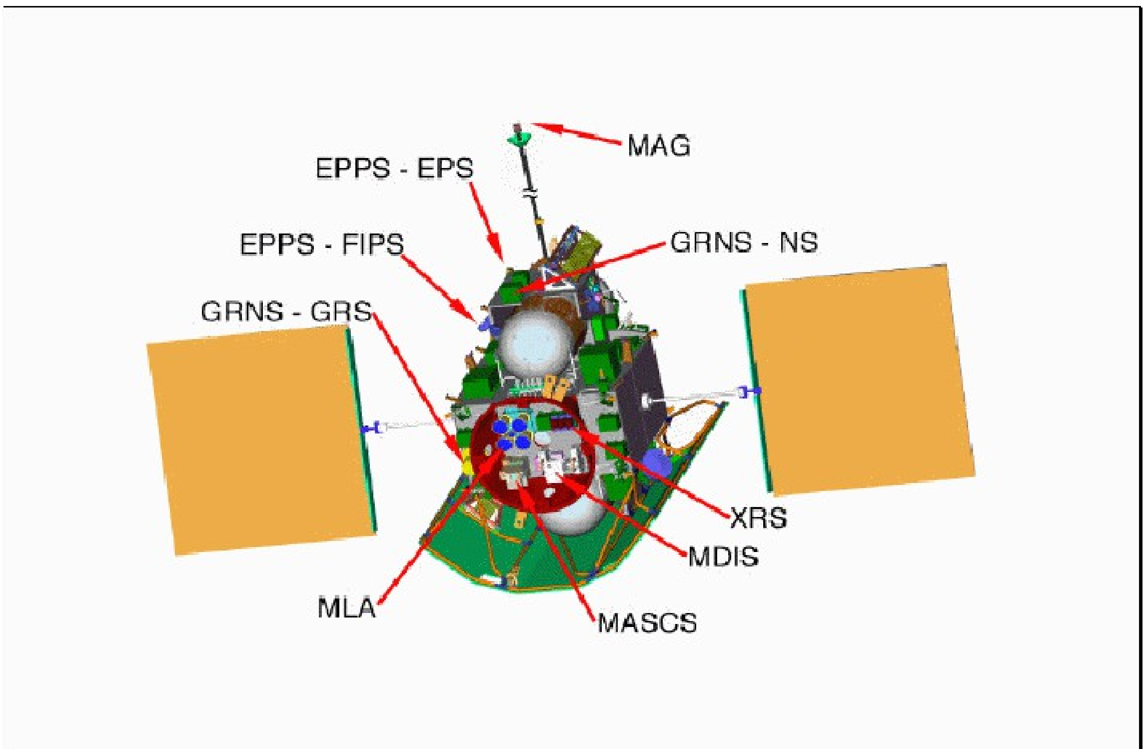
MESSENGER:
Software Interface Specification
For The
Mercury Laser Altimeter
Calibrated, Reduced and Gridded Data Records

Revision 6.01



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March 16, 2017

Document Review

This document and the archive it describes have been through PDS Peer Review and have been accepted into the PDS archive.

Gregory Neumann, MESSENGER MLA Scientist, has reviewed and approved this document.

Susan Slavney, PDS Geosciences Node Representative, has reviewed and approved this document.

Susan Ensor, MESSENGER Science Operations Center Lead, has reviewed and approved this document.

CHANGE LOG

DATE	SECTIONS CHANGED	REASON FOR CHANGE	REVISION
03/01/09	Various	Peer Review	4.00
11/10/09	5.4.3	Cartographic Coordinate Systems section added	5.10
12/18/09	06/06/08	1. Added Document Change History table. 2. Removed duplicate table of contents. 3. Appendices: moved "PDS_VERSION_ID" down one line. 4. DOCUMENT directory section: changed "documents are stored in PDF and HTML format" to indicate TXT format.	5.20

		5. CATALOG directory: "INSTRUMENT_HOST.CAT" changed to "INSTHOST.CAT"; "INSTRUMENT.CAT" changed to "MLAINST.CAT; added PERSON.CAT 6. INDEX directory: Added MD5.TAB; removed non-existent columns from INDEX Table Contents section 1.	
04/11/11	Various	Revision, RDR and GDR sample labels added	5.13
06/17/11	Signature page Change Log table	1. Replace signature page with document review information. 2. Resized columns in this table, moved revision 4 entry to proper place in table.	5.14
11/11/11	All	Fixed formatting. (M. Reid, JHU/APL)	5.15
04/04/12	Appendices	Mission Phase name, HDEM product names, data quality flag in RDR label	5.16
06/01/12	Appendices, 6.2, 6.7	Radiometry Product Description	5.17
06/03/12	2, 7	1. Change app. doc. 2 name from "Data Management and Science Analysis Plan"	5.18

		to "Data Management and Archiving Plan" and update references to it. 2. 2. Replace PDS release schedule with reference to schedule in Data Management and Archiving Plan.	
06/06/12	Fixed diagram Fig. 1	Formatting	5.19
06/13/12	All	Added page numbers, section numbers, fixed table of contents, added missing spacecraft diagrams.	5.20
06/14/12	5.2 6.4	Fixed GDR DATA_SET_ID	5.21
06/14/12	8.4 8.5 8.6 8.10	Updated RDR altimetric data label. Updated RADR label. Added GDR label. Updated MLASCIRDR.FMT.	5.22
10/08/12	6.5	Updated section to accommodate PDS liens	
10/15/12	8 Appendix	Replaced labels and fmt files with revised versions	5.24
10/18/12	6.6	Added an EXTRAS and BROWSE image directories and browse images.	5.25
01/15/13	6.5, 8 Appendix	Fixed formatting, editing for clarification; updated labels and format files.	5.26
01/18/13	5.1	kj: Edited to clarify orbit; mr: deleted TBD Items table. General edits.	5.27

