to await delivery to the Planetary Data System’s (PDS) Geosciences Node where it will be archived to CD-ROM and made available to the science community. The PEDR Data Product shall remain available to the MOLA Science Team on the MOLA operations file system.

1.4.3 Recipients and Utilization

The PEDR data product shall be used to create the Experiment Gridded Data Record (EGDR) data products.

The PDS shall receive the PEDR data product and make it available to the science community.

The PEDR data product shall remain on the MOLA operations file system and be available to the MOLA Science Team for further investigations.

1.4.4 Pertinent Relationships with Other Interfaces

The PEDR data product is created from the Aggregated Experiment Data Record (AEDR) data product. Any changes to the AEDR data product could affect the format or content of the PEDR data product. See Applicable Document #2 for a detailed description of the AEDR Data Product.

Any changes to the PEDR data product, either format or content shall affect the software that creates the data product.

Additionally, any changes to the PEDR data product could affect the EGDR data products' content or format or affect the software that creates the EGDR data products. See Applicable Document #6 for a detailed description of the EGDR Data Products.

1.5 Assumptions and Constraints

The PEDR data product contains only MOLA science mode data.

Each PEDR data product shall encompass one orbit of MOLA data.

2.0 Environment

2.1 Hardware Characteristics and Limitations

Not applicable.

2.2 Interface Medium and Characteristics

The PEDR data product shall be produced on computer(s) within the MOLA operations environment. The PEDR data product shall be transferred to the MOLA SOPC via FTP in preparation for distribution to the PDS Geosciences Node. The SOPC architecture is described in Applicable Document #1. The PEDR data product will be transferred to the PDS Geosciences Node via FTP from the SOPC. The PDS will write the data products to CD-ROMs for distribution to the science community.

2.3 Failure Protection, Detection, and Recovery Features

2.3.1 Backup Requirements

The PEDR data product will be retained on the MOLA operations file system for back up purposes and shall be archived on magnetic media. The PEDR data product is distributed to the PDS for archival. The MGS Project Database will be available as an additional backup location.

2.3.2 Security / Integrity Measures

Refer to Applicable Document #1 for a description of the MOLA *operations* system security and integrity plan.

2.4 End-Of-File (or Medium) Convention

The PEDR data product is a standard UNIX flat file in Standard Formatted Data Unit (SFDU) format. SFDU formatted objects have labels and headers describing the high level structure of the object and the content of the object. The end of the PEDR data product will be detected by the end-of-file marker.

3.0 Access

3.1 Access Tools

The MOLA Science Team shall have the capability to access the PEDR data product on the MOLA operations file system via FTP. The science community will have access to the PEDR Data Product through the Archive Volume produced by the PDS Geosciences Node and should obtain the MOLA CD-ROM Archive Volume SIS, Applicable Document #7 for information on data access. The MOLA Science Team will not provide the PDS any special tools to access the PEDR Data Product.

3.2 Input / Output Protocol

N/A

3.3 Timing and Sequencing Characteristics

A PEDR data product will be created for each orbit containing MOLA science data. Data products will be created as precision orbit data becomes available. The PEDR data product may be re-processed up to three times depending on new releases of precision orbit data. PEDR data products will be created for all the MOLA science data collected during the MGS mapping mission.

3.4 PDB Information

The PEDR Data Product will be stored in the Science category as a science data product in the PDB. See Applicable Document #4 for an end user overview of the PDB.

The data set id for the MOLA PEDR data product is MGS-M-MOLA-3-PEDR-L1B-V1.0. This is the data set id that was provided to the PDB and the Planetary Data System. This id describes the overall PEDR data product. The version number is incremented should the PEDR Data Product format change.

The PDB required keywords are

```
PDS_VERSION_ID          PRODUCT_RELEASE_DATE
RECORD_TYPE             PRODUCT_VERSION_TYPE
FILE_RECORDS            START_TIME
RECORD_BYTES            STOP_TIME
LABEL_RECORDS           NATIVE_START_TIME
FILE_NAME               NATIVE_STOP_TIME
DATA_SET_ID             SPACECRAFT_CLOCK_START_COUNT
PRODUCT_ID              SPACECRAFT_CLOCK_STOP_COUNT
SPACECRAFT_NAME         PRODUCT_CREATION_TIME
INSTRUMENT_ID           MISSION_PHASE_NAME
INSTRUMENT_NAME         ORBIT_NUMBER
TARGET_NAME             PRODUCER_ID
SOFTWARE_NAME           PRODUCER_FULL_NAME
UPLOAD_ID               PRODUCER_INSTITUTION_NAME
SOURCE_PRODUCT_ID       DESCRIPTION
```

4.0 Detailed Interface Specifications

4.1 Labeling and Identification

The PEDR Data Product shall be labeled to form an SFDU as described in Section 4.3. The data set id for the PEDR Data Product and required catalog keywords are listed in Section 3.4.

The file naming convention for each PEDR data product produced is `AP#####a.b`, where:

`A`	represents the MOLA instrument, an altimeter
`P`	is the data product, PEDR, identifier
`#####`	is the orbit number with leading zeros
`a`	is the product edition number
`b`	indicates the file is fixed point, binary.

4.2 Structure and Organization Overview

The PEDR Data Product shall be written as a standard UNIX flat, sequential file with the MOLA data in spacecraft event time-ordered sequence. Each 776-BYTE record contains two seconds of data (a frame) extracted from the science mode telemetry packet. The data records are wrapped with the appropriate SFDU labels and headers, comprising a total of 10 776-byte records. There shall be a primary label, a catalog label and header, and a data label. The catalog label shall have a corresponding end label to delimit the catalog information from the data. See Figure 1 for a representation of the PEDR data product.

4.3 Substructure Definition and Format

The following sections define in detail the label, header, and data formats and content.

4.3.1 Header / Trailer Description Details

An example of the labels and K-header is in Appendix C.

4.3.1.1 Primary SFDU Label

The Primary SFDU Label, also known as the aggregation label or Z-label delimits the entire product. The Primary Label is 20 bytes long and shall have the following format for the PEDR data product.

```
CCSD3ZF0000100000001
```

where:

`CCSD`	is the Control Authority ID
`3`	is the SFDU version ID
`Z`	is the class ID for primary labels
`F`	is the SFDU delimiter type, total EOFs.
`0`	is a spare octet
`0001`	is the Data Descriptive Package ID (DDPID)
`00000001`	is the delimiter value for this label; indicates the number of EOFs delimiting the product.

4.3.1.2 Catalog Label and Header

The catalog labels and header, also known as the K-header, are made up of the start and end labels and the catalog data objects that are to be stored in the Mars Global Surveyor PDB and the Planetary Data System's data base. The start label has the following form:

```
NJPL3KS0PDSX$$INFO$$
```

where:

`NJPL`	is the Control Authority ID
`3`	is the SFDU version ID
`K`	is the class ID for catalog data object labels
`S`	is the SFDU delimiter type, start marker.
`0`	is a spare octet
`PDSX`	is the Data Descriptive Package ID
`$$INFO$$`	is the delimiter value for this label

After the label, shall be the catalog entries required by the Project. These shall be in the `KEYWORD=VALUE` format. Each `KEYWORD=VALUE` string shall be terminated by a carriage return, line feed combination. The required keywords are listed in Section 3.4. The catalog entries (keywords) with example values are listed in Appendix C.1. Applicable Document #5 contains definitions of the keywords listed in the appendix.

Planetary Data System required object definitions and pointers are contained in the catalog header. Each data parameter in the product is defined by the object structure; the pointers direct the user to format files which fully define the PEDR record format and contents. Appendix C contains an example of the object definitions and pointers.

The catalog entries will be delimited by the K-header end label; it has the following form:

```
CCSD$$MARKER$$INFO$$
```

4.3.1.3 Data Label

The data or I-class Label precedes the actual data in the SFDU. This label is also known as the data object label or the tertiary header. The I-class label is registered individually with the JPL Control Authority and bears a unique DDPID. The start label has the following format

```
NJPL3IF0004100000001
```

where:

`NJPL`	is the Control Authority ID
`3`	is the SFDU version ID
`I`	is the class ID for data labels
`F`	is the SFDU delimiter type, Total EOFs
`0`	is a spare octet
`0041`	is the Data Descriptive Package ID
`00000001`	is the delimiter value for this label; indicates the number of EOFs delimiting the product.

4.3.2 Data Description Details

A Precision Experiment Data Record contains MOLA science mode telemetry data that has been converted to engineering and physical units. Each PEDR contains a 2 second span of data, called a frame, that is retrieved from the 14 second MOLA science mode telemetry packet. Therefore, seven PEDRs are generated from each MOLA science mode telemetry packet. In addition to the frame data, the packet's engineering and housekeeping data are retained and subcommutated among the seven PEDRs that comprise a packet. Additional packet information, *e.g.*, packet header, are stored in the PEDR as well as data correction values which were used to process the telemetry data into the PEDR data. Storing the data correction values ensures that the telemetry data can be re-created from the PEDR data.

Contained in a PEDR are the range value computed at the frame mid-point, the planetary radius at the frame mid-point, and the planetary radius for each shot. There are 20 possible shots in a 2 second frame. Additionally, location, i.e., latitude, longitude, and radial distance, obtained from the precision orbit data, is stored in the PEDR. The precision orbit data is gathered at the frame midpoint with respect to the Mars Global Surveyor center of mass. The range and planetary radius values are computed with respect to the center of mass of the Mars Global Surveyor. Additional information describing the instrument and its configuration are included in the PEDR.

A complete listing of all parameters contained in a PEDR can be found in Table 1. A description of the parameters contained in a PEDR is found in Table 2. The engineering/housekeeping data are listed in Table 3; this table also describes the location of the engineering/housekeeping data among the seven PEDRs that constitute a MOLA telemetry packet. Additionally, the PEDR format and contents are described in the PEDR Data Dictionary in Appendix B.

4.4 Volume, Size, and Frequency Estimates

The size of each PEDR data product shall vary depending in the number of science mode packets produced during an orbit. The maximum number of science mode packets that could be produced during an orbit is approximately 486, therefore the maximum number of PEDRs in a PEDR Data Product would be approximately 3402. Each PEDR shall contain 776 bytes.

The PEDR data product will be produced as the AEDR files and corresponding precision orbit data become available. The data products will be produced during a standard 5 day / 40 hour work week.

Approximately 13 PEDR Data Products shall be produced for each mapping mission day resulting in a daily volume of 34 Mbytes. During the period of time designated as contingency science or phasing orbits, MOLA ranges to the surface for only 20-30 minutes and the volume is accordingly reduced.

FIGURES

PRIMARY SFDU START LABEL
CATALOG START LABEL
CATALOG HEADER
CATALOG END LABEL
DATA START LABEL
DATA RECORD 1
DATA RECORD 2
DATA RECORD 3
. . .
DATA RECORD N

Figure 1: PEDR Data Product Structure and Organization

TABLES

Table 1: PEDR Data Product Record Format

Start Byte	Parameter	Bytes	Units	End Byte
1	frame mid-point time whole seconds (Elapsed Time from J2000)	4	seconds	4
5	frame mid-point time fractional seconds (Elapsed Time from J2000)	4	microseconds	8
9	orbit reference number	4	counts	12
13	frame mid-point areocentric latitude of spacecraft	4	degrees * 10^6	16
17	frame mid-point areocentric longitude	4	degrees * 10^6	20
21	frame mid-point radial distance of spacecraft	4	centimeters	24
25	frame mid-point range	4	centimeters	28
29	shot quality flag	4		32
33	shot quality descriptor flag	16		48
49	shot planetary radius (20 * 4)	80	centimeters	128
129	frame mid-point planetary radius	4	centimeters	132
133	instrument attitude right ascension	4	milliradians	136
137	instrument attitude declination	4	milliradians	140
141	instrument attitude twist	4	milliradians	144
145	corrected received pulse energy (20 * 2)	40	attojoules	184
185	surface reflectivity * atmospheric transmittance	40	parts in 10^5	224
225	trigger channel number (20 * 1)	20		244
245	returned pulse width at threshold	40	nanoseconds * 10	284
285	received optical pulse width (20 * 2)	40	nanoseconds * 10	324
325	frame mid-point coordinates (x,y,z)	12	centimeters	336
337	frame mid-point latitude and longitude	8	degrees * 10^6	344
345	laser transmit power (20 * 2)	40	mJ * 100	384
385	shot classification code	40		424
425	channel background noise counts (8 * 4) (per half-frame and channel)	32	counts	456
457	range delay	4	centimeters	460
461	range width	4	centimeters	464
465	receiver channel threshold settings (8 * 2) (per half-frame and channel)	16	millivolts	480
481	receiver channel mask	2		482
483	algorithm word (MIN_HITS)	2		484
485	algorithm word (HIT_COUNT)	2	counts	486
487	frame counter	2		488
489	trigger channel	2		490

