MARS GLOBAL SURVEYOR

Mars Orbiter Laser Altimeter

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

MGS-M-MOLA-3-PEDR-L1A-V1.0

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NASA Goddard Space Flight Center
Greenbelt, MD 20771

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Submitted: ________________________________ __________

Gregory A. Neumann — Date

MOLA Science Team

Concurred: ________________________________ __________

Maria Zuber — Date

MOLA Deputy Principal Investigator

Approved: ________________________________ __________

David E. Smith — Date

MOLA Principal Investigator

MARS ORBITER LASER ALTIMETER
PRECISION EXPERIMENT DATA RECORD
SOFTWARE INTERFACE SPECIFICATION
(MOLA PEDR SIS)

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2/18/00	2.8	Tables 1 and 2; Appendix C	Crossover correction lat_lon replaces flags. Along_track_shift and across_track_shift replace atmospheric opacity. These may be used as indicators of total position accuracy.

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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 day; 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. In the FORTRAN programming language, fixed-length record files may be opened using the keyword access='direct', recl=776, and end-of-file may be detected by the err= keyword in the READ statement.

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-L1A-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 (see below)
- a is the product edition number or letter
- B indicates the file is fixed point, binary.

4.2 Orbit Numbering

On March 9, 1999, the MGS spacecraft entered the Mapping Phase of the mission after spending nearly two years in the Orbit Insertion Phase. The MGS Project reset the orbit count to 1 at the beginning of the Mapping Phase, at the descending equator crossing of actual orbit 1683. Since MOLA had already generated many products during Orbit Insertion with product IDs based on the orbit number, there was a potential problem that the product ID would not be unique if MOLA continued to use the Project orbit number. To ensure a unique product ID, MOLA Mapping Phase products are therefore identified by the Project orbit number plus 10000. For example, a PEDR product containing data acquired starting in Mapping Phase orbit 24 is identified as AP10024a.B.

4.3 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.

4.4 Substructure Definition and Format

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

4.4.1 Header / Trailer Description Details

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

4.4.1.1 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.