02/08/13	6.6	Listed items in the DOCUMENT directory.	5.28
12/12/13	2, 5.2.3	Updated list of “Applicable Documents” and proper references to calibration materials	5.29
12/23/13	2, 5.1, 5.2	Formatting and corrected error relating to spacecraft orbital inclination. Ref. to calibration document.	5.30
12/01/14	8.4, 8.11	Added STARTPLS_WIDTH field to MLASCIRDR products in sample label and format files.	5.40
04/07/16	Various	Updated for coordinate system, final product generation, end game, RDR and RADR format.	5.50
04/21/16	Various	Updates to reflect the end of the mission and general edits. Revised labels and FMT files.	5.57
04/26/16	8.12	Restored MLASCIRDR.FMT file to indicate that the SAT_ALTITUDE is referenced to the 2440 km planetary radius. Changed reference for a document.	5.57
03/16/17	6.6, Various	Added a section (6.6) about the reprocessed RDR & GDR products, the creation of a new version of the data sets, and the GSFC/MLA SPK. Multiple small edits in other sections.	6.01

Table of Contents

1 Purpose and Scope of Document

1.1 Purpose

This document describes the higher level data products generated from the MLA instrument telemetry. These products are formatted and organized to facilitate access to the instrument data by scientists and the public. The Committee on Data Management and Computation (CODMAC) has defined levels of data products as described in Appendix 8.13. The MLA Experiment Data Records (EDR) are the CODMAC Level 2 products, while the Calibrated Data Records (CDR), Reduced Data Records (RDR) and Radiometric Active Data Records (RADR) are higher level (calibrated, edited) products. The MLA Hardware EDR, Status EDR, and raw Science EDR are the source input to producing the Hardware and Status CDRs. The Science CDR, combined with the SPICE-format geometry and timing information derived from the spacecraft telemetry and radio tracking, is the source for the generation of the Science RDR and Gridded Data Record (GDR) products. The CDR, RDR, and GDR products are calibrated to scientific and engineering units. They provide altimetric profiles, laser pulse measurements, and instrument housekeeping for scientific and engineering purposes. Time-of-flight data are merged with the Spacecraft, Planet, Instrument, C-matrix Events (SPICE) archives. These provide instrument orientation, spacecraft orbit position and pointing, timing, planetary orientation and ephemerides to locate the Mercury Laser Altimeter (MLA) ranges in a planet-fixed, center-of-mass coordinate system. The merged data are aggregated into the CODMAC Level 4 RDR. The RDR is the primary altimeter science data product, from which resampled topographic models may be obtained. These models, and representations of these models by means of spherical harmonic expansions and other basis functions, constitute the Level 5 GDR data products. Active measurements of surface albedo and roughness may be derived from the RDR, as well as more precise models of spacecraft trajectory, planetary gravity, and libration.

This document serves to provide users of the MESSENGER MLA CDR, RDR, RADR, and GDR data products with a detailed description of MLA product generation, validation, and storage. The MLA data products are deliverables to the Planetary Data System (PDS) and the scientific community that it supports. All data formats are based on the PDS standard. This document is a Data Product Software Interface Specification, or SIS. The description of the MLA archive volume is contained in section 6.5 of this document rather than in a separate Archive Volume SIS.

1.2 Scope

The CDR/RDR/RADR/GDR Software Interface Specification (SIS) document is intended for general use by data analysts outside of the MESSENGER project and is intended to enable the typical science user to access the products routinely. The CDRs, RDRs, and RADRs are accessible as ASCII tables so as to be readable without regard to computer system and require no additional software for decoding. GDRs are stored as binary image arrays readable with standard image processing software.

2 Applicable Documents

The MESSENGER MLA SIS is consistent with the following Documents:

1. Planetary Data System Standards Reference, February 27, 2009, Version 3.8. JPL D-7669, Part-2
2. MESSENGER Data Management and Archiving Plan, The Johns Hopkins University,