Table 1: PEDR Data Product Record Format (Continued)

Start Byte	Parameter	Bytes	Units	End Byte
491	within-packet frame index	2	(1-7)	492
493	packet source header	8		500
501	telemetry packet coarse time code - seconds (J2000 elapsed time)	4	seconds	504
505	telemetry packet coarse time code - milliseconds	2	ms	506
507	telemetry packet fine time code	2	counts	508
509	engineering / housekeeping data	28		536
537	Orbit quality flag 1	2		538
539	Orbit quality flag 2	2		540
541	Orbit quality flag 3	2		542
543	Phase angle	2	radians * 10^4	544
545	Solar incidence angle	2	radians * 10^4	546
547	Emission angle	2	radians * 10^4	548
549	Atmospheric opacity (Tau)	4	pure number * 10^6	552
553	Double precision frame mid-point time in IEEE standard (Elapsed time from J2000)	8	seconds	560
561	trigger channel raw received pulse energy (20 * 1)	20	counts (0-255)	580
581	trigger channel raw received pulse width (20 * 1)	20	counts (0-63)	600
601	Spacecraft body fixed XYZ coordinates	12	centimeters	612
613	Geoid radius	4	centimeters	616
617	Off-nadir angle	4	degrees * 10^6	620
621	Encoder bits	20	counts	640
641	delta geoid	4	cm	644
645	MOLA clock rate	4	Hz	648
649	MOLA range value (20 * 4)	80	centimeters	688
729	range correction (20 * 2)	40	centimeters	768
769	delta latitude	4	degrees * 10^6	772
773	delta longitude	4	degrees * 10^6	776
		776	**bytes total**	

Table 2: MOLA Precision Experiment Data Record (PEDR) Contents
Rate: 1 every 2 seconds

Parameter	Bytes	Units	Description
- frame mid-point time whole seconds	4	Seconds	The whole portion of the Elapsed Time since J2000 at the frame mid-point[a] in the MOLA data frame
- frame mid-point time fractional seconds	4	Microseconds	The fractional portion of the Elapsed Time since J2000 at the frame mid-point[a] in the MOLA data frame
- orbit reference number	4	Counts	Mapping mission orbit number determined by Mars Global Surveyor flight operations system at frame mid-point
- frame mid-point areocentric latitude of spacecraft	4	Degrees * 10^6	MGS Spacecraft areocentric latitude associated with MOLA data frame mid-point; from Precision Orbit data
- frame mid-point areocentric longitude	4	Degrees * 10^6	MGS Spacecraft east longitude value associated with MOLA data frame mid-point; from Precision Orbit data
- frame mid-point radial distance of spacecraft	4	Centimeters	Radial distance (*i.e.*, the distance from Martian body-center to Mars Global Surveyor spacecraft center of mass) associated with MOLA data frame mid-point; from Precision Orbit data
- frame mid-point range	4	Centimeters	MOLA range (corrected to Mars Global Surveyor center of mass) associated with MOLA data frame mid-point, obtained from a straight line best-fit of the individual (up to 20) MOLA range measurements in the MOLA data frame
- shot quality flag	4		3 bytes—flag whether good/bad shot (20 least significant bits, one for each of the 20 shots, with least significant bit, 0, being shot 1 and bit 19 being shot 20) and each bit set to 0 for good, 1 for bad shot; bits 20–23 are unused 1 byte—good shot counter, (total of bits set to 0 in above 20 bits)
- shot quality descriptor flag	16		Flag indicating whether the packet or individual shots passed or failed the various shot quality tests. Reading the flag from right to left with the rightmost bit being bit 0 and the leftmost bit being bit 127 the format of the flag is bit 0: packet validity checksum test bit 1: computer software checksum test bit 2: frame acquisition vs. tracking mode test bit 3: first shot is an OTS shot test bits 4–23: transmit power test bits 24–43: non-zero 1st channel test bits 44–63: return energy test bits 64–83: range window test bits 84–103: range comparison test bits 104–127: unused

Table 2: MOLA Precision Experiment Data Record (PEDR) Contents (Continued)
Rate: 1 every 2 seconds

Parameter	Bytes	Units	Description
- shot quality descriptor flag (contd.)			A 1 indicates the test was failed, 0 indicates the test was passed. For the bits that flag each shot the lower bit corresponds to shot 1 and the higher bit corresponds to shot 20.
- shot planetary radius	80	Centimeters	Array of 20 MOLA planetary radii, one per shot, in the data frame; the distance from the center of Mars to the point on the surface of Mars described by the MOLA range, 20 4-byte values
- frame mid-point planetary radius	4	Centimeters	Planetary radius associated with MOLA data frame mid-point; the distance from the center of Mars to the point on the surface of Mars described by the MOLA mid-point range
- instrument attitude right ascension	4	Milliradians	MOLA right ascension at data frame mid-point
- instrument attitude declination	4	Milliradians	MOLA declination at data frame mid-point
- instrument attitude twist	4	Milliradians	MOLA twist at data frame mid-point
- corrected received pulse energy	40	Attojoules	Corrected surface-scattered return energy as measured by the pulse width and area counters, corrected for threshold setting, 20 2-byte values
- surface reflectivity * atmospheric transmittance	40	Pure fraction * 10^5	Relative Martian surface reflectivity values, one per shot; 20 2-byte values
- trigger channel number	20		Channel number of first MOLA filter channel to trigger, 20 1-byte values
- returned pulse width at threshold	40	Nanoseconds * 10	Time between threshold crossings of the detected pulse. The pulse width is used to correct the time-of-flight to the optical pulse centroid, but recv_pulse_energy_counts may be saturated. In this case, the timing correction is limited to the equivalent of a six-degree slope. 20 2-byte values
- received optical pulse width	40	Nanoseconds * 10	Received optical pulse width, corrected for filter characteristics and threshold settings, as determined by the receiver model (one sigma value, with the minimum limited by the filter response). The pulse width provides an estimate of target slope and/or roughness, assuming nadir-looking geometry
- frame mid-point coordinates	12	Centimeters	X, Y, Z coordinates of the intersection point between the frame mid-point shot and the Mars surface; from Precision Orbit data; 3 4-byte values
- frame mid-point latitude, longitude	8	Degrees * 10^6	The areocentric latitude and the East longitude of the intersection point between the frame mid-point shot and the Mars surface; from Precision Orbit data; 2 4-byte values

Table 2: MOLA Precision Experiment Data Record (PEDR) Contents (Continued)
Rate: 1 every 2 seconds

Parameter	Bytes	Units	Description
- laser transmit power	40	mJ * 100	MOLA laser transmitted pulse energy, corrected for detector and heat sink temperatures, 20 2-byte values
- shot classification code	40		shot classification and weighting codes: a zero value denotes a noise return; 1 denotes a good return
- channel background noise counts	32	Counts	Frame value for background levels in the MOLA channels, at half-frame rate (order: 1A, 2A, 3A, 4A, 1B, 2B, 3B, and 4B where A is first half and B is second half of data frame), for raw background counts (prior to engineering unit conversion) equal to or less than 23 the converted value is set to 1.0, 8 4-byte values
- range delay	4	Centimeters	Frame value of range gate delay (to beginning of range window)
- range width	4	Centimeters	Frame value of range gate width
- receiver channel threshold settings	16	Millivolts	Threshold settings for the 4 MOLA channels, at half-frame rate (order: 1A, 2A, 3A, 4A, 1B, 2B, 3B, and 4B), 8 2-byte values
- receiver channel mask	2		MOLA channel mask setting for the frame; the mask indicates whether any of the 4 channels have been commanded off
- algorithm word MIN_HITS	2		Frame value for the flight software word MIN_HITS
- algorithm word HIT_COUNT	2	Counts	Frame value for the flight software word HIT_COUNT
- frame counter	2		Software status value
- trigger channel	2		Software status value
- within-packet frame index	2	Count	Frame number (among seven frames in MOLA telemetry packet) generated in Ground Data System processing
- packet source header	8		Information placed in MOLA telemetry packet by Payload Data System
- telemetry packet coarse time code seconds	4	ET (Elapsed Time) seconds	The whole portion of the Payload Data System generated time code in ET seconds referenced to J2000; a signed number.
- telemetry packet coarse time code milliseconds	2	ET milliseconds	The fractional portion of the Payload Data System generated time code in ET seconds referenced to J2000; a signed number.
- telemetry packet fine time code	2	counts	MOLA generated fine time counter
- engineering/ housekeeping data	28		Complete set of packet engineering and housekeeping data (196 bytes) from each MOLA telemetry packet, subcommutated into 7 data frames, 28 bytes appear at this location in each frame.

Table 2: MOLA Precision Experiment Data Record (PEDR) Contents (Continued)
Rate: 1 every 2 seconds

Parameter	Bytes	Units	Description
- orbit quality flag 1	2		Flag indicating origin of orbit. 0 indicates JPL was producer; 1 or higher indicates the MOLA Science Investigation Team.
- orbit quality flag 2	2		Precision orbit quality flag, TBD.
- orbit quality flag 3	2		Precision orbit quality flag, TBD.
- phase angle	2	radians * 10^4	The angle between the vectors from Mars to Mars Global Surveyor and from Mars to the Sun at the frame mid-point location
- solar incidence angle	2	radians * 10^4	Originally, the angle between the Mars surface normal vector and the Mars Global Surveyor vector at the frame mid-point location, now set to 0
- emission angle	2	radians * 10^4	Originally, the angle between the Mars surface normal vector and the Sun vector at the frame mid-point location, now set equal to the phase angle
- Atmospheric opacity	4	Pure number * 10^6	May be retrieved from TES data; nominally 0.5
- double precision frame mid-point time	8	seconds	The frame mid-point time represented in IEEE standard double precision; ET seconds (referenced to J2000)
- trigger channel raw received pulse energy	20	Counts	The received pulse energy counts; 255=>saturation; 20 1-byte values
- trigger channel raw received pulse width	20	Counts	The received pulse width counts; 63=>saturation; 20 1-byte values
spacecraft body-fixed XYZ coordinates	12	Centimeters	The Mars fixed X, Y, Z coordinates of the MGS spacecraft; from Precision Orbit data
- Geoid radius	4	Centimeters	The radius of the reference geoid with 3396 kilometer mean equatorial radius
- Off-nadir angle	4	Degrees * 10^6	Angle between the actual frame-midpoint shot direction and areocentric direction
- Encoder bits	20		The start and stop encoder bits for each MOLA shot. With these bits, the MOLA shot range is interpolated within each clock count. The start and stop encoders are stored in bits 0-1 and 4-5 of each byte
- delta geoid	4	centimeters	The average change in geoid associated with each 20-shot MOLA frame.
- MOLA clock rate	4	Hertz	The MOLA clock frequency used to calculate laser pulse time-of-flight.
- MOLA range	80	centimeters	The MOLA range value per shot; these values have been corrected by the range correction below, 20 4-byte values
- range correction	40	centimeters	Correction to the range value due to the detector response and range walk, 20 2-byte values
- delta latitude	4	Degrees * 10^6	The average distance between each areocentric latitude associated with each 20-shot MOLA frame.

Table 2: MOLA Precision Experiment Data Record (PEDR) Contents (Continued)
Rate: 1 every 2 seconds

Parameter	Bytes	Units	Description
- delta longitude	4	Degrees * 10^6	The average distance between each areocentric longitude associated with each 20-shot MOLA frame.
TOTAL:	776		

a. The phrase “frame mid-point” is used to denote the *receipt* time of shot 10.5, a point between the 10th and 11th shots in the set of 20 laser shots in a data frame.