4.4.1.2 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$$
```

4.4.1.3 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.

4.4.2 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 mid-point 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.

4.5 Volume, Size, and Frequency Estimates

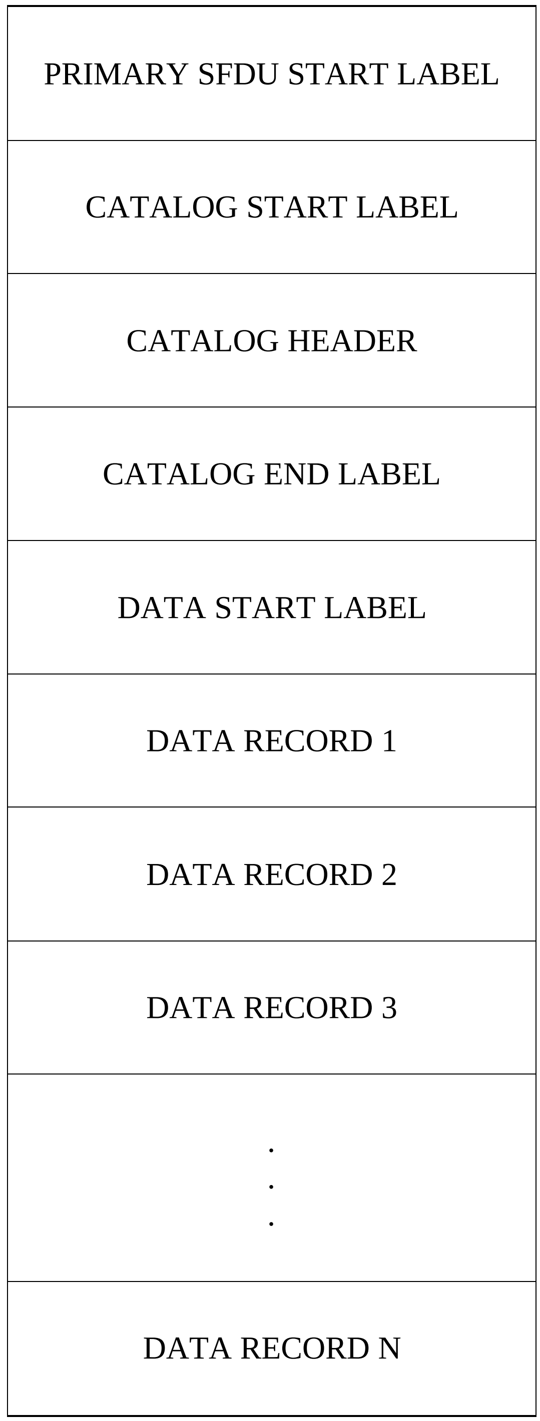
The size of each PEDR data product shall vary depending in the number of science mode packets obtained. The maximum number of science mode packets that could be produced during a day is approximately 6170, therefore the maximum number of PEDRs in a PEDR Data Product would be approximately 43190. Each 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 1 PEDR Data Product shall be produced for each mapping mission day resulting in a daily volume of 33.5 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

Figure 1: PEDR Data Product Structure and Organization



TABLES

Table 1: PEDR Data Product Record Format

Star t 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 of spacecraft	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	8		40
41	crossover correction lat_lon	8		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	parallax delta-latitude	4	degrees * 109m-1	328
329	parallax delta-longitude	4	degrees * 109m-1	332
333	crossover residual	4	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 (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 (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

Star t Byte	Parameter	Bytes	Units	End Byte
487	frame counter	2		488
489	trigger channel	2		490
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	2		538
539	Attitude flag	2		540
541	Frame local time	2	radians * 10^4	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	Along-track shift[b]	4	seconds* 10^5	550
551	Across-track shift[b]	4	seconds* 10^5	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	delta spacecraft latitude	4	degrees * 10^6	604
605	delta spacecraft longitude	4	degrees * 10^6	608
609	delta spacecraft radial distance	4	centimeters	612
613	Areoid radius	4	centimeters	616
617	Off-nadir angle	4	degrees * 10^6	620
621	Encoder bits	20	counts	640
641	delta areoid	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[1] 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 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 areo-centric latitude of spacecraft	4	Degrees * 10^6	MGS Spacecraft areocentric latitude, in IAU1991 coordinates, associated with MOLA data frame mid-point; from Precision Orbit data
- frame mid-point areo-centric longitude	4	Degrees * 10^6	MGS Spacecraft east longitude, in IAU1991 coordinates, 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 20Ð 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

[1] The phrase 'frame mid-point' is used to denote the transmit time of shot 10.5, a point midway between the 10th and 11th shots in the set of 20 laser shots in a MOLA frame.

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
parallax delta-latitude	4	degrees * 109m-1	change in latitude with respect to planetary radius at frame midpoint due to parallax
parallax delta-longitude	4	degrees * 109m-1	change in longitude with respect to planetary radius at frame midpoint due to parallax
crossover residual	4	Centimeters	Crossover residual of planetary radius with respect to MOLA database at frame midpoint
- frame mid-point latitude, longitude	8	Degrees * 106	The areocentric latitude and the East longitude, in IAU1991 coordinates, of the intersection point between the frame mid-point shot and the Mars surface; from Precision Orbit data; 2 4-byte values
- laser transmit power	40	mJ * 100	MOLA laser transmitted pulse energy, corrected for detector and heat sink temperatures, 20 2-byte values

Parameter	Bytes	Units	Description
- shot classification code	40		shot classification and weighting codes: 0 denotes a false return or no trigger; 1 denotes a ground 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
- orbit quality flag	2		Flag indicating origin of orbit. 0 indicates JPL NAV team was producer; 1 or higher indicates the MOLA Science Team reference gravity model number.
- attitude flag	2		Flag to indicate spacecraft attitude information was missing for this frame. Set to 2 if attitude information was missing for part of the frame; 3 if missing for entire frame; otherwise 0.
- frame local time	2	radians * 10^4	The subsolar longitude on Mars, -Pi to Pi.
- phase angle	2	radians * 10^4	The angle between the vectors from Mars to Mars

Parameter	Bytes	Units	Description
			Global Surveyor and from Mars to the Sun at the frame mid-point location
- solar incidence angle	2	radians * 10^4	The angle between the Mars surface normal vector and the Sun vector at the frame mid-point location
- emission angle	2	radians * 10^4	The angle between the Mars surface normal vector and the Mars Global Surveyor vector at the frame mid-point location
- along-track shift[b]	2	seconds * 10^5	Empirical adjustment of frame mid-point on ground in the along-track direction from crossover analysis
- across-track shift[b]	2	seconds * 10^5	Empirical adjustment of frame mid-point on ground in the across-track direction (90º ccw from along-track)
- double precision frame mid-point time	8	seconds	The frame mid-point time represented in IEEE standard double precision; ET seconds from 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
delta spacecraft latitude	4	Degrees * 10^6	The average change in spacecraft areocentric latitude associated with each 20-shot MOLA frame