APL, http://pds-geosciences.wustl.edu/missions/messenger/
3. MESSENGER Mercury: Surface, Space Environment, Geochemistry, Ranging; A mission to Orbit and Explore the Planet Mercury, Concept Study, March 1999. Document ID number FG632/99-0479
4. Sun, X., and G. A. Neumann, Calibration of the Mercury Laser Altimeter on the MESSENGER Spacecraft, IEEE Transactions on Geoscience and Remote Sensing, Vol. 53, Issue 5, pp. 2860-2874, doi:10.1109/TGRS.2014.2366080, 2015. [SUN&NEUMANN2014]
5. MESSENGER mission overview, Sean C. Solomon, Ralph L. McNutt, Jr., Robert E. Gold, Deborah L. Domingue, *Space Science Reviews*, **131**, 3-39, 2007
6. The Mercury Laser Altimeter Instrument for the MESSENGER Mission, John F. Cavanaugh, James C. Smith, Xiaoli Sun, Arlin E. Bartels, Luis Ramos-Izquierdo, Danny J. Krebs, Anne Marie Novo-Gradac, Jan F. McGarry, Raymond Trunzo, Anne Marie Novo-Gradac, Jamie L. Britt, Jerry Karsh, Richard B. Katz, Alan Lukemire, Richard Szymkiewicz, Daniel L. Berry, Joseph P. Swinski, Gregory A. Neumann, David E. Smith, Maria T. Zuber, and David E. Smith, *Space Sciences Reviews*, **131**, 1-4, 10.1007/s11214-007-9273-4, 451-479, 2007.
7. Bright and dark polar deposits on Mercury: Evidence for surface volatiles, G. A. Neumann, J. F. Cavanaugh, X. Sun, E. Mazarico, D. E. Smith, M. T. Zuber, D. Mao, D. A. Paige, S. C. Solomon, C. M. Ernst, and O. S. Barnouin, *Science*, **339**, 296-300, 2013
8. [PLR] Appendix 7 to the Discovery Program Plan; Program Level Requirement for the MESSENGER Discovery Project; June 20, 2001.
9. MESSENGER: Software Interface Specification For The Mercury Laser Altimeter Experiment Data Record, July 2015.

3 Relationships with Other Interfaces

The MLA data products are stored at the MESSENGER Science Operations Center at the Johns Hopkins University Applied Physics Laboratory (JHU/APL) for rapid access during mission operations. The data products are electronically transferred to the PDS Geosciences Node according to the delivery schedule in the MESSENGER Data Management and Archiving Plan (Applicable Document 2).

4 Roles and Responsibilities

The roles and responsibilities of the MLA instrument team, Applied Physics Lab (APL), Applied Coherent Technology (ACT), and the Planetary Data System (PDS), are defined in the MESSENGER Data Management and Archiving Plan (Applicable Document 2).

5 Data Product Characteristics and Environment

5.1 Overview

MESSENGER stands for MErcury Surface, Space ENvironment, Geochemistry, and Ranging. It is a scientific spacecraft designed to aid in the study of the planet Mercury. It is the first mission to go to Mercury since Mariner 10 in 1975. MESSENGER's orbit about Mercury was highly elliptical, passing 200 km above the surface at its lowest point (periherm) and more than 15,000 km at its highest point (apoherm). Periherm altitude varied from 200 km to 505 km in the orbital portion of the primary mission (March 18, 2011 – March 17, 2012) and somewhat less in the extended mission (XM, March 18, 2012 – March 17, 2013) (230 to 412). During the mission endgame, spacecraft periherm altitude descended below 15 km and was raised to avoid impact by a series of propulsive Orbit Correction Maneuvers (OCM-10 to OCM-19) over the space of seven months until all propellant was exhausted and the spacecraft impacted the surface of Mercury as expected on April 30, 2015, concluding the second extended mission (XM2). The range to the southern hemisphere usually exceeded the 1800-km maximum range of the MLA instrument. The working range varied with laser energy, surface characteristics, and incidence/emission angle and was usually limited to 800 to 1200 km, depending on geometry and instrument status. See SOLOMONETAL2007 for a description of orbital ellipticity and mission design.

The plane of the MESSENGER spacecraft orbit was inclined 83 degrees to Mercury's equatorial plane and the low point in the orbit was reached initially at latitude 60° N. Orbit inclination varied from 82.85°N to 83.96°N in the primary mission and 84.04° N latitude in XM with minor oscillations driven by perturbations. Owing to solar gravitational perturbations the periherm latitude precessed over the north pole and reached latitude 60 deg. N again on the descending track during the final weeks of the mission. MESSENGER's first 12 months in orbit covered 2 Mercurian solar days. Because Mercury's rotation period (~58 Earth days) is two thirds of its revolution period around the Sun (~88 Earth days), the solar day, from sunrise to sunrise, is equal to ~176 Earth days. The first solar day of orbital operations was focused on obtaining global map products from the different instruments, and the second focused mainly on targeted science investigations. The first extended mission provided an additional two Mercurian solar days of operations focused mainly on targeted science investigations. At different times during Mercury's solar orbit, the Sun, Mercury, and MESSENGER were in different configurations, necessitating different observing strategies. The second extended mission provided an additional four Mercurian solar days of operations.

MESSENGER's primary mission had a 12-hour orbit of which approximately 25-50 minutes were dedicated to MLA science, depending on Sunshade Keep-In (SKI) constraints. On April 17th and 20th, 2012, propulsive maneuvers reduced the orbital period to 8 hours. During a nominal orbit, the planet was within range for 35-50 minutes, although restrictions on pointing the spacecraft toward the Sun could limit the period of collection to less than 20 minutes. Approximately 15 minutes prior to taking science data, the MLA instrument was put into standby mode. The laser electronics and range measurement unit were powered on at the start of this mode and time was provided to allow the electronics and laser bench to warm up. Standby mode used less power than science mode because the laser was generally not firing. Hardware Diagnostic packets could be generated in Standby mode. When the planet was within 1800 km range, the MLA was put into Science mode, and the laser commenced firing within the minute. The science algorithms configured the electronics and generated Science raw telemetry packets. Hardware packets were not generated in Science mode, while Status packets continued to be output at more frequent intervals. The length of the Science mode varied during the course of Mercury's orbit about the Sun and the temperature of the instrument rose as it crossed the sunlit face of Mercury, in some cases approaching its highest working limits. For the remaining hours of the orbit MLA was in Keep Alive mode, during which time the instrument radiated heat into space and cooled down. This was a low power mode in which the analog and laser electronics were powered off and only Status packets were generated.