Table 3: PEDR Data Product Subcommutated Data Format

Packet Byte	Contents	Length in Bytes	Frame	Frame Start Byte	Frame Stop Byte
12	Computer Memory temperature	2	PEDR 1	509	510
13	Computer CPU temperature	2	PEDR 1	511	512
14	Power Supply temperature	2	PEDR 1	513	514
15	Computer I/O temperature	2	PEDR 1	515	516
16	LASER array sink heat temperature	2	PEDR 1	517	518
17	LASER diode array drive electronics temperature	2	PEDR 1	519	520
18	Optical Test Source (OTS) LED temperature	2	PEDR 1	521	522
19	100 MHz Oscillator temperature	2	PEDR 1	523	524
20	Start Detector temperature	2	PEDR 1	525	526
21	Outside Detector box temperature	2	PEDR 1	527	528
22	LASER Radiator Opposite Output port temperature	2	PEDR 1	529	530
23	LASER Radiator Output port temperature	2	PEDR 1	531	532
24	Interface Plate near “hot foot” temperature	2	PEDR 1	533	534
25	Radiation shield transition temperature	2	PEDR 1	535	536
26	Electronics Box top near S/C thermistor temperature	2	PEDR 2	509	510
27	LASER box near “hot foot” temperature	2	PEDR 2	511	512
28	28 Volt monitor	2	PEDR 2	513	514
29	Reference Voltage monitor	2	PEDR 2	515	516
30	+12 Volt voltage monitor	2	PEDR 2	517	518
31	24 Volt voltage monitor	2	PEDR 2	519	520
32	+5 Volt voltage monitor	2	PEDR 2	521	522
33	-12 Volt voltage monitor	2	PEDR 2	523	524
34	LASER / thermal current monitor	2	PEDR 2	525	526
35	-5 Volt voltage monitor	2	PEDR 2	527	528
36	Power Supply current monitor	2	PEDR 2	529	530
37	High Voltage current monitor	2	PEDR 2	531	532
38	-12 Volt current monitor	2	PEDR 2	533	534
39	+12 Volt current monitor	2	PEDR 2	535	536
40	-5 Volt current monitor	2	PEDR 3	509	510
41	+5 Volt current monitor	2	PEDR 3	511	512
42	Current STATUS register value (SEU counter)	1	PEDR 3	513	513
43	Software Version Number Upper (4.4 bit format)	1	PEDR 3	514	514
43	Software Version Number Lower (4.4 bit format)	1	PEDR 3	515	515
55	Range Tracking Status (frame #7654321) “(1= tracking, 0 = acquisition) (MSB=OTS)”	1	PEDR 3	516	516
44	Flag word (2 KB RAM block test)	2	PEDR 3	517	518

Table 3: PEDR Data Product Subcommutated Data Format (Continued)

Packet Byte	Contents	Length in Bytes	Frame	Frame Start Byte	Frame Stop Byte
46	Status Flags (SFLAG1 (16 bits), SFLAG2 (16 bits))	4	PEDR 3	519	522
50	Software validity checksum	2	PEDR 3	523	524
52	Received command count (modulo 8 bits)	1	PEDR 3	525	525
53	Command error count (modulo 8 bits)	1	PEDR 3	526	526
54	Transmitter threshold setting (XMITDA)	2	PEDR 3	527	528
56	Range gate tracker array (73.728 km)	8	PEDR 3	529	536
64	Range gate tracker array (cont.)	28	PEDR 4	509	536
92	Range gate tracker array (cont.)	12	PEDR 5	509	520
104	HSTART value for HISTOGRAM dump	4	PEDR 5	521	524
	unused	4	PEDR 5	525	528
106	Valid commands received count (modulo 16 bits)	2	PEDR 5	529	530
108	Memory dump segment (16 Kbytes/16 bytes = 1024 packets ~= 4 hours)	6	PEDR 5	531	536
114	Memory dump segment (cont.)	10	PEDR 6	509	518
124	Command echo	16	PEDR 6	519	534
140	Packet validity checksum	2	PEDR 6	535	536
142	OTS Range	4	PEDR 7	509	512
144	OTS 1st channel received energy	4	PEDR 7	513	516
145	Spare	4	PEDR 7	517	520
223	OTS transmit power	4	PEDR 7	521	524
3	OTS pulse width	1	PEDR 7	525	525
3	OTS pulse amplitude	1	PEDR 7	526	526
	OTS quality flag	1	PEDR 7	527	527
11	Packet Type (0 for Science Mode)	1	PEDR 7	528	528
	Areocentric longitude of the Sun	2	PEDR 7	529	530
	unused	6	PEDR 7	531	536

APPENDICES

Appendix A Acronyms

AEDR	Aggregated Experiment Data Record
aJ	attoJoule
DDPID	Data Descriptive Package ID
EGDR	Experiment Gridded Data Record
ET	Elapsed Time
EUC	Engineering Unit Conversion
FTP	File Transfer Protocol
Gbytes	gigabytes
GMM-1	Goddard Mars Model-1 potential model (Smith et al., 1993)
GSFC	Goddard Space Flight Center
JPL	Jet Propulsion Laboratory
MGS	Mars Global Surveyor
Mbytes	megabytes
mJ	milliJoule
MOLA	Mars Orbiter Laser Altimeter
ms	milliseconds
NAIF/ SPICE	Navigation Ancillary Information Facility / Spacecraft Ephemeris, Planet Ephemeris, Instrument Offset, Instrument Inertial Orientation (C), Event Oriented Information Kernels
PEDR	Precision Experiment Data Record
PDB	Project Data Base
PDS	Planetary Data System
SFDU	Standard Formatted Data Unit
SFOC	Space Flight Operations Center
SIS	Software Interface Specification
SOPC	Science Operations Planning Computer
SPICE	Spacecraft Ephemeris, Planet Ephemeris, Instrument Offset, Instrument Inertial Orientation (C), Event Oriented Information Kernels
TBD	to be determined
WFF	Wallops Flight Facility

Appendix B Precision Experiment Data Record Catalog Files

This version of the MOLAPEDR SIS contains no listing of PDS Catalog Files

Appendix C PEDR Data Product SFDU Labels and Format Files

C.1 PEDR Data Product SFDU Labels and Catalog Header

```
CCSD3ZF0000100000001NJPL3KS0PDSX$$INFO$$
PDS_VERSION_ID       = PDS3
RECORD_TYPE          = FIXED_LENGTH
FILE_RECORDS         = 'UNK'
RECORD_BYTES         = 776
LABEL_RECORDS        = 10
FILE_NAME            = 'AP90003U.B'
^PEDR_FR_1_TABLE     = 11
^PEDR_FR_2_TABLE     = 11
^PEDR_FR_3_TABLE     = 11
^PEDR_FR_4_TABLE     = 11
^PEDR_FR_5_TABLE     = 11
^PEDR_FR_6_TABLE     = 11
^PEDR_FR_7_TABLE     = 11
DATA_SET_ID          = 'MGS-M-MOLA-3-PEDR-L1B-V1.0'
PRODUCT_ID           = 'MOLA-AP90003U.B'
SPACECRAFT_NAME      = 'MARS_GLOBAL_SURVEYOR'
INSTRUMENT_ID        = 'MOLA'
INSTRUMENT_NAME      = 'MARS_ORBITER_LASER_ALTIMETER'
TARGET_NAME          = 'MARS'
SOFTWARE_NAME        = 'PP_MAIN_5.00'
UPLOAD_ID            = 'SM-7.6'
SOURCE_PRODUCT_ID    = {"MOLA-AA90003F.B","MOLA-APPLCT00.T",
  "NAF0000E-CK","NAF0000E-CK","","NAF0000C-SPK","NAF0000C-
  SPK",""}
PRODUCT_RELEASE_DATE = 1998-141
START_TIME           = 1997-212T19:10:00.000
STOP_TIME            = 1997-212T19:45:00.000
NATIVE_START_TIME    = -76351736.816730
NATIVE_STOP_TIME     = -76349636.816730
SPACECRAFT_CLOCK_START_COUNT=443588190.140
SPACECRAFT_CLOCK_STOP_COUNT=443595246.140
PRODUCT_CREATION_TIME= 1998-051T17:42:37.881
MISSION_PHASE_NAME   = 'CONTINGENCY'
ORBIT_NUMBER         = 90003
PRODUCT_VERSION_TYPE = {"R004-CALIBRATED REL.","O90003 - ORBIT 3",
  "P004-CALIBRATED REL.","E004-CALIBRATED REL."}
PRODUCER_ID          = 'MGS_MOLA_TEAM'
PRODUCER_FULL_NAME   = 'DAVID E. SMITH'
PRODUCER_INSTITUTION_NAME='GODDARD SPACE FLIGHT CENTER'
DESCRIPTION          = "The PEDR data product contains the along-
  track, time series collection of MOLA instrument, science mode
  data in engineering and physical units. Precision orbit data
  describing the instrument's position and location has been added
  to each record. The precision data is supplied by the MOLA Science
  Team."

OBJECT               = PEDR_FR_1_TABLE
 INTERCHANGE_FORMAT  = BINARY
 ROWS                = 'UNK'
 COLUMNS             = 71
 ROW_BYTES           = 776
 ^FIRST_STRUCTURE    = 'PEDRSEC1.FMT'
```

```
 ^FR_1_ENG_STRUCTURE = 'PEDRENG1.FMT'
 ^THIRD_STRUCTURE    = 'PEDRSEC3.FMT'
 DESCRIPTION         = "This is one of seven table definitions that
   apply to the seven possible PEDR record structures, one for each
   frame. In each data record, byte 492 (counting from one)
   identifies the frame number for the record. This table structure
   incorporates the engineering information returned in Frame 1. The
   'first_structure' format file includes descriptions of the first
   500 bytes of the record, 'fr_1_eng_structure' format file
   describes bytes 501 to 528, and the 'third_structure' format file
   describes bytes 529 to 776."
END_OBJECT           = PEDR_FR_1_TABLE

OBJECT               = PEDR_FR_2_TABLE
 INTERCHANGE_FORMAT  = BINARY
 ROWS                = 'UNK'
 COLUMNS             = 71
 ROW_BYTES           = 776
 ^FIRST_STRUCTURE    = 'PEDRSEC1.FMT'
 ^FR_2_ENG_STRUCTURE = 'PEDRENG2.FMT'
 ^THIRD_STRUCTURE    = 'PEDRSEC3.FMT'
 DESCRIPTION         = "This is one of seven table definitions that
   apply to the seven possible PEDR record structures, one for each
   frame. In each data record, byte 492 (counting from one)
   identifies the frame number for the record. This table structure
   incorporates the engineering information returned in Frame 2. The
   'first_structure' format file includes descriptions of the first
   500 bytes of the record, 'fr_2_eng_structure' format file
   describes bytes 501 to 528, and the 'third_structure' format file
   describes bytes 529 to 776."
END_OBJECT           = PEDR_FR_2_TABLE

OBJECT               = PEDR_FR_3_TABLE
 INTERCHANGE_FORMAT  = BINARY
 ROWS                = 'UNK'
 COLUMNS             = 70
 ROW_BYTES           = 776
 ^FIRST_STRUCTURE    = 'PEDRSEC1.FMT'
 ^FR_3_ENG_STRUCTURE = 'PEDRENG3.FMT'
 ^THIRD_STRUCTURE    = 'PEDRSEC3.FMT'
 DESCRIPTION         = "This is one of seven table definitions that
   apply to the seven possible PEDR record structures, one for each
   frame. In each data record, byte 492 (counting from one)
   identifies the frame number for the record. This table structure
   incorporates the engineering information returned in Frame 3. The
   'first_structure' format file includes descriptions of the first
   500 bytes of the record, 'fr_3_eng_structure' format file
   describes bytes 501 to 528, and the 'third_structure' format file
   describes bytes 529 to 776."
END_OBJECT           = PEDR_FR_3_TABLE

OBJECT               = PEDR_FR_4_TABLE
 INTERCHANGE_FORMAT  = BINARY
 ROWS                = 'UNK'
 COLUMNS             = 58
 ROW_BYTES           = 776
 ^FIRST_STRUCTURE    = 'PEDRSEC1.FMT'
 ^FR_4_ENG_STRUCTURE = 'PEDRENG4.FMT'
 ^THIRD_STRUCTURE    = 'PEDRSEC3.FMT'
```

```
 DESCRIPTION         = "This is one of seven table definitions that
   apply to the seven possible PEDR record structures, one for each
   frame. In each data record, byte 492 (counting from one)
   identifies the frame number for the record. This table structure
   incorporates the engineering information returned in Frame 4. The
   'first_structure' format file includes descriptions of the first
   500 bytes of the record, 'fr_4_eng_structure' format file
   describes bytes 501 to 528, and the 'third_structure' format file
   describes bytes 529 to 776."
END_OBJECT           = PEDR_FR_4_TABLE

OBJECT               = PEDR_FR_5_TABLE
 INTERCHANGE_FORMAT  = BINARY
 ROWS                = 'UNK'
 COLUMNS             = 62
 ROW_BYTES           = 776
 ^FIRST_STRUCTURE    = 'PEDRSEC1.FMT'
 ^FR_5_ENG_STRUCTURE = 'PEDRENG5.FMT'
 ^THIRD_STRUCTURE    = 'PEDRSEC3.FMT'
 DESCRIPTION         = "This is one of seven table definitions that
   apply to the seven possible PEDR record structures, one for each
   frame. In each data record, byte 492 (counting from one)
   identifies the frame number for the record. This table structure
   incorporates the engineering information returned in Frame 5. The
   'first_structure' format file includes descriptions of the first
   500 bytes of the record, 'fr_5_eng_structure' format file
   describes bytes 501 to 528, and the 'third_structure' format file
   describes bytes 529 to 776."
END_OBJECT           = PEDR_FR_5_TABLE

OBJECT               = PEDR_FR_6_TABLE
 INTERCHANGE_FORMAT  = BINARY
 ROWS                = 'UNK'
 COLUMNS             = 60
 ROW_BYTES           = 776
 ^FIRST_STRUCTURE    = 'PEDRSEC1.FMT'
 ^FR_6_ENG_STRUCTURE = 'PEDRENG6.FMT'
 ^THIRD_STRUCTURE    = 'PEDRSEC3.FMT'
 DESCRIPTION         = "This is one of seven table definitions that
   apply to the seven possible PEDR record structures, one for each
   frame. In each data record, byte 492 (counting from one)
   identifies the frame number for the record. This table structure
   incorporates the engineering information returned in Frame 6. The
   'first_structure' format file includes descriptions of the first
   500 bytes of the record, 'fr_6_eng_structure' format file
   describes bytes 501 to 528, and the 'third_structure' format file
   describes bytes 529 to 776."
END_OBJECT           = PEDR_FR_6_TABLE

OBJECT               = PEDR_FR_7_TABLE
 INTERCHANGE_FORMAT  = BINARY
 ROWS                = 'UNK'
 COLUMNS             = 66
 ROW_BYTES           = 776
 ^FIRST_STRUCTURE    = 'PEDRSEC1.FMT'
 ^FR_7_ENG_STRUCTURE = 'PEDRENG7.FMT'
 ^THIRD_STRUCTURE    = 'PEDRSEC3.FMT'
 DESCRIPTION         = "This is one of seven table definitions that
   apply to the seven possible PEDR record structures, one for each
```

```
  frame. In each data record, byte 492 (counting from one)
  identifies the frame number for the record. This table structure
  incorporates the engineering information returned in Frame 7. The
  'first_structure' format file includes descriptions of the first
  500 bytes of the record, 'fr_7_eng_structure' format file
  describes bytes 501 to 528, and the 'third_structure' format file
  describes bytes 529 to 776."
END_OBJECT            = PEDR_FR_7_TABLE

END
```