delta spacecraft longitude	4	Degrees * 106	The average change in spacecraft areocentric longitude associated with each 20-shot MOLA frame
delta spacecraft radius	4	Centimeters	The average change in spacecraft areocentric radius associated with each 20-shot MOLA frame
- Areoid radius	4	Centimeters	The radius of the reference areoid with 3396 kilometer mean equatorial radius, determined from the GMM-1 or more recent potential model of degree and order 70
- Off-nadir angle	4	Degrees * 106	Angle between the transmitted laser shot direction and areocentric direction, at spacecraft frame mid-point
- 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 areoid	4	centimeters	The average change in areoid 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 one-way range value per shot; the raw MOLA time-of-flight range plus 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
- delta longitude	4	Degrees * 10^6	The average distance between each areocentric longitude associated with each 20-shot MOLA frame
TOTAL:	776		

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

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

325	frame mid-point coordinates (x,y,z)	12	centimeters	336

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325	frame mid-point coordinates (x,y,z)	12	centimeters	336

325	frame mid-point coordinates (x,y,z)	12	centimeters	336

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
IAU1991	Report of the IAU/IAG/COSPAR Working Group on Cartographic Coordinates and Rotational Elements of the Planets and Satellites, Buenos Aires, 1991.
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 Ori ented Information Kernels
OTS	Optical Test Source
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 MOLA PEDR 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            = 'AP00003K.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-L1A-V1.0'
PRODUCT_ID           = 'MOLA-AP00003K.B'
SPACECRAFT_NAME      = 'MARS_GLOBAL_SURVEYOR'
INSTRUMENT_ID        = 'MOLA'
INSTRUMENT_NAME      = 'MARS_ORBITER_LASER_ALTIMETER'
TARGET_NAME          = 'MARS'
SOFTWARE_NAME        = 'PREC_PP_7.20'
UPLOAD_ID            = 'SM-7.6'
SOURCE_PRODUCT_ID    = {"MOLA-AA00003F.B","MOLA-APPLCT01.T",
  "","","","","",""}
PRODUCT_RELEASE_DATE = 1998-141
START_TIME           = 1997-258T19:10:00.000
STOP_TIME            = 1997-258T19:45:00.000
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   = 'ORBIT INSERTION'
ORBIT_NUMBER         = 00003
PRODUCT_VERSION_TYPE = {"R007-CALIBRATED REL.","O000003 - ORBIT
   3",
  "P007-CALIBRATED REL.","E007-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               = 73
 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               = 73
 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               = 72
 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             = 60
 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             = 64
 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             = 62
 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             = 68
 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              = "Frame mid-point time whole seconds. The
   integer represents the whole portion of the Ephemeris Time (in
   number of seconds) past J2000."
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 Ephemeris Time (in number of
   microseconds) past J2000."
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, IAU1991, of the
   MOLA data frame mid-point of the Mars Global Surveyor
   spacecraft center of mass. Obtained from the MOLA Science
   Investigation Team precision orbit data."
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, IAU1991, of the MOLA
  data frame mid-point of the Mars Global Surveyor spacecraft
  center of mass. Obtained from the MOLA Science Investigation
  Team precision orbit data."
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. 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. 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."

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
   full 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 full 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 full 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 full 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 full
   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 full
   description."
 END_OBJECT            = BIT_COLUMN

 END_OBJECT            = COLUMN

 OBJECT                = COLUMN
  NAME                 = CROSSOVER_CORRECTION_LAT_LON
  DATA_TYPE            = MSB_UNSIGNED_INTEGER
  START_BYTE           = 41
  BYTES                = 8
  ITEMS                = 2
  ITEM_BYTES           = 4
  UNIT                 = 'DEGREES *(10**6)'
  DESCRIPTION          = "Array of 2 correction values that were
```

```
  added to the FRAME_LAT_LON values to account for systematic
  crossover mismatch."
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 Mars center of mass 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 Mars center of mass to
  the point on the surface of Mars described by the frame mid-
  point range. Obtained from a weighted fit to the valid
  observations in the data frame."
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                = PARALLAX_DELTA_LATITUDE
 DATA_TYPE           = MSB_INTEGER
 START_BYTE          = 325
 BYTES               = 4
 ITEMS               = 1