During the extended mission phases, the orbital period was 8 hours and operations were similar with more orbits devoted to targeted observations. MLA operated nominally on each orbit where attitude permitted, subject to SKI and other operational constraints. More information on the mission phases is provided in Appendix 8 and the MISSION.CAT.

The MLA was used to calculate the range between the spacecraft and Mercury's surface. The transmitter generated a brief laser pulse and the instrument measured the time required for the light to reach the surface and return. The time-of-flight measurements were used to make accurate determinations of Mercury's shape and determine its rotational dynamics. These shape and kinematics measurements, when combined with analyses of the very precisely tracked spacecraft orbit around Mercury, yield information on its internal density structure. More information on the MLA instrument is provided in the Appendix – MLA Instrument Overview.

5.2 Data Product Overview

The MLA Level 3 and 4 products are grouped together into one data set, MESS-E/V/H-MLA-3/4-CDR/RDR-DATA-V1.0. Within that data set there are three CDR data products (Science CDR, Status CDR, and Hardware Diagnostic Lite CDR), a Science RDR data product, and a Radiometric Active Data Record (RADR) product. The Level 5 Gridded Data Records (GDR) are grouped into a separate data set, MESS-E/V/H-MLA-4-GDR-V1.0. See *Sun and Neumann, 2013* for a description of calibration.

Each MLA data product consists of two files. One contains the data itself, and is arranged in a PDS compliant table or image file. The other is a PDS label file that describes the content of the data file. GDR JPEG 2000 products have a third accompanying XML file that contains image metadata. The label file defines the start and end times of the observation, product creation time, etc. The label file may also contains a pointer to a format file that describes the different fields within the data table.

During the Mercury Orbit mission phases a single CDR, RDR, or RADR data file contains the observations obtained in one orbit of the spacecraft around Mercury. Prior to the Mercury Orbit mission phases a single CDR, RDR, or RADR data file aggregates the observations such that all data within the file are taken on the same year, month, day, and hour. The CDR, RDR, RADR, and GDR data products are described as follows:

5.2.1 Science CDR

The Calibrated Data Record contains the ranging time-of-flight and ancillary information as collected by the instrument in "Science" mode, as a set of eight time-ordered records per 1-s telemetry packet, for a nominal rate of 8 Hz. The values have been calibrated or converted into physical and engineering units. Up to 10 triggers on one of three filter channels may be associated with a given laser fire, as well as one trigger on channel 1 at a higher trigger threshold. Some or all of these triggers may be noise from sources other than the laser pulse itself. For each of the triggers, a channel identifier, leading edge time, and pulse width at the detection threshold are recorded.

5.2.2 Science RDR

The time-of-flight data are merged with the Spacecraft, Planet, Instrument, C-matrix and Events (SPICE) archives of instrument orientation, spacecraft orbit position and pointing, timing, planetary orientation and ephemerides to locate the Mercury Laser Altimeter (MLA) ranges in a planet-fixed (planetocentric), center-of-mass coordinate system as well as inertial coordinates tied to a celestial frame. One or more records are generated for each laser shot due to noise concerns. The orbit position is a joint product of the Laser Altimeter and Radio Science investigations, based primarily on radio tracking of the MESSENGER spacecraft. To facilitate analysis of the planetary rotational dynamics, extraneous (noise) returns collected within the range of a laser shot, if any, are flagged, and where appropriate, derived quantities regarding the laser pulse returns are provided.

5.2.3 Radiometric Active Data Record (RADR)

The active radiometric measurement consists of time-ordered, geolocated, 1064-nm geometric albedo at zero phase and ancillary data, derived from energy measurements inferred from pairs of laser returns via the lidar link equation. The radiometry is available for a subset of ground detections where sufficient link provides detections on multiple thresholds and enables a differential analysis of return signal strength. Such measurements are of particular interest in the persistently or permanently shadowed polar craters, where the very low surface and near-surface temperatures act as cold traps for volatiles. References to relevant papers in peer-reviewed journals are provided in REF.CAT, in particular the Supporting Online Information in NEUMANNETAL2013.

5.2.4 Status (STATUS) CDR

The Status CDR contains the instrument status information, such as voltages, temperatures, and timing parameters. Status records are customarily output at intervals of 16 to 60 seconds. The measurements and status flags are stored in the CDR as original telemetry counts. The Status CDR also contains engineering values in the appropriate units.

5.2.5 Hardware Diagnostic Lite (HAD) CDR

The HAD CDR contains diagnostic information about the instrument and background brightness information from the detector at 8 Hz resolution. It is designated as “Lite” because the “full” version of the packet, which contains more diagnostic fields, cannot be utilized during the course of the mission due to bandwidth limitations. The CDR product contains the original telemetry counts as well as the engineering values in the appropriate units.

5.2.6 Topographic (TOPO) GDR

The GDR contains the binned, interpolated planetary shape (or elevation with respect to a reference spherical datum) at the appropriate sampling intervals. Coverage of the northern hemisphere reaches a density of approximately 64 pixels per degree in latitude and somewhat less in longitude, corresponding to 0.66 km at the equator, with sparse coverage obtained for several hundred kilometers south of the equator. These data are augmented with planetary occultations to produce a global Digital Elevation Model (DEM) in cylindrical equidistant coordinates that is transformed to spherical harmonic coefficients and archived at the PDS in the Radio Science volume as the SHADR product (PDS data set MESS-H-RSS/MLA-5-SDP-V1.0). A planetocentric, east-positive (right-handed) coordinate system is employed, in contrast to older planetographic coordinates using west-positive longitudes. Where the polar coverage reaches sufficient density, stereographic projections are used to interpolate data at higher resolution. The values are scaled from meters to integers and represented in a PDS compatible binary image format.