C.2 Contents of the MOLA PEDRSEC1.FMT Format File

```
OBJECT                = COLUMN
 NAME                 = FRAME_TIME_WHOLE_SECONDS
 DATA_TYPE            = MSB_INTEGER
 START_BYTE           = 1
 BYTES                = 4
 UNIT                 = 'SECONDS'
 DESCRIPTION          = "Mid-point frame time whole seconds. The
  integer represents the whole portion of the Elapsed time (in
  number of seconds) past J2000 -- may be a negative number."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = FRAME_TIME_FRAC_SECONDS
 DATA_TYPE            = MSB_INTEGER
 START_BYTE           = 5
 BYTES                = 4
 UNIT                 = 'MICROSECONDS'
 DESCRIPTION          = "The frame mid-point time fractional
  seconds, scaled to microseconds. The integer represents the
  fractional portion of the Elapsed time (in number of
  microseconds) past J2000 -- may be a negative number."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = ORBIT_NUMBER
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 9
 BYTES                = 4
 DESCRIPTION          = "Mapping mission orbit number, determined by
  Mars Global Surveyor flight operations system."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = AREOCENTRIC_LATITUDE
 DATA_TYPE            = MSB_INTEGER
 START_BYTE           = 13
 BYTES                = 4
 UNIT                 = 'DEGREES * (10**6)'
 DESCRIPTION          = "The areocentric latitude value associated
  with the MOLA data frame mid-point with respect to the Mars Global
  Surveyor spacecraft center of mass. Obtained from the MOLA
  Science Investigation Team precision orbit data. Scaled to
  degrees * 1000000."
```

```
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = AREOCENTRIC_LONGITUDE
 DATA_TYPE           = MSB_INTEGER
 START_BYTE          = 17
 BYTES               = 4
 UNIT                = 'DEGREES * (10**6)'
 DESCRIPTION         = "The East longitude value associated with the
   MOLA data frame mid-point with respect to the Mars Global Surveyor
   spacecraft center of mass. Obtained from the MOLA Science
   Investigation Team precision orbit data. Scaled to degrees *
   1000000."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = RADIAL_DISTANCE
 DATA_TYPE           = MSB_UNSIGNED_INTEGER
 START_BYTE          = 21
 BYTES               = 4
 UNIT                = 'CENTIMETERS'
 DESCRIPTION         = "The distance from the Mars body center to
   the Mars Global Surveyor spacecraft center of mass associated
   with the MOLA frame mid-point, based on a coordinate system with
   origin at the center of mass of Mars. Obtained from the MOLA
   Science Investigation Team precision orbit data."
END_OBJECT           = COLUMN


OBJECT               = COLUMN
 NAME                = FRAME_MID_POINT_RANGE
 DATA_TYPE           = MSB_UNSIGNED_INTEGER
 START_BYTE          = 25
 BYTES               = 4
 UNIT                = 'CENTIMETERS'
 DESCRIPTION         = "MOLA range (corrected to Mars Global
   Surveyor center of mass) associated with MOLA data frame mid-
   point, obtained from a straight line best fitted to the individual
   MOLA range measurements (up to 20) in the MOLA data frame."
END_OBJECT           = COLUMN


OBJECT               = COLUMN
 NAME                = SHOT_QUALITY_FLAG
 DATA_TYPE           = MSB_UNSIGNED_INTEGER
 START_BYTE          = 29
 BYTES               = 4
 DESCRIPTION         = "3 bytes - flag whether good/bad shot (20
   least significant bits, one for each of the 20 shots, with least
   significant bit, 0, being shot 20) and each bit set to 1 for good,
   0 for bad shot. 1 byte - good shot counter, (total of bits set to
   1 in above 20 bits)."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = SHOT_QUALITY_DESCRIPTOR_FLAG
 DATA_TYPE           = LSB_BIT_STRING
 START_BYTE          = 33
 BYTES               = 16
```

```
 DESCRIPTION          = "Flag indicating whether the packet or
   individual shots passed or failed the various shot quality tests.
   Reading the flag from right to left with the rightmost bit being
   bit 0 and the leftmost bit being bit 63 the format of the flag is
    bit 0: packet validity checksum test, (per packet test)
   bit 1: computer software validity checksum test, (per packet test)
   bit 2: frame acquisition vs. tracking mode test. (per frame test)
    bit 3: first shot of the packet is OTS test, (per packet test)
    bits 4 - 23: transmit power test, (per shot test)
    bits 24 - 43: return energy test, (per shot test)
    bits 44 - 63: range test, (per shot test)
    bits 64 - 83: range window test
    bits 84 - 103: range comparison test
    bits 104 - 127: unused
    A 1 indicates the test was failed, 0 indicates the test was
   passed. For the bits that flag each shot, the lower bit
   corresponds to shot 1 and the higher bit corresponds to shot 20."

OBJECT                = BIT_COLUMN
 NAME                 = PACKET_VALIDITY_CHECKSUM_FLAG
 BIT_DATA_TYPE        = UNSIGNED_INTEGER
 START_BIT            = 1
 BITS                 = 1
 DESCRIPTION          = "Packet validity checksum test flag bit.
   Please see 'shot_quality_descriptor_flag' column object for
   fuller description."
END_OBJECT            = BIT_COLUMN

OBJECT                = BIT_COLUMN
 NAME                 = SOFTWARE_VALIDITY_CHCKSM_FLAG
 BIT_DATA_TYPE        = UNSIGNED_INTEGER
 START_BIT            = 2
 BITS                 = 1
 DESCRIPTION          = "Computer software validity checksum test
   flag bit. Please see 'shot_quality_descriptor_flag' column object
   for fuller description."
END_OBJECT            = BIT_COLUMN

OBJECT                = BIT_COLUMN
 NAME                 = ACQ_TRACK_MODE_TEST_FLAG
 BIT_DATA_TYPE        = UNSIGNED_INTEGER
 START_BIT            = 3
 BITS                 = 1
 DESCRIPTION          = "Frame Acquisition vs. Tracking Mode Test
   flag bit. Please see 'shot_quality_descriptor_flag' column object
   for fuller description."
END_OBJECT            = BIT_COLUMN

OBJECT                = BIT_COLUMN
 NAME                 = FIRST_SHOT_OTS_FLAG
 BIT_DATA_TYPE        = UNSIGNED_INTEGER
 START_BIT            = 4
 BITS                 = 1
 DESCRIPTION          = "First shot in the packet is OTS test flag
   bit. Please see 'shot_quality_descriptor_flag' column object for
   fuller description."
END_OBJECT            = BIT_COLUMN

OBJECT                = BIT_COLUMN
```

```
 NAME                = TRANSMIT_POWER_TEST
 BIT_DATA_TYPE       = UNSIGNED_INTEGER
 START_BIT           = 5
 BITS                = 20
 DESCRIPTION         = "Transmit power test flag bits. Please see
  'shot_quality_descriptor_flag' column object for fuller
  description."
END_OBJECT           = BIT_COLUMN

OBJECT               = BIT_COLUMN
 NAME                = RETURN_ENERGY_TEST
 BIT_DATA_TYPE       = UNSIGNED_INTEGER
 START_BIT           = 25
 BITS                = 20
 DESCRIPTION         = "Return energy test flag bits. Please see
  'shot_quality_descriptor_flag' column object for fuller
  description."
END_OBJECT           = BIT_COLUMN

OBJECT               = BIT_COLUMN
 NAME                = RANGE_TEST
 BIT_DATA_TYPE       = UNSIGNED_INTEGER
 START_BIT           = 45
 BITS                = 20
 DESCRIPTION         = "Range test flag bits. Please see
  'shot_quality_descriptor_flag' column object for fuller
  description."
END_OBJECT           = BIT_COLUMN

OBJECT               = BIT_COLUMN
 NAME                = RANGE_WINDOW_TEST
 BIT_DATA_TYPE       = UNSIGNED_INTEGER
 START_BIT           = 65
 BITS                = 20
 DESCRIPTION         = "Range window test flag bits.  Please see
  'shot_quality_descriptor_flag' column object for fuller
  description."
END_OBJECT           = BIT_COLUMN

OBJECT               = BIT_COLUMN
 NAME                = RANGE_COMPARISON_TEST
 BIT_DATA_TYPE       = UNSIGNED_INTEGER
 START_BIT           = 85
 BITS                = 20
 DESCRIPTION         = "Range comparison test flag bits.  Please see
  'shot_quality_descriptor_flag' column object for fuller
  description."
END_OBJECT           = BIT_COLUMN

END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = SHOT_PLANETARY_RADIUS
 DATA_TYPE           = MSB_UNSIGNED_INTEGER
 START_BYTE          = 49
 BYTES               = 80
 ITEMS               = 20
 ITEM_BYTES          = 4
 UNIT                = 'CENTIMETERS'
```

```
 DESCRIPTION         = "Array of 20 MOLA planetary radius values in
   the data frame; the distance from the center of Mars to the point
   on the surface of Mars described by the MOLA range; per shot."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = FRAME_PLANETARY_RADIUS
 DATA_TYPE           = MSB_UNSIGNED_INTEGER
 START_BYTE          = 129
 BYTES               = 4
 UNIT                = 'CENTIMETERS'
 DESCRIPTION         = "Planetary radius associated with MOLA data
   frame mid-point; the distance from the center of Mars to the point
   on the surface of Mars described by the frame mid-point range."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = RIGHT_ASCENSION
 DATA_TYPE           = MSB_INTEGER
 START_BYTE          = 133
 BYTES               = 4
 UNIT                = 'MILLIRADIANS'
 DESCRIPTION         = "Right ascension angle of the MOLA instrument
   at data frame mid-point."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = DECLINATION
 DATA_TYPE           = MSB_INTEGER
 START_BYTE          = 137
 BYTES               = 4
 UNIT                = 'MILLIRADIANS'
 DESCRIPTION         = "Declination angle of the MOLA instrument at
   data frame mid-point."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = TWIST
 DATA_TYPE           = MSB_INTEGER
 START_BYTE          = 141
 BYTES               = 4
 UNIT                = 'MILLIRADIANS'
 DESCRIPTION         = "Twist angle of the MOLA instrument at data
   frame mid-point."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = CORR_RECV_PULSE_ENRGY
 DATA_TYPE           = MSB_UNSIGNED_INTEGER
 START_BYTE          = 145
 BYTES               = 40
 ITEMS               = 20
 ITEM_BYTES          = 2
 UNIT                = 'ATTOJOULES'
 DESCRIPTION         = "Corrected surface-scattered return energy
   measured by first MOLA channel to trigger (an array of 20 values
   for the data frame). Saturation of energy detector may occur (see
   RECV_PULSE_ENERGY_COUNTS)."
END_OBJECT           = COLUMN
```

```
OBJECT              = COLUMN
 NAME               = SURF_REFLECTIVITY
 DATA_TYPE          = MSB_UNSIGNED_INTEGER
 START_BYTE         = 185
 BYTES              = 40
 ITEMS              = 20
 ITEM_BYTES         = 2
 DESCRIPTION        = "Relative Martian surface reflectivity *
   atmospheric transmittance values, one per shot; stored as a pure
   fraction * 10**5."
END_OBJECT          = COLUMN

OBJECT              = COLUMN
 NAME               = TRIGGER_CHANNEL_NUMBER
 DATA_TYPE          = UNSIGNED_INTEGER
 START_BYTE         = 225
 BYTES              = 20
 ITEMS              = 20
 ITEM_BYTES         = 1
 DESCRIPTION        = "Channel number of first MOLA channel to
   trigger (array of 20 values for data frame)."
END_OBJECT          = COLUMN

OBJECT              = COLUMN
 NAME               = PULSE_WIDTH
 DATA_TYPE          = MSB_UNSIGNED_INTEGER
 START_BYTE         = 245
 BYTES              = 40
 ITEMS              = 20
 ITEM_BYTES         = 2
 UNIT               = 'NANOSECONDS * 10'
 DESCRIPTION        = "The time between threshold crossings of the
   detected pulse, one per shot, 20 2-byte values. Detector
   saturation may occur (see RECV_PULSE_WIDTH_COUNTS)."
END_OBJECT          = COLUMN

OBJECT              = COLUMN
 NAME               = RECV_OPTICAL_PULSE_WIDTH
 DATA_TYPE          = MSB_UNSIGNED_INTEGER
 START_BYTE         = 285
 BYTES              = 40
 ITEMS              = 20
 ITEM_BYTES         = 2
 UNIT               = 'NANOSECONDS * 10'
 DESCRIPTION        = "Received optical pulse width, corrected for
   filter characteristics and threshold settings, as determined by
   the receiver model (an array of 20 values for the data frame).
   The pulse width provides an estimate of target slope and/or
   roughness, assuming linear detector response and nadir-looking
   geometry."
END_OBJECT          = COLUMN

OBJECT              = COLUMN
 NAME               = FRAME_XYZ
 DATA_TYPE          = MSB_INTEGER
 START_BYTE         = 325
 BYTES              = 12
 ITEMS              = 3
```

```
 ITEM_BYTES          = 4
 UNIT                = 'CENTIMETERS'
 DESCRIPTION         = "X, Y, Z coordinates of the intersection
   point between the frame mid-point shot and the Mars surface; from
   Precision Orbit data; 3 4-byte values."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = FRAME_LAT_LON
 DATA_TYPE           = MSB_INTEGER
 START_BYTE          = 337
 BYTES               = 8
 ITEMS               = 2
 ITEM_BYTES          = 4
 UNIT                = 'DEGREES * (10**6)'
 DESCRIPTION         = "The areocentric latitude and the East
   longitude of the intersection point between the frame mid-point
   shot and the Mars surface; from Precision Orbit data; 2 4-byte
   values."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = LASER_TRANSMIT_POWER
 DATA_TYPE           = MSB_UNSIGNED_INTEGER
 START_BYTE          = 345
 BYTES               = 40
 ITEMS               = 20
 ITEM_BYTES          = 2
 UNIT                = 'MILLIJOULES * 100'
 DESCRIPTION         = "MOLA laser transmitted pulse energy (array
   of 20 values for data frame)."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = SHOT_CLASSIFICATION_CODE
 DATA_TYPE           = MSB_UNSIGNED_INTEGER
 START_BYTE          = 385
 BYTES               = 40
 ITEMS               = 20
 ITEM_BYTES          = 2
 DESCRIPTION         = "Shot classification: 0=false trigger or no
   trigger; 1=probable ground trigger; other=unassigned."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = CHANNEL_BACKGROUND_NOISE_CTS
 DATA_TYPE           = MSB_UNSIGNED_INTEGER
 START_BYTE          = 425
 BYTES               = 32
 ITEMS               = 8
 ITEM_BYTES          = 4
 UNIT                = 'COUNTS'
 DESCRIPTION         = "Background noise levels in the MOLA
   channels; at half-frame rate; array of 8 four-byte values where
   array elements 1-4 are 1st half-frame values for channels 1-4 and
   array elements 5-8 are 2nd half-frame values for channel 1-4."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
```

```
 NAME                 = RANGE_DELAY
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 457
 BYTES                = 4
 UNIT                 = 'CENTIMETERS'
 DESCRIPTION          = "Frame value of range gate delay (to
   beginning of range window)."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = RANGE_WIDTH
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 461
 BYTES                = 4
 UNIT                 = 'CENTIMETERS'
 DESCRIPTION          = "Frame value of range gate width."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = CHANNEL_THRESHOLD_SETTINGS
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 465
 BYTES                = 16
 ITEMS                = 8
 ITEM_BYTES           = 2
 UNIT                 = 'MILLIVOLTS'
 DESCRIPTION          = "Threshold settings for the 4 MOLA channels;
   at half-frame rate; array of 8 four-byte values where array
   elements 1-4 are 1st half-frame values for channels 1-4 and array
   elements 5-8 are 2nd half-frame values for channel 1-4."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = RECEIVER_CHAN_MASK
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 481
 BYTES                = 2
 DESCRIPTION          = "The receiver channel mask status; set to the
   value read from the ATLMOD sent by the altimeter electronics; the
   mask setting indicates which channels are commanded on and off."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = ALGORITHM_WORD_MIN_HITS
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 483
 BYTES                = 2
 DESCRIPTION          = "The minimum shot hit count value required
   for a matched filter channel to trigger; MIN_HITS value set in
   algorithm from the previous data frame."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = ALGORITHM_WORD_HIT_COUNT
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 485
 BYTES                = 2
 DESCRIPTION          = "Current value from the active data frame,
   showing the number of hits counted in the possible 20 shot hits
```

```
   in the single frame or the number of hits summed over the possible
   100 shots when in the 5-frame mode. Tracking algorithm
   performance indicator. If in the acquisition mode, this field
   will contain the number of shot hits from a possible 80 shots
   within the 4 frame acquisition window."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = FRAME_COUNTER
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 487
 BYTES                = 2
 DESCRIPTION          = "The frame counter value is set from the
   previous data frame tracking algorithm operation."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = TRIGGER_CHANNEL
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 489
 BYTES                = 2
 DESCRIPTION          = "The first channel triggering at or above the
   minimum hit count is set from the previous data frame tracking
   algorithm operation."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = FRAME_INDEX
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 491
 BYTES                = 2
 DESCRIPTION          = "Frame number (among seven frames produced
   from the MOLA telemetry packet) generated in Ground Data System
   processing."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = PACKET_SOURCE_HEADER
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 493
 BYTES                = 8
 ITEMS                = 2
 ITEM_BYTES           = 4
 DESCRIPTION          = "The header put on the MOLA telemetry packet
   by the Payload Data System."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = TIME_CODE_SECONDS
 DATA_TYPE            = MSB_INTEGER
 START_BYTE           = 501
 BYTES                = 4
 UNIT                 = 'SECONDS'
 DESCRIPTION          = "The whole portion of the packet time
   referenced to J2000 in Elapsed Time seconds -- may be a negative
   number. The time is obtained from the Payload Data System supplied
   coarse time code that is generated at the time of the MOLA packet
   collection."
END_OBJECT            = COLUMN
```

```
OBJECT                  = COLUMN
 NAME                   = PKT_TIME_CODE_MILLISECONDS
 DATA_TYPE              = MSB_INTEGER
 START_BYTE             = 505
 BYTES                  = 2
 UNIT                   = 'MILLISECONDS'
 DESCRIPTION            = "The fractional portion of the packet time
   referenced to J2000 in Elapsed Time seconds * 1000 -- may be a
   negative number. The time is obtained from the Payload Data System
   supplied coarse time code that is generated at the time of the
   MOLA packet collection."
END_OBJECT              = COLUMN

OBJECT                  = COLUMN
 NAME                   = PKT_FINE_TIME
 DATA_TYPE              = MSB_UNSIGNED_INTEGER
 START_BYTE             = 507
 BYTES                  = 2
 UNIT                   = 'COUNTS'
 DESCRIPTION            = "MOLA-generated fine time counter."
END_OBJECT              = COLUMN
```