 UNIT                = 'DEGREES*(10**9) PER METER'
 DESCRIPTION         = "Change in latitude with respect to
   planetary radius at frame midpoint due to parallax."
END_OBJECT           = COLUMN

OBJECT               = COLUMN
 NAME                = PARALLAX_DELTA_LONGITUDE
 DATA_TYPE           = MSB_INTEGER
 START_BYTE          = 329
 BYTES               = 4
 UNIT                = 'DEGREES*(10**9) PER METER'
 DESCRIPTION         = "Change in longitude with respect to
   planetary radius at frame midpoint due to parallax."
END_OBJECT           = COLUMN
```

```
OBJECT                = COLUMN
 NAME                 = CROSSOVER_RESIDUAL
 DATA_TYPE            = MSB_INTEGER
 START_BYTE           = 333
 BYTES                = 4
 UNIT                 = 'CENTIMETERS'
 DESCRIPTION          = "Crossover residual of planetary radius
  with respect to MOLA Science Team database at frame midpoint.
  May be added to planetary radius to correct for radial orbit
  error."
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, IAU1991, 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_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 values
  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 two-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_SIGNED_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_SIGNED_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_SIGNED_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_SIGNED_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_SIGNED_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_SIGNED_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_SIGNED_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_SIGNED_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_SIGNED_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_SIGNED_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_SIGNED_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_SIGNED_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_SIGNED_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_SIGNED_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_SIGNED_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_SIGNED_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
 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 potential model GMM-1 or higher."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = ATTITUDE_FLAG
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 539
 BYTES                = 2
 DESCRIPTION          = "Flag indicating spacecraft attitude data
   was not available for all (3) or part (2) of a MOLA frame, in
   which case ground location is calculated assuming nadir-
   pointing geometry."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = FRAME_LOCAL_TIME
 DATA_TYPE            = MSB_INTEGER
 START_BYTE           = 541
 BYTES                = 2
 UNIT                 = 'RADIANS * (10**4)'
 DESCRIPTION          = "The subsolar longitude on Mars at the
   frame mid-point, in the range from -Pi to Pi."
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                  = DELTA_SC_LATITUDE
 DATA_TYPE             = MSB_INTEGER
 START_BYTE            = 601
 BYTES                 = 4
 UNIT                  = 'DEGREES*(10**6)'
 DESCRIPTION           = "The average change in spacecraft
   areocentric latitude associated with each 20-shot MOLA frame."
END_OBJECT             = COLUMN

OBJECT                 = COLUMN
 NAME                  = DELTA_SC_LONGITUDE
 DATA_TYPE             = MSB_INTEGER
 START_BYTE            = 605
 BYTES                 = 4
 UNIT                  = 'DEGREES*(10**6)'
 DESCRIPTION           = "The average change in spacecraft
   areocentric longitude associated with each 20-shot MOLA frame."
END_OBJECT             = COLUMN

OBJECT                 = COLUMN
 NAME                  = DELTA_SC_RADIUS
 DATA_TYPE             = MSB_INTEGER
 START_BYTE            = 609
 BYTES                 = 4
 UNIT                  = 'CENTIMETERS'
 DESCRIPTION           = "The average change in spacecraft radial
   distance associated with each 20-shot MOLA frame."
END_OBJECT             = COLUMN
```

```
OBJECT                = COLUMN
 NAME                 = AREOID_RADIUS
 DATA_TYPE            = MSB_UNSIGNED_INTEGER
 START_BYTE           = 613
 BYTES                = 4
 UNIT                 = 'CENTIMETERS'
 DESCRIPTION          = "The radius of the reference areoid 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 transmitted laser shot
   direction and areocentric direction, at spacecraft frame mid-
   point."
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 to improve shot range
   precision."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = DELTA_AREOID
 DATA_TYPE            = MSB_INTEGER
 START_BYTE           = 641
 BYTES                = 4
 UNIT                 = 'CENTIMETERS'
 DESCRIPTION          = "The average change in reference areoid
   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. Array of 20 two-byte values."
END_OBJECT            = COLUMN

OBJECT                = COLUMN
 NAME                 = DELTA_LATITUDE
 DATA_TYPE            = MSB_INTEGER
 START_BYTE           = 769
 BYTES                = 4
 UNIT                 = 'DEGREES *(10**6)'
 DESCRIPTION          = "The average change in 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 *(10**6)'
 DESCRIPTION            = "The average change in longitude
   associated with each 20-shot MOLA frame."
END_OBJECT              = COLUMN
```