5.3 Data Processing

5.3.1 Data Processing Level

The CDR/RDR/RADR/GDR Data Archive for the MLA instrument contain Level 3 and higher data products. Each product has a unique file name and conforms to the file naming convention in section 6.5. All CDR/RDR/RADR/GDR products are stored at the Applied Physics Laboratory/Science Operations Center (APL/SOC) during mission operations. Volumes are electronically transferred to the PDS Geosciences Node following the procedure in section 5.3.3.

5.3.2 Data Product Generation

The MLA CDR/RDR/RADR/GDR files are produced by the MLA Science Team at the NASA Goddard Space Flight Center (GSFC). Inputs to the CDR/RDR/RADR/GDR consist of Experiment Data Records. Level 2 CODMAC data are extracted from the spacecraft telemetry and stored online at the SOC facility. Software ingests the Level 2 CODMAC data in the PDS format defined in the EDR SIS, applies calibrations, and outputs Level 2 and 3 tables (section 6.2). The CDR data products are made available to the MESSENGER Science Team for initial evaluation and validation. At the end of the evaluation and validation period, the data are organized and stored in the directory structure described in section 6.6 for transmittal to the Geosciences Node. The transmittal process is described in section 5.3.3, Data Flow.

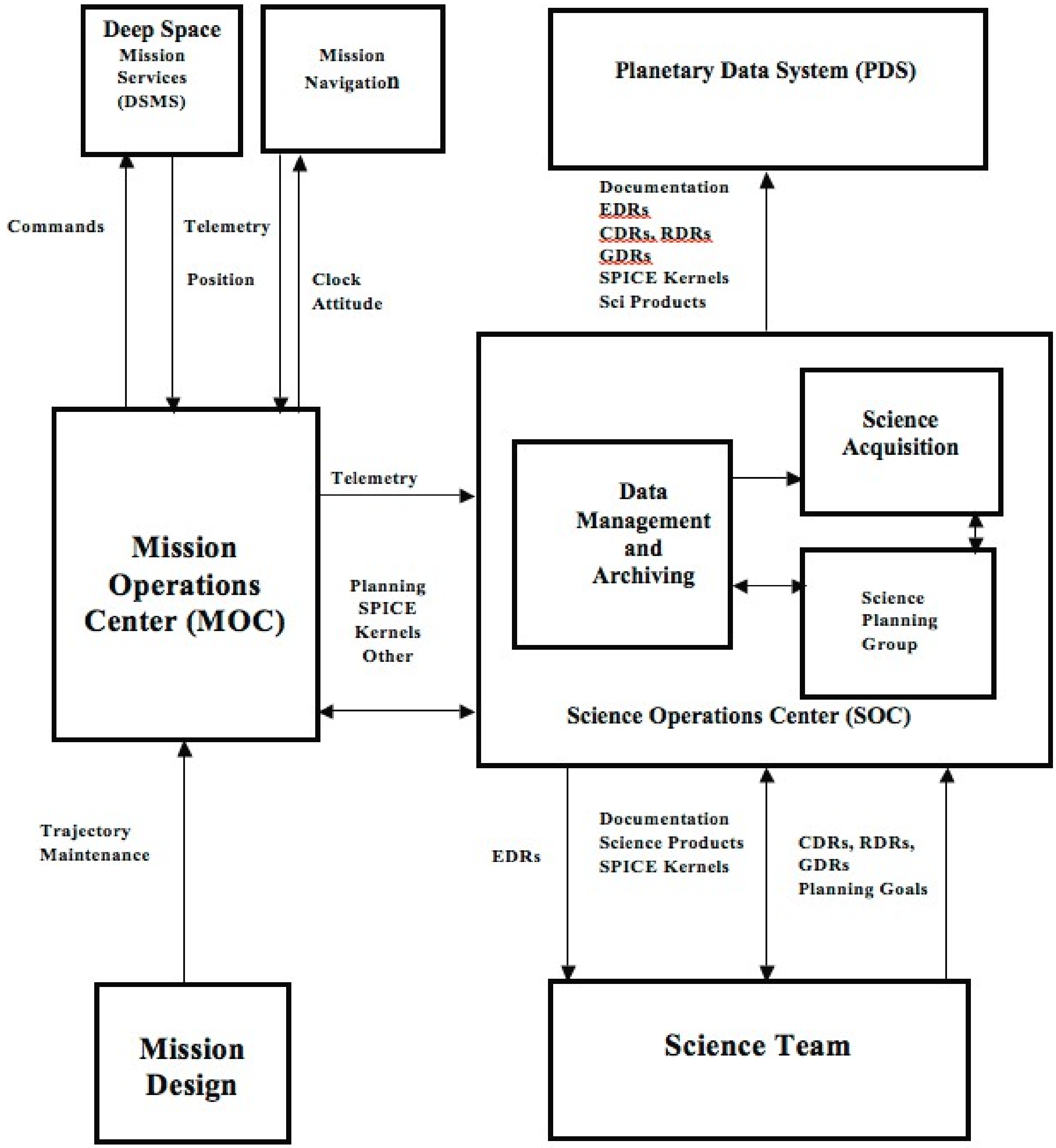
5.3.3 Data Flow

The MESSENGER SOC operates under the auspices of the MESSENGER Project Scientist to plan data acquisition, and to generate and validate data archives. The SOC supports and works with the MOC, the Science Team, instrument scientists, and the PDS. The SOC is located at the Johns Hopkins University/Applied Physics Lab (JHU/APL). The Data flow diagram in Figure 1 shows the general flow of data within the MESSENGER project as well as data flow to the PDS. The MOC handles raw data flow to and from the MESSENGER spacecraft and the SOC converts the raw telemetry into EDRs. The Science Team generates the derived products, transmitting them to the SOC for eventual delivery to the PDS Geosciences Node. SPICE kernels are delivered to the PDS Navigation and Ancillary Information (NAIF) node. Low altitude SPICE kernels that were generated by the MLA team to aid spacecraft positioning towards the end of the mission have been archived at the Geosciences node at the PDS (Volume MESSMLA_2101: DOCUMENT/NAVASSMT/SPK) as they have limited general use.

The MESSENGER SOC delivers data for the MLA derived data volume to the PDS Geosciences Node in standard product packages. Each package comprises data and files organized into directory structures consistent with the volume design described in section 6.6. The electronic transfer process used to release data to PDS is described in the EDR SIS. No changes are anticipated to the delivery process, but should any arise, they are noted in an update to the SIS document and include the specific dates from which the changes take effect. The delivery of products to the PDS data archive follows the schedule in the MESSENGER Data

Management and Archiving Plan (Applicable Document 2).

Figure 1. MESSENGER data flow



There is a PDS label file for every MLA data product. Example label files are shown in Appendices 8.1, 8.2, 8.3, and 8.4 for the Calibrated, Status, and Hardware Diagnostic Lite CDR products, as well as the Science Reduced Data Record. A sample GDR label is included in the appendices. The specific table structure for each data file is detailed in section 6.2.

5.4 Standards Used in Generating Data Products

5.4.1 PDS Standards

The MLA data products are constructed according to the data object concepts developed by the PDS. By adopting the PDS format, the MLA data products are consistent in content and organization with other planetary data collections. In the PDS standard, the data file is grouped into objects with PDS labels describing the objects. The CDR and RDR data products contain