C.3 Contents of the MOLA PEDRENG1.FMT File

```
OBJECT                  = COLUMN
 NAME                   = COMPUTER_MEMORY_TEMPERATURE
 DATA_TYPE              = MSB_INTEGER
 START_BYTE             = 509
 BYTES                  = 2
 UNIT                   = 'DEGREES CELSIUS * 100'
 MINIMUM                = 0
 MAXIMUM                = 7203
 DESCRIPTION            = "The computer memory temperature."
END_OBJECT              = COLUMN

OBJECT                  = COLUMN
 NAME                   = COMPUTER_CPU_TEMPERATURE
 DATA_TYPE              = MSB_INTEGER
 START_BYTE             = 511
 BYTES                  = 2
 UNIT                   = 'DEGREES CELSIUS * 100'
 MINIMUM                = 0
 MAXIMUM                = 7203
 DESCRIPTION            = "The computer CPU temperature."
END_OBJECT              = COLUMN

OBJECT                  = COLUMN
 NAME                   = POWER_SUPPLY_TEMPERATURE
 DATA_TYPE              = MSB_INTEGER
 START_BYTE             = 513
 BYTES                  = 2
 UNIT                   = 'DEGREES CELSIUS * 100'
 MINIMUM                = 0
 MAXIMUM                = 7203
 DESCRIPTION            = "The power supply temperature."
```

```
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = 'COMPUTER_I/O_TEMPERATURE'
 DATA_TYPE           = MSB_INTEGER
 START_BYTE          = 515
 BYTES               = 2
 UNIT                = 'DEGREES CELSIUS * 100'
 MINIMUM             = 0
 MAXIMUM             = 7203
 DESCRIPTION         = "The computer I/O temperature."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = LASER_DIODE_ARRAY_TEMPERATURE
 DATA_TYPE           = MSB_INTEGER
 START_BYTE          = 517
 BYTES               = 2
 UNIT                = 'DEGREES CELSIUS * 100'
 MINIMUM             = 0
 MAXIMUM             = 7203
 DESCRIPTION         = "The LASER diode array temperature."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = LASER_DIODE_DRIVE_ELECS_TEMP
 DATA_TYPE           = MSB_INTEGER
 START_BYTE          = 519
 BYTES               = 2
 UNIT                = 'DEGREES CELSIUS * 100'
 MINIMUM             = 0
 MAXIMUM             = 7203
 DESCRIPTION         = "The LASER diode drive electronics
   temperature."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = OPTICAL_TEST_SOURCE_LED_TEMP
 DATA_TYPE           = MSB_INTEGER
 START_BYTE          = 521
 BYTES               = 2
 UNIT                = 'DEGREES CELSIUS * 100'
 MINIMUM             = 0
 MAXIMUM             = 7203
 DESCRIPTION         = "The optical test source LED temperature."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = HUNDRED_MHZ_OSCILLATOR_TEMP
 DATA_TYPE           = MSB_INTEGER
 START_BYTE          = 523
 BYTES               = 2
 UNIT                = 'DEGREES CELSIUS * 100'
 MINIMUM             = 0
 MAXIMUM             = 7203
 DESCRIPTION         = "The 100 MHz Oscillator temperature."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
```

```
 NAME                    = START_DETECTOR_TEMPERATURE
 DATA_TYPE               = MSB_INTEGER
 START_BYTE              = 525
 BYTES                   = 2
 UNIT                    = 'DEGREES CELSIUS * 100'
 MINIMUM                 = 0
 MAXIMUM                 = 7203
 DESCRIPTION             = "The start detector temperature."
END_OBJECT               = COLUMN

OBJECT                   = COLUMN
 NAME                    = OUTSIDE_DETECTOR_HOUSING_TEMP
 DATA_TYPE               = MSB_INTEGER
 START_BYTE              = 527
 BYTES                   = 2
 UNIT                    = 'DEGREES CELSIUS * 100'
 MINIMUM                 = 0
 MAXIMUM                 = 7203
 DESCRIPTION             = "The outside detector housing temperature."
END_OBJECT               = COLUMN

OBJECT                   = COLUMN
 NAME                    = LASR_RADIATR_OPP_OPT_PORT_TEMP
 DATA_TYPE               = MSB_INTEGER
 START_BYTE              = 529
 BYTES                   = 2
 UNIT                    = 'DEGREES CELSIUS * 100'
 MINIMUM                 = 0
 MAXIMUM                 = 7203
 DESCRIPTION             = "The LASER radiator opposite output port
  temperature."
END_OBJECT               = COLUMN

OBJECT                   = COLUMN
 NAME                    = LSER_RADIATOR_OUTPUT_PORT_TEMP
 DATA_TYPE               = MSB_INTEGER
 START_BYTE              = 531
 BYTES                   = 2
 UNIT                    = 'DEGREES CELSIUS * 100'
 MINIMUM                 = 0
 MAXIMUM                 = 7203
 DESCRIPTION             = "The LASER radiator output port
  temperature."
END_OBJECT               = COLUMN

OBJECT                   = COLUMN
 NAME                    = INTERFACE_PLATE_HOT_FOOT_TEMP
 DATA_TYPE               = MSB_INTEGER
 START_BYTE              = 533
 BYTES                   = 2
 UNIT                    = 'DEGREES CELSIUS * 100'
 MINIMUM                 = 0
 MAXIMUM                 = 7203
 DESCRIPTION             = "The interface plate temperature."
END_OBJECT               = COLUMN

OBJECT                   = COLUMN
 NAME                    = HONEYCOMB_PANEL_TEMPERATURE
 DATA_TYPE               = MSB_INTEGER
```

```
 START_BYTE          = 535
 BYTES               = 2
 UNIT                = 'DEGREES CELSIUS * 100'
 MINIMUM             = 0
 MAXIMUM             = 7203
 DESCRIPTION         = "The honeycomb panel temperature."
END_OBJECT           = COLUMN
```

C.4 Contents of the MOLA PEDRENG2.FMT Format File

```
OBJECT               = COLUMN
 NAME                = ELECTRONICS_BOX_TOP_SC_THRMSTR
 DATA_TYPE           = MSB_INTEGER
 START_BYTE          = 509
 BYTES               = 2
 UNIT                = 'DEGREES CELSIUS * 100'
 MINIMUM             = 0
 MAXIMUM             = 7203
 DESCRIPTION         = "The electronics box top near spacecraft
   thermistor temperature."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = LASER_CASE_HOT_FOOT_TEMP
 DATA_TYPE           = MSB_INTEGER
 START_BYTE          = 511
 BYTES               = 2
 UNIT                = 'DEGREES CELSIUS * 100'
 MINIMUM             = 0
 MAXIMUM             = 7203
 DESCRIPTION         = "The LASER case near 'hot foot' temperature."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = PLUS_28_VOLT_VOLTAGE_MONITOR
 DATA_TYPE           = MSB_UNSIGNED_INTEGER
 START_BYTE          = 513
 BYTES               = 2
 UNIT                = 'MILLIVOLTS'
 MINIMUM             = 0
 MAXIMUM             = 63531
 DESCRIPTION         = "The 28-volt monitor reading."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = REFERENCE_VOLTAGE_MONITOR
 DATA_TYPE           = MSB_UNSIGNED_INTEGER
 START_BYTE          = 515
 BYTES               = 2
 UNIT                = 'MILLIVOLTS'
 MINIMUM             = 0
 MAXIMUM             = 5000
 DESCRIPTION         = "The reference voltage monitor reading."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
```

```
  NAME                 = PLUS_12_VOLT_VOLTAGE_MONITOR
  DATA_TYPE            = MSB_UNSIGNED_INTEGER
  START_BYTE           = 517
  BYTES                = 2
  UNIT                 = 'MILLIVOLTS'
  MINIMUM              = 0
  MAXIMUM              = 27346
  DESCRIPTION          = "The 12-volt voltage monitor reading."
END_OBJECT             = COLUMN

OBJECT                 = COLUMN
  NAME                 = PLUS_24_VOLT_VOLTAGE_MONITOR
  DATA_TYPE            = MSB_UNSIGNED_INTEGER
  START_BYTE           = 519
  BYTES                = 2
  UNIT                 = 'MILLIVOLTS'
  MINIMUM              = 0
  MAXIMUM              = 65535
  DESCRIPTION          = "The 24-volt voltage monitor reading."
END_OBJECT             = COLUMN

OBJECT                 = COLUMN
  NAME                 = PLUS_5_VOLT_VOLTAGE_MONITOR
  DATA_TYPE            = MSB_UNSIGNED_INTEGER
  START_BYTE           = 521
  BYTES                = 2
  UNIT                 = 'MILLIVOLTS'
  MINIMUM              = 0
  MAXIMUM              = 11320
  DESCRIPTION          = "The 5-volt voltage monitor reading."
END_OBJECT             = COLUMN

OBJECT                 = COLUMN
  NAME                 = MINUS_12_VOLT_VOLTAGE_MONITOR
  DATA_TYPE            = MSB_UNSIGNED_INTEGER
  START_BYTE           = 523
  BYTES                = 2
  UNIT                 = 'MILLIVOLTS'
  MINIMUM              = 0
  MAXIMUM              = 27149
  DESCRIPTION          = "The negative-12-volt voltage monitor
    reading."
END_OBJECT             = COLUMN

OBJECT                 = COLUMN
  NAME                 = LASER_THERMAL_CURRENT_MONITOR
  DATA_TYPE            = MSB_UNSIGNED_INTEGER
  START_BYTE           = 525
  BYTES                = 2
  UNIT                 = 'MILLIAMPS * 10'
  MINIMUM              = 0
  MAXIMUM              = 8462
  DESCRIPTION          = "The LASER/thermal current monitor reading."
END_OBJECT             = COLUMN

OBJECT                 = COLUMN
  NAME                 = MINUS_5_VOLT_VOLTAGE_MONITOR
  DATA_TYPE            = MSB_UNSIGNED_INTEGER
  START_BYTE           = 527
```

```
 BYTES                = 2
 UNIT                 = 'MILLIVOLTS'
 MINIMUM              = 0
 MAXIMUM              = 11330
 DESCRIPTION          = "The negative-5-volt voltage monitor
   reading."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = POWER_SUPPLY_CURRENT_MONITOR
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 529
 BYTES                = 2
 UNIT                 = 'MILLIAMPS * 10'
 MINIMUM              = 0
 MAXIMUM              = 8263
 DESCRIPTION          = "The power supply current monitor reading."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = HIGH_VOLTAGE_MONITOR
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 531
 BYTES                = 2
 UNIT                 = 'DECIVOLTS'
 MINIMUM              = 0
 MAXIMUM              = 12349
 DESCRIPTION          = "The high voltage monitor reading."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = MINUS_12_VOLT_CURRENT_MONITOR
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 533
 BYTES                = 2
 UNIT                 = 'MILLIAMPS * 100'
 MINIMUM              = 0
 MAXIMUM              = 24424
 DESCRIPTION          = "The negative-12-volt current monitor
   reading."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = PLUS_12_VOLT_CURRENT_MONITOR
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 535
 BYTES                = 2
 UNIT                 = 'MILLIAMPS * 100'
 MINIMUM              = 0
 MAXIMUM              = 24395
 DESCRIPTION          = "The 12-volt current monitor reading."
END_OBJECT            = COLUMN
```

C.5 Contents of the MOLA PEDRENG3.FMT Format File

```
OBJECT                = COLUMN
```

```
 NAME                 = MINUS_5_VOLT_CURRENT_MONITOR
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 509
 BYTES                = 2
 UNIT                 = 'MILLIAMPS * 100'
 MINIMUM              = 0
 MAXIMUM              = 25199
 DESCRIPTION          = "The negative-5-volt current monitor
   reading."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = PLUS_5_VOLT_CURRENT_MONITOR
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 511
 BYTES                = 2
 UNIT                 = 'MILLIAMPS * 10'
 MINIMUM              = 0
 MAXIMUM              = 13537
 DESCRIPTION          = "The 5-volt current monitor reading."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = CURRENT_STATUS_REGISTER_VALUE
 DATA_TYPE            = UNSIGNED_INTEGER
 START_BYTE           = 513
 BYTES                = 1
 MINIMUM              = 0
 MAXIMUM              = 255
 DESCRIPTION          = "Value read from STATUS register at end of
   packet collection cycle. Read STATUS register and store lower 8
   bits. MSnibble = SEU counter value."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = SOFTWARE_VERSION_NUMBER
 DATA_TYPE            = UNSIGNED_INTEGER
 START_BYTE           = 514
 BYTES                = 1
 MINIMUM              = 0
 MAXIMUM              = 255
 DESCRIPTION          = "The software version number in the telemetry
   packet in 4.4 bit format."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = FLAG_WORD
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 515
 BYTES                = 2
 MINIMUM              = 0
 MAXIMUM              = 65535
 DESCRIPTION          = "RAM block test flag word. Memory test
   results. Bit representation of the results of the RAM write/read/
   verify block test performed after a CPU reset (HOT or COLD start).
   MSB (#15) represents the memory block from 7800h to 7FFFh; LSB
   (#0) from 0000h to 7FFh. 1 = error detected, 0 = block O.K."
END_OBJECT            = COLUMN
```

```
OBJECT              = COLUMN
 NAME               = STATUS_FLAGS
 DATA_TYPE          = MSB_UNSIGNED_INTEGER
 START_BYTE         = 517
 BYTES              = 4
 ITEMS              = 2
 ITEM_BYTES         = 2
 MINIMUM            = 0
 MAXIMUM            = 65535
 DESCRIPTION        = "Values of SFLAG1 and SFLAG2 stored at packet
   completion. Each flag represents four 4 bit words. B[0] = byte 0;
   B[1] = byte 1; B[2] = byte 2; B[3] = byte 3. The meanings of the
   individual bit settings is in Appendix A of the MOLA Flight
   Software Users' Guide."
END_OBJECT          = COLUMN

OBJECT              = COLUMN
 NAME               = SOFTWARE_VALIDITY_CHECKSUM
 DATA_TYPE          = MSB_UNSIGNED_INTEGER
 START_BYTE         = 521
 BYTES              = 2
 MINIMUM            = 0
 MAXIMUM            = 65535
 DESCRIPTION        = "Checksum (end-around-carry, word adds)
   calculated using start address and length from Parameter Table.
   One word calculated using (CHKLEN/2)# of word end-around-carry
   additions start at word # (CHKSTART/2). Note: CHKLEN and CHKSTART
   exist in the parameter table and are BYTE length and BYTE address
   or offset. B[0] is MSByte and B[1] is LSByte of software validity
   checksum."
END_OBJECT          = COLUMN

OBJECT              = COLUMN
 NAME               = RECEIVED_COMMAND_COUNT
 DATA_TYPE          = UNSIGNED_INTEGER
 START_BYTE         = 523
 BYTES              = 1
 MINIMUM            = 0
 MAXIMUM            = 255
 DESCRIPTION        = "Number of commands received in the DMA
   buffer, i.e., number separated by CMD_START bits set, never
   cleared, init = 0. Number of CMD_START bits set in the commands
   received buffer. Only look at the number of commands received
   during that RTI interval. Count performed during RTI 4ms 'quiet
   time'. Counter starts at 0 from a HOT/COLD start, counts up and
   rolls over from 0FFh to 00h."
END_OBJECT          = COLUMN

OBJECT              = COLUMN
 NAME               = COMMAND_ERROR_COUNT
 DATA_TYPE          = UNSIGNED_INTEGER
 START_BYTE         = 524
 BYTES              = 1
 MINIMUM            = 0
 MAXIMUM            = 255
 DESCRIPTION        = "Number of invalid MOLA specific commands
   received, never cleared, init = 0. Command errors counter works
   the same way as Received command count (see above), except, this
   counts the # of command errors, defined as wrong instrument id,
```

```
    wrong command type bit, parity error in 1st word of multi-word
    command, incorrect opcode word (NOT 0x2120) in multi-word
    command, or unknown single-word command."
END_OBJECT             = COLUMN

OBJECT                 = COLUMN
 NAME                  = TRANSMITTER_THRESHOLD_SETTING
 DATA_TYPE             = MSB_UNSIGNED_INTEGER
 START_BYTE            = 525
 BYTES                 = 1
 MINIMUM               = 0
 MAXIMUM               = 255
 DESCRIPTION           = "Value of XMITDA from Parameter table, stored
    at packet completion. LSB is equivalent to 1 mv. This byte reports
    the value of XMITDA from PARAM_TABLE. It is stored in the packet
    at the end of the packet collection cycle."
END_OBJECT             = COLUMN

OBJECT                 = COLUMN
 NAME                  = RANGE_TRACKING_STATUS
 DATA_TYPE             = UNSIGNED_INTEGER
 START_BYTE            = 526
 BYTES                 = 1
 MINIMUM               = 0
 MAXIMUM               = 255
 DESCRIPTION           = "MSB = OTS_FIRE value, bits 7654321, 1 =
    TRACKING, 0 = ACQ. MSB (#7) is the LSB of OST_FIRE from
    PARAM_TABLE, stored at the end of the packet collection cycle. It
    is the value used to determine the firing status of the Optical
    Test Shot for the first shot of the packet cycle. Bits 6-0
    represent frames 7-1 tracking status. 0 means that the software
    was in acquisition mode for that frame, while 1 represents
    tracking mode."
END_OBJECT             = COLUMN

OBJECT                 = COLUMN
 NAME                  = SPARE
 DATA_TYPE             = MSB_UNSIGNED_INTEGER
 START_BYTE            = 527
 BYTES                 = 2
 DESCRIPTION           = "Two unused bytes."
END_OBJECT             = COLUMN

OBJECT                 = COLUMN
 NAME                  = RANGE_GATE_TRACKER_ARRAY
 DATA_TYPE             = MSB_UNSIGNED_INTEGER
 START_BYTE            = 529
 BYTES                 = 8
 ITEMS                 = 4
 ITEM_BYTES            = 2
 MINIMUM               = 0
 MAXIMUM               = 255
 DESCRIPTION           = "The range gate tracker array information is
    actually 48 bytes of data. These 8 bytes represent the first 8 in
    the array. Subsequent bytes appear in Frame 4 and 5 engineering
    data. 73.728 km, 48 HISTOGRAM bins starting at HSTART. 48
    sequential bins of the ranging histogram, stored after the sixth
    shot is collected, but before the ranging algorithm is executed
    on that frame's data. HSTART, from PARAM_TABLE, with the LSB
```

```
   cleared is the number of the first bin stored. Bins are
   represented as bytes, but they are stored as words. Therefore,
   the bytes are swapped. HSTART correction: HSTART = HSTART +
   0xFFFE. The following denotes the range of each bin for each data
   byte (B[x]). C = 1.536km.
    B[ 0] : (HSTART +  1) * C; B[ 1] : (HSTART +  0) * C;
    B[ 2] : (HSTART +  3) * C; B[ 3] : (HSTART +  2) * C;
    B[ 4] : (HSTART +  5) * C; B[ 5] : (HSTART +  4) * C;
    B[ 6] : (HSTART +  7) * C; B[ 7] : (HSTART +  6) * C;
    B[ 8] : (HSTART +  9) * C; B[ 9] : (HSTART +  8) * C;
    B[10] : (HSTART + 11) * C; B[11] : (HSTART + 10) * C;
    B[12] : (HSTART + 13) * C; B[13] : (HSTART + 12) * C;
    B[14] : (HSTART + 15) * C; B[15] : (HSTART + 14) * C;
    B[16] : (HSTART + 17) * C; B[17] : (HSTART + 16) * C;
    B[18] : (HSTART + 19) * C; B[19] : (HSTART + 18) * C;
    B[20] : (HSTART + 21) * C; B[21] : (HSTART + 20) * C;
    B[22] : (HSTART + 23) * C; B[23] : (HSTART + 22) * C;
    B[24] : (HSTART + 25) * C; B[25] : (HSTART + 24) * C;
    B[26] : (HSTART + 27) * C; B[27] : (HSTART + 26) * C;
    B[28] : (HSTART + 29) * C; B[29] : (HSTART + 28) * C;
    B[30] : (HSTART + 31) * C; B[31] : (HSTART + 30) * C;
    B[32] : (HSTART + 33) * C; B[33] : (HSTART + 32) * C;
    B[34] : (HSTART + 35) * C; B[35] : (HSTART + 34) * C;
    B[36] : (HSTART + 37) * C; B[37] : (HSTART + 36) * C;
    B[38] : (HSTART + 39) * C; B[39] : (HSTART + 38) * C;
    B[40] : (HSTART + 41) * C; B[41] : (HSTART + 40) * C;
    B[42] : (HSTART + 43) * C; B[43] : (HSTART + 42) * C;
    B[44] : (HSTART + 45) * C; B[45] : (HSTART + 44) * C;
    B[46] : (HSTART + 47) * C; B[47] : (HSTART + 46) * C"
END_OBJECT              = COLUMN
```