1. A table object (the primary data) contained in a fixed-length record ASCII data file. The fields in the MLASCIRDR*.TAB files are separated by commas. The fields in the MLARADR*.TAB files are separated by spaces. All tables have carriage-return+line-feed (<CR><LF>) end of line terminators.
2. A detached PDS label file. This contains a pointer to the data file as well as meta-data information and a pointer to a detailed description of the table structure.
3. A format file contained in the LABEL directory. All labels and format (.FMT) files also contain the required <CR><LF> end-of-line terminators.

MLA GDR products contain

1. An image object contained in data files in standard IMG and JPEG2000 formats.
2. A detached PDS label file, with a pointer to the data file as well as meta-data information.
3. Browse images in JPEG format are provided for some GDR products in the EXTRAS/BROWSE directory.

5.4.2 Time Standards

The MET field in the MLA CDR table matches the spacecraft time in integer seconds that is transmitted to MESSENGER subsystems by the Integrated Electronics Module (IEM). This is referred to by the MESSENGER project as Mission Elapsed Time (MET). MET = 0 is August 3, 2004, at 05:59:16 UTC, which is 1000 seconds prior to the MESSENGER launch. Relativistic effects and circumstances occurring during the mission would result in MET not being a true account of seconds since launch. Following a planned spacecraft clock reset on January 8, 2013, partition numbers (1/, or 2/) were added to product labels to disambiguate MET seconds after the spacecraft clock reset (if partition number is not present, SPICE defaults to partition 1/). MET values that correspond to times prior to the clock reset fall into partition 1. Those after, into partition 2. For this reason the MESSENGER spacecraft clock coefficients file is archived at the PDS Navigation and Ancillary Information Facility (NAIF) Node (PDS data set MESS-E/V/H-SPICE-6-V1.0). This file is used in conjunction with the leap seconds kernel file to calculate the conversion between MET and UTC.

5.4.3 Data Storage Conventions

The data are organized following PDS standards and stored on hard disk and in an SQL (Structured Query Language) database for rapid access during mission operations. The MESSENGER SOC transfers data to the PDS via electronic transfer and delivery methods detailed in section 5.3.3. After verification of the data transfer the PDS will provide public access to MESSENGER science data products through its online data distribution system.

5.5 Data Validation

MLA data products are validated by the MLA Instrument scientist for science content and for compliance with PDS archive standards as described in the MESSENGER Data Management and Archiving Plan (Applicable Document 2).

6 Detailed Data Product Specifications

6.1 Data Product Structure and Organization

The MESSENGER MLA derived data sets are archived at the PDS Geosciences Node as a data archive volume. The MLA CDR products in the data archive volume are calibrated products. The RDR and RADR products are a reduced product and were revised one or more times. The production and release of CDRs followed the release schedule in the MESSENGER Data Management and Archiving Plan (Applicable Document 2). When revisions occurred, the RDR and RADR data were replaced with updated RDRs and RADRs on the next scheduled delivery date. The GDR products were also revised one or more times.

There are two MLA derived products archive volumes using PDS volume identifiers MESSMLA_2001 and MESSMLA_2101.