C.6 Contents of the MOLA PEDRENG4.FMT Format File

```
OBJECT                  = COLUMN
 NAME                   = RANGE_GATE_TRACKER_ARRAY
 DATA_TYPE              = MSB_UNSIGNED_INTEGER
 START_BYTE             = 509
 BYTES                  = 28
 ITEMS                  = 14
 ITEM_BYTES             = 2
 MINIMUM                = 0
 MAXIMUM                = 255
 DESCRIPTION            = "The range gate tracker array information is
   actually 48 bytes of data. These 28 bytes represent bytes 9 - 36
   (counting from 1) in the array. Previous and subsequent bytes
   appear in Frame 3 and 5 engineering data, respectively. 73.728
   km, 48 HISTOGRAM bins starting at HSTART. 48 sequential bins of
   the ranging histogram, stored after the sixth shot is collected,
   but before the ranging algorithm is executed on that frame's data.
   HSTART, from PARAM_TABLE, with the LSB cleared is the number of
   the first bin stored. Bins are represented as bytes, but they are
   stored as words. Therefore, the bytes are swapped. HSTART
   correction: HSTART = HSTART + 0xFFFE. The following denotes the
   range of each bin for each data byte (B[x]). C = 1.536km.
    B[ 0] : (HSTART +  1) * C; B[ 1] : (HSTART +  0) * C;
    B[ 2] : (HSTART +  3) * C; B[ 3] : (HSTART +  2) * C;
```

```
   B[ 4] : (HSTART +  5) * C; B[ 5] : (HSTART +  4) * C;
   B[ 6] : (HSTART +  7) * C; B[ 7] : (HSTART +  6) * C;
   B[ 8] : (HSTART +  9) * C; B[ 9] : (HSTART +  8) * C;
   B[10] : (HSTART + 11) * C; B[11] : (HSTART + 10) * C;
   B[12] : (HSTART + 13) * C; B[13] : (HSTART + 12) * C;
   B[14] : (HSTART + 15) * C; B[15] : (HSTART + 14) * C;
   B[16] : (HSTART + 17) * C; B[17] : (HSTART + 16) * C;
   B[18] : (HSTART + 19) * C; B[19] : (HSTART + 18) * C;
   B[20] : (HSTART + 21) * C; B[21] : (HSTART + 20) * C;
   B[22] : (HSTART + 23) * C; B[23] : (HSTART + 22) * C;
   B[24] : (HSTART + 25) * C; B[25] : (HSTART + 24) * C;
   B[26] : (HSTART + 27) * C; B[27] : (HSTART + 26) * C;
   B[28] : (HSTART + 29) * C; B[29] : (HSTART + 28) * C;
   B[30] : (HSTART + 31) * C; B[31] : (HSTART + 30) * C;
   B[32] : (HSTART + 33) * C; B[33] : (HSTART + 32) * C;
   B[34] : (HSTART + 35) * C; B[35] : (HSTART + 34) * C;
   B[36] : (HSTART + 37) * C; B[37] : (HSTART + 36) * C;
   B[38] : (HSTART + 39) * C; B[39] : (HSTART + 38) * C;
   B[40] : (HSTART + 41) * C; B[41] : (HSTART + 40) * C;
   B[42] : (HSTART + 43) * C; B[43] : (HSTART + 42) * C;
   B[44] : (HSTART + 45) * C; B[45] : (HSTART + 44) * C;
   B[46] : (HSTART + 47) * C; B[47] : (HSTART + 46) * C"
END_OBJECT            = COLUMN
```

C.7 Contents of the MOLA PEDRENG5.FMT Format File

```
OBJECT                = COLUMN
 NAME                 = RANGE_GATE_TRACKER_ARRAY
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 509
 BYTES                = 12
 ITEMS                = 6
 ITEM_BYTES           = 2
 MINIMUM              = 0
 MAXIMUM              = 255
 DESCRIPTION          = "The range gate tracker array information is
   actually 48 bytes of data. These 28 bytes represent bytes 37-48
   (counting from 1) in the array. Previous bytes appear in Frame 3
   and 4 engineering data. 73.728 km, 48 HISTOGRAM bins starting at
   HSTART. 48 sequential bins of the ranging histogram, stored after
   the sixth shot is collected, but before the ranging algorithm is
   executed on that frame's data. HSTART, from PARAM_TABLE, with the
   LSB cleared is the number of the first bin stored. Bins are
   represented as bytes, but they are stored as words. Therefore,
   the bytes are swapped. HSTART correction: HSTART =HSTART +
   0xFFFE. The following denotes the range of each bin for each data
   byte (B[x]). C = 1.536km.
   B[ 0] : (HSTART +  1) * C; B[ 1] : (HSTART +  0) * C;
   B[ 2] : (HSTART +  3) * C; B[ 3] : (HSTART +  2) * C;
   B[ 4] : (HSTART +  5) * C; B[ 5] : (HSTART +  4) * C;
   B[ 6] : (HSTART +  7) * C; B[ 7] : (HSTART +  6) * C;
   B[ 8] : (HSTART +  9) * C; B[ 9] : (HSTART +  8) * C;
   B[10] : (HSTART + 11) * C; B[11] : (HSTART + 10) * C;
   B[12] : (HSTART + 13) * C; B[13] : (HSTART + 12) * C;
   B[14] : (HSTART + 15) * C; B[15] : (HSTART + 14) * C;
   B[16] : (HSTART + 17) * C; B[17] : (HSTART + 16) * C;
```

```
   B[18] : (HSTART + 19) * C; B[19] : (HSTART + 18) * C;
   B[20] : (HSTART + 21) * C; B[21] : (HSTART + 20) * C;
   B[22] : (HSTART + 23) * C; B[23] : (HSTART + 22) * C;
   B[24] : (HSTART + 25) * C; B[25] : (HSTART + 24) * C;
   B[26] : (HSTART + 27) * C; B[27] : (HSTART + 26) * C;
   B[28] : (HSTART + 29) * C; B[29] : (HSTART + 28) * C;
   B[30] : (HSTART + 31) * C; B[31] : (HSTART + 30) * C;
   B[32] : (HSTART + 33) * C; B[33] : (HSTART + 32) * C;
   B[34] : (HSTART + 35) * C; B[35] : (HSTART + 34) * C;
   B[36] : (HSTART + 37) * C; B[37] : (HSTART + 36) * C;
   B[38] : (HSTART + 39) * C; B[39] : (HSTART + 38) * C;
   B[40] : (HSTART + 41) * C; B[41] : (HSTART + 40) * C;
   B[42] : (HSTART + 43) * C; B[43] : (HSTART + 42) * C;
   B[44] : (HSTART + 45) * C; B[45] : (HSTART + 44) * C;
   B[46] : (HSTART + 47) * C; B[47] : (HSTART + 46) * C"
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = HSTART_VALUE_HISTOGRAM_DUMP
 DATA_TYPE           = MSB_UNSIGNED_INTEGER
 START_BYTE          = 521
 BYTES               = 4
 MINIMUM             = 0
 MAXIMUM             = 100663296
 UNIT                = CENTIMETERS
 DESCRIPTION         = "Value of HSTART from Parameter table, stored
  at packet completion. Stored at the end of the packet collection
  cycle. HSTART is used to store the Histogram dump bins on the
  previous frame (2 seconds earlier)."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = SPARE
 DATA_TYPE           = MSB_UNSIGNED_INTEGER
 START_BYTE          = 525
 BYTES               = 4
 ITEMS               = 2
 ITEM_BYTES          = 2
 DESCRIPTION         = "Four unused bytes."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = VALID_COMMANDS_RECEIVED_COUNT
 DATA_TYPE           = MSB_UNSIGNED_INTEGER
 START_BYTE          = 529
 BYTES               = 2
 MINIMUM             = 0
 MAXIMUM             = 65535
 DESCRIPTION         = "Number of Time broadcast and Parameter
  update and channel on/off commands executed, never cleared, init.
  = 0. This is a 16 bit counter that starts at 0 after a CPU reset
  and rolls over from 0FFFFh to 0. Valid MOLA specific commands are
  defined as Channel ON/OFF commands and Parameter Update command
  All other MOLA specific commands are either flagged as errors or
  cause a mode change or CPU reset. B[0] = MSByte and B[1] = LSByte
  of valid command counter"
END_OBJECT           = COLUMN

OBJECT               = COLUMN
```

```
 NAME                 = MEMORY_DUMP_SEGMENT
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 531
 BYTES                = 6
 ITEMS                = 3
 ITEM_BYTES           = 2
 MINIMUM              = 0
 MAXIMUM              = 255
 DESCRIPTION          = "The memory dump segment is 16 bytes in
   length. This portion represents the first 6 bytes. The next 10
   bytes are located in the Frame 6 engineering data. 16 bytes read
   from memory space starting at ((SEQUENCE & 0x3FFh)*16), dumps 0
   - 3FFFh then starts again at 0. Using the lower 11 bits of the
   SEQUENCE count, stored in this packet, multiplied by 16 as the
   starting byte address, 8 words are read from RAM and stored in
   the packet. The following denotes the memory address at each data
   byte (B[x]). C =((SEQUENCE & 0x3FFF) *16).
    B[ 0] : C+  1; B[ 1] : C+  0; B[ 2] : C+  3; B[ 3] : C+  2;
    B[ 4] : C+  5; B[ 5] : C+  4; B[ 6] : C+  7; B[ 7] : C+  6;
    B[ 8] : C+  9; B[ 9] : C+  8; B[10] : C+ 11; B[11] : C+ 10;
    B[12] : C+ 13; B[13] : C+ 12; B[14] : C+ 15; B[15] : C+ 14"
END_OBJECT            = COLUMN
```

C.8 Contents of the MOLA PEDRENG6.FMT Format File

```
OBJECT                = COLUMN
 NAME                 = MEMORY_DUMP_SEGMENT
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 509
 BYTES                = 10
 ITEMS                = 5
 ITEM_BYTES           = 2
 MINIMUM              = 0
 MAXIMUM              = 255
 DESCRIPTION          = "The memory dump segment is 16 bytes in
   length. This portion represents the last 10 bytes. The previous
   6 bytes are located in the Frame 5 engineering data. 16 bytes read
   from memory space starting at ((SEQUENCE & 0x3FFh)*16), dumps 0
   - 3FFFh then starts again at 0. Using the lower 11 bits of the
   SEQUENCE count, stored in this packet, multiplied by 16 as the
   starting byte address, 8 words are read from RAM and stored in
   the packet. The following denotes the memory address at each data
   byte (B[x]). C =((SEQUENCE & 0x3FFF) *16).
    B[ 0] : C+  1; B[ 1] : C+  0; B[ 2] : C+  3; B[ 3] : C+  2;
    B[ 4] : C+  5; B[ 5] : C+  4; B[ 6] : C+  7; B[ 7] : C+  6;
    B[ 8] : C+  9; B[ 9] : C+  8; B[10] : C+ 11; B[11] : C+ 10;
    B[12] : C+ 13; B[13] : C+ 12; B[14] : C+ 15; B[15] : C+ 14"
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = COMMAND_ECHO
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 519
 BYTES                = 16
 ITEMS                = 8
 ITEM_BYTES           = 2
```

```
 MINIMUM             = 0
 MAXIMUM             = 65535
 DESCRIPTION         = "First 8 command words received during
   current packet, only complete commands are stored, MOLA specific
   commands only. The software attempts to echo all valid commands.
   If the command will fit in the room remaining in the buffer, then
   it is stored and that much room is removed from that which remains
   in the echo buffer. If a command will not fit, then a buffer
   overflow is flagged, but subsequent commands that will fit are
   still stored in the buffer. The command echo buffer is filled with
   zeros at the start of each packet."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = PACKET_VALIDITY_CHECKSUM
 DATA_TYPE           = MSB_UNSIGNED_INTEGER
 START_BYTE          = 535
 BYTES               = 2
 MINIMUM             = 0
 MAXIMUM             = 65535
 DESCRIPTION         = "Simple 16 bit addition of entire packet
   contents upon completion. This location is zeroed for addition.
   This word is zeroed, then words 0-539 are added without carry to
   a variable that is initially zero. The resulting lower 16 bits
   are stored in this location. To verify, read, store, and clear
   this location. Then, word add without carry these 540 words and
   compare the lower 16 bits with the stored value."
END_OBJECT           = COLUMN
```

C.9 Contents of the MOLA PEDRENG7.FMT Format File

```
OBJECT               = COLUMN
 NAME                = OTS_RANGE
 DATA_TYPE           = MSB_UNSIGNED_INTEGER
 START_BYTE          = 509
 BYTES               = 4
 UNIT                = 'CENTIMETERS'
 DESCRIPTION         = "The range value of the Optical Test Shot in
   the packet."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = FIRST_CH_RECEIVED_ENERGY
 DATA_TYPE           = MSB_UNSIGNED_INTEGER
 START_BYTE          = 513
 BYTES               = 4
 UNIT                = 'ATTOJOULES'
 DESCRIPTION         = "The first channel received energy for the
   Optical Test Shot."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = SPARE
 DATA_TYPE           = MSB_UNSIGNED_INTEGER
 START_BYTE          = 517
 BYTES               = 4
```

```
 DESCRIPTION         = "Unused spare."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = OTS_TRANSMIT_POWER
 DATA_TYPE           = MSB_UNSIGNED_INTEGER
 START_BYTE          = 521
 BYTES               = 4
 UNIT                = 'NANOJOULES'
 DESCRIPTION         = "The Optical Test Shot transmit power."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = OTS_PULSE_WIDTH
 DATA_TYPE           = UNSIGNED_INTEGER
 START_BYTE          = 525
 BYTES               = 1
 DESCRIPTION         = "The Optical Test Shot pulse width setting."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = OTS_PULSE_AMPLITUDE
 DATA_TYPE           = UNSIGNED_INTEGER
 START_BYTE          = 526
 BYTES               = 1
 DESCRIPTION         = "The Optical Test Shot pulse amplitude
   setting."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = OTS_QUAL_FLAG
 DATA_TYPE           = UNSIGNED_INTEGER
 START_BYTE          = 527
 BYTES               = 1
 DESCRIPTION         = "The Optical Test Shot quality flag."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = PACKET_TYPE
 DATA_TYPE           = UNSIGNED_INTEGER
 START_BYTE          = 528
 BYTES               = 1
 DESCRIPTION         = "Packet type identifier byte. Distinguishes
   Science Mode packets from Maintenance Mode packets. Science Mode
   is 0 Maintenance Mode = [1 = Status packet, 2 = memory dump].
   Values 3 - 255 are reserved for future modes. Modes 0, 1, 2 are
   hard coded in the flight software. The packet type value should
   be patched when a code patch occurs that affects that mode's
   packet content."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = AREOCENTRIC_LONGITUDE_OF_SUN
 DATA_TYPE           = MSB_UNSIGNED_INTEGER
 START_BYTE          = 529
 BYTES               = 2
 UNIT                = 'DEGREES * 100'
 MINIMUM             = 0
 MAXIMUM             = 36000
```

```
 DESCRIPTION         = "The angle between the Mars-Sun line and the
   line of the equinoxes. Mars seasonal variable."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = SPARE
 DATA_TYPE           = UNSIGNED_INTEGER
 START_BYTE          = 531
 BYTES               = 6
 ITEMS               = 6
 ITEM_BYTES          = 1
 DESCRIPTION         = "Unused spares."
END_OBJECT           = COLUMN
```

C.10 Contents of the MOLA PEDRSEC3.FMT Format File

```
OBJECT               = COLUMN
 NAME                = ORBIT_QUALITY_FLAG_1
 DATA_TYPE           = MSB_UNSIGNED_INTEGER
 START_BYTE          = 537
 BYTES               = 2
 DESCRIPTION         = "Flag indicating origin of orbit. A 0
   indicates that JPL is the producer; a 1 or higher indicates that
   the MOLA Science Investigation Team is the producer, using the
   geopotential model GMM-1 or higher."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = ORBIT_QUALITY_FLAG_2
 DATA_TYPE           = MSB_UNSIGNED_INTEGER
 START_BYTE          = 539
 BYTES               = 2
 DESCRIPTION         = "Precision orbit quality flag; TBD."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = ORBIT_QUALITY_FLAG_3
 DATA_TYPE           = MSB_UNSIGNED_INTEGER
 START_BYTE          = 541
 BYTES               = 2
 DESCRIPTION         = "Precision orbit quality flag; TBD."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = PHASE_ANGLE
 DATA_TYPE           = MSB_UNSIGNED_INTEGER
 START_BYTE          = 543
 BYTES               = 2
 UNIT                = 'RADIANS * (10**4)'
 DESCRIPTION         = "The angle between the vectors from Mars to
   Mars Global Surveyor and from Mars to the Sun at the frame mid-
   point location."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = SOLAR_INCIDENCE_ANGLE
```

```
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 545
 BYTES                = 2
 UNIT                 = 'RADIANS * (10**4)'
 DESCRIPTION          = "The angle between the Mars surface normal
   vector and the Sun vector at the frame mid-point location."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = EMISSION_ANGLE
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 547
 BYTES                = 2
 UNIT                 = 'RADIANS * (10**4)'
 DESCRIPTION          = "The angle between the Mars surface normal
   vector and the Mars Global Surveyor vector at the frame mid-point
   location."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = ATMOS_OPACITY
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 549
 BYTES                = 4
 DESCRIPTION          = "The Mars atmospheric opacity Tau; may be
   retrieved from TES data. Nominally 0.5. Stored as a pure number
   * 10**6. To calculate surface reflectivity, the reflectivity-
   transmission product should be divided by exp(2*Tau)."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = DP_FRAME_TIME
 DATA_TYPE            = IEEE_REAL
 START_BYTE           = 553
 BYTES                = 8
 UNIT                 = 'SECONDS'
 DESCRIPTION          = "The IEEE standard 754-1985 double precision
   frame mid-point time in elapsed time from J2000, in seconds."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = RECV_PULSE_ENERGY_COUNTS
 DATA_TYPE            = UNSIGNED_INTEGER
 START_BYTE           = 561
 BYTES                = 20
 ITEMS                = 20
 ITEM_BYTES           = 1
 UNIT                 = 'COUNTS'
 DESCRIPTION          = "The raw pulse energy reading for the trigger
   channel; in the range 0-255. (An array of 20 values per frame.)"
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = RECV_PULSE_WIDTH_COUNTS
 DATA_TYPE            = UNSIGNED_INTEGER
 START_BYTE           = 581
 BYTES                = 20
 ITEMS                = 20
 ITEM_BYTES           = 1
```

```
 UNIT                 = 'COUNTS'
 DESCRIPTION          = "The raw pulse width reading for the trigger
   channel; in the range 0-63. (An array of 20 values per frame.)"
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = SC_BODY_FIXED_XYZ
 DATA_TYPE            = MSB_INTEGER
 START_BYTE           = 601
 BYTES                = 12
 ITEMS                = 3
 ITEM_BYTES           = 4
 UNIT                 = 'CENTIMETERS'
 DESCRIPTION          = "The Mars fixed X, Y, Z coordinates of the
   MGS spacecraft; from Precision Orbit data."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = GEOID_RADIUS
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 613
 BYTES                = 4
 UNIT                 = 'CENTIMETERS'
 DESCRIPTION          = "The radius of the reference geoid at frame
   midpoint, with a 3396 kilometer mean radius at the equator.
   Initially, the Goddard Mars Model 1 (GMM1) of Smith et al., 1993,
   with the coordinate system of IAU1991, is used."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = OFF_NADIR_ANGLE
 DATA_TYPE            = MSB_INTEGER
 START_BYTE           = 617
 BYTES                = 4
 UNIT                 = 'DEGREES * (10**6)'
 DESCRIPTION          = "Angle between the actual frame-midpoint
   shot direction and areocentric direction."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = ENCODER_BITS
 DATA_TYPE            = UNSIGNED_INTEGER
 START_BYTE           = 621
 BYTES                = 20
 ITEMS                = 20
 ITEM_BYTES           = 1
 DESCRIPTION          = "The start encoder bits (0-3) plus 16*stop
   encoder bits (0-3) for each MOLA shot. These bits interpolate the
   time of the start and stop detectors, allowing the MOLA shot range
   to  be more precisely computed. The encoder bits are accounted
   for in the shot range algorithm."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = DELTA_GEOID
 DATA_TYPE            = MSB_INTEGER
 START_BYTE           = 641
 BYTES                = 4
 UNIT                 = 'CENTIMETERS'
```

```
 DESCRIPTION          = "The average change in reference geoid
   associated with each 20-shot MOLA frame."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = MOLA_CLOCK_RATE
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 645
 BYTES                = 4
 UNIT                 = 'HERTZ'
 DESCRIPTION          = "The MOLA clock rate estimated from the fine
   time counter drift with respect to the spacecraft clock."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = MOLA_RANGE
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 649
 BYTES                = 80
 ITEMS                = 20
 ITEM_BYTES           = 4
 UNIT                 = 'CENTIMETERS'
 DESCRIPTION          = "MOLA range value per shot; this value is
   corrected by the range_correction. Array of 20 four byte values."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = RANGE_CORRECTION
 DATA_TYPE            = MSB_INTEGER
 START_BYTE           = 729
 BYTES                = 40
 ITEMS                = 20
 ITEM_BYTES           = 2
 UNIT                 = 'CENTIMETERS'
 DESCRIPTION          = "Correction to the shot range values due to
   the detector response and range walk. An array of 20 two-byte
   values (one for each shot), in centimeters."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = DELTA_LATITUDE
 DATA_TYPE            = MSB_INTEGER
 START_BYTE           = 769
 BYTES                = 4
 UNIT                 = 'DEGREES X 1000000'
 DESCRIPTION          = "The average distance between each latitude
   associated with each 20-shot MOLA frame."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = DELTA_LONGITUDE
 DATA_TYPE            = MSB_INTEGER
 START_BYTE           = 773
 BYTES                = 4
 UNIT                 = 'DEGREES X 1000000'
 DESCRIPTION          = "The average distance between each longitude
   associated with each 20-shot MOLA frame."
END_OBJECT            = COLUMN
```