6.2 Data Format Description

Calibrated and reduced data are stored in table format. The structure of the table is defined by an external format (.FMT) file. The MLA Science CDR or RDR is an ASCII table with all of the packet telemetry points needed to analyze the instrument data, and is only produced when the instrument is in Science Mode. It is a Level 3 product, in that units are not resampled or converted. The range data consist of multiple coarse and fine timing counts for transmitted and received pulses that must be combined with instrument configuration data. The MLA Hardware Diagnostic Lite (MLAHAD) CDR is derived from an engineering-mode packet used for calibration experiments and contains all of the background noise counter data but only a sample of the range measurement data. These packets are generated only in Standby Mode. The MLA Status CDR is a low-rate packet that contains instrument environmental parameters needed to interpret the science data, and may be generated in all modes.

Gridded data consist of a map or DEM derived from the RDR products, stored as a binary image array. The dimensions, data type, and map projection information for the image are given in its detached PDS label. The files in the CATALOG directory of the data archive may provide additional useful information.

6.2.1 Science CDR Table

The table consists of fixed-length records with 55 individual columns, each delimited by a comma (ASCII 44). The records are delimited with carriage-return (ASCII 13), line-feed (ASCII 10) pairs at the end of each line. The column position, length, data type, and descriptions are given in a pointer to a data structure, MLASCICDR.FMT, provided in the LABEL directory and given in the Appendix (8.6).

6.2.2 MLA Status CDR Table

The table consists of fixed-length records with 116 individual columns, each delimited by a comma (ASCII 44). The column position, length, data type, and descriptions are given in a pointer to a data structure, “MLASTACDR.FMT”, provided in the LABEL directory and given in the Appendix (8.7).

6.2.3 MLA Hardware Diagnostic Lite CDR Table

The table consists of fixed-length records with 90 individual columns, each delimited by a comma (ASCII 44). The column position, length, data type, and descriptions are given in a pointer to a data structure, “MLAHADCDR.FMT”, provided in the LABEL directory and given in the Appendix (8.8).

6.2.4 MLA Science RDR Table

The table consists of fixed-length records, one or more per laser shot, having 24 individual columns. The column position, length, data type, and descriptions are given in a pointer to a data structure, “MLASCIRDR.FMT”, provided in the LABEL directory and given in the Appendix (8.12). Data quality indicators applied are by manual edits, as noted in a comment appended to the detached label.

6.2.5 MLA GDR Image

Geolocated, binned altimetry data are accumulated from all mission phases to create a digital elevation model of Mercury, with interpolation as necessary between individual profiles. Each DEM is a raster image composed of a set of pixels that represent finite areas, and not discrete points. Missing data (beyond a distance of 4 km from the nearest data point) are flagged with a special value. The models are provided at resolutions of 2^ n pixels per degree in cylindrical equidistant projection, and in north polar stereographic projection. The polar stereographic maps are provided as well at spacings of 250, 500, and 1000 meters where sufficient data coverage permits. The models are PDS IMG and JPEG2000 files with detached labels.

6.2.6 Radiometric Active Data Record (RADR)

The table consists of fixed-length records, one per energy measurement, having 17 individual columns. The column position, length, data type and descriptions are given in a pointer to the data structure, “MLARADR.FMT”, provided in the label directory and given in the Appendix.

6.3 Formats of Other Files in the MLA CDR/RDR/GDR Archive

Aside from data products, the archive includes documentation, catalog and index files. Documents are provided in either ASCII or HTML, and an Adobe PDF version is also often provided. Each file is accompanied by either an internal (attached) or detached PDS label. Index files are given as ASCII tables with detached PDS labels. (See Section 6.7.2 for contents of index files.) Catalog files contain important descriptive information about the data products, MLA instrument, MESSENGER spacecraft and mission, and are provided in a keyword=value format similar to a PDS label, to be both human and software-readable. Viewable, reduced-size browse images are provided for the GDR images in the EXTRAS/BROWSE directory.

6.3.1 Label and Header Descriptions

The following are the keyword definitions for the detached PDS label files accompanying the ASCII table data file. The detached PDS label file has the same name as the data file it describes, except for the extension .LBL.

PDS_VERSION_ID
Represents the version number of the PDS standards documents that is valid when a data product label is created. PDS3 is used for the MESSENGER data products.

FILE_RECORDS
Indicates the number of physical file records, including both label records and data records.

RECORD_TYPE
Indicates the record format of a file.

RECORD_BYTES
Indicates the number of bytes in a physical file record, including record terminators and separators.

PRODUCT_ID
Represents a permanent, unique identifier assigned to a data product by its producer. The product file name is used for a unique PRODUCT_ID.

PRODUCT_VERSION_ID
Identifies the version of the product, represented initially by "V1". The version number is incremented if the product needs to be regenerated as a result of a correction of the data or as a result of a change in the method used to create the product.

PRODUCT_CREATION_TIME
Defines the UTC system format time when a product was created.

PRODUCT_TYPE
Identifies whether the CDR contains science data ("DATA") or ancillary engineering data ("ANCILLARY").

STANDARD_DATA_PRODUCT_ID
The MLA CDR files are identified as belonging to the same standard data product via this ID.

SOFTWARE_NAME
Identifies the data processing software used to convert from spacecraft telemetry into CDR products.

SOFTWARE_VERSION_ID
Indicates the version (development level) of the program defined in SOFTWARE_NAME. It is incremented if the program is modified during the course of the mission.

INSTRUMENT_HOST_NAME
The full name of the host on which an instrument is based. For MESSENGER this is the "MERCURY SURFACE, SPACE ENVIRONMENT, GEOCHEMISTRY, AND RANGING" satellite. However, since the project commonly uses the acronym for the satellite, it is simply MESSENGER.

INSTRUMENT_NAME
The "MERCURY LASER ALTIMETER".

INSTRUMENT_ID
Provides an abbreviated name or acronym that identifies an instrument. In this case “MLA”.

DATA_SET_ID
The data_set_id for the MLA data products. There is only 1 data set id for the entire MLA CDR/RDR archive, MESS-E/V/H-MLA-3/4-CDR/RDR-DATA-V1.0. The gridded data product id is MESS-E/V/H-MLA-4-GDR-V1.0.

DATA_SET_NAME
The full PDS name of the data set.

MISSION_PHASE_NAME
Identifies the project designation of the mission phase associated with the data product.

COORDINATE_SYSTEM_NAME
The name of the coordinate system to which state vectors are referenced.

TARGET_NAME
Identifies a target. The targets for the MLA are Earth, Venus, Mercury, and Calibration.

PRODUCER_ID
The identifier of the organization that produced the data set.

PRODUCER_FULL_NAME
The full name of the person or organization that produced the data set.

PRODUCER_INSTITUTION_NAME
The name of the institution with which the data producers are affiliated.

PRODUCT_RELEASE_DATE
The data that the PDS publicly released the data set.

ORBIT_NUMBER
The number of the orbit during which the spacecraft acquired the source data.

START_TIME
Provides the UTC date and time corresponding to the MET of the first record in the table.

STOP_TIME
Provides the UTC date and time corresponding to the MET of the last record in the table.

SPACECRAFT_CLOCK_START_COUNT
The value of the spacecraft clock corresponding to the MET of the first record in the table. This value has the form “<p>/<MET> where <p> is the clock partition number 1 or 2 and <MET> is the integer clock count (e.g., "2/67509886").

SPACECRAFT_CLOCK_STOP_COUNT
The value of the spacecraft clock corresponding to the MET of the last record in the table. This value has the form “<p>/<MET> where <p> is the clock partition number 1 or 2 and <MET> is the integer clock count (e.g., "2/67511852").

INSTRUMENT_MODE_ID
The mode that the instrument was in at the time of data acquisition.

^TABLE
This is a pointer to the external data file containing the table. The TABLE object is a uniform collection of rows containing ASCII values stored in columns.

6.4 File Naming Conventions

The file names developed for PDS data volumes are restricted to a maximum 36 character file name and a 3 character extension name with a period separating the file and extension names. Given this restriction the general form of the MLA CDR, RDR, and RADR data product files is "MLAZZZZZZYYMMDDHHNN". All ASCII table data files will end in ".TAB" and PDS label files will end in ".LBL". The components of the base filename are described below. Note that references to time units in the filename refer to UTC time. The UTC time used in the filename corresponds to the first record in the table. Recall that the data files group observations in two different methods, depending on whether the data is gathered during the Mercury Orbit phases or prior to Mercury orbit (section 5.2).

MLA : Instrument name – Mercury Laser Altimeter
ZZZZZZ: Data record type:
- SCICDR – Science calibrated range and ancillary data
- SCIRDR – Science reduced data
- STACDR – Status calibrated data
- HADCDR – Hardware Diagnostic Lite calibrated data.
- RADR – Radiometric active data

YY : The last two digits of the year in which the first data record was acquired.
MM : The two digit month in which the first data record was acquired.
DD : The two digit day in which the first data record was acquired.
HH : The two digit hour corresponding to the first record in the data.
NN : The two digit minute corresponding to the first record in the data.

Each PDS label file contains a ^STRUCTURE pointer to an external file. This external file will contain the definition of the table object. Due to the large number of columns in the table, and since the structure of the table does not change, the structure is defined once in an external file in the LABEL directory and a pointer to it is in every PDS detached label file.

GDR image data products are named according to resolution in pixels per degree or in kilometers per pixel. They have the form:

H<PPP>_<RR>

Where
H : Target planet Mercury
PPP : Product type:
- DEM – Digital Elevation Model
- DEC – Digital Counts

RR : Resolution in pixels per degree
- LBL – PDS label

For example, the topographic projection HDEM_16 is named as follows: H represents Mercury, DEM stands for Digital Elevation Model, and 16 would be the resolution in pixels per degree. The corresponding "counts" file, HDEC_16, has values for the number of ground returns corresponding to a particular topographic value. Image file names end in ".IMG" and are accompanied by detached PDS labels with the same name but with the extension ".LBL". Geospatially referenced JPEG-2000 files will have the extension ".JP2".

The GDR data set also contains a north polar stereographic map DEM product produced from MLA data. This product has the form MSGR_DEM_MLA_NP.IMG with accompanying JP2, XML, and label files. It is named in accordance with the naming convention of corresponding DEM products produced by the USGS with MDIS data available at the PDS in the MESS-H-MDIS-5-DEM-ELEVATION-V1.0 data set. “NP” refers to “north polar.” This product is accompanied by a supporting “counts” product that contains a graphical depiction of the number of observations for each pixel that were used to produce the primary product. This product nam is MSGR_DEM_MLA_NP_COUNT_V01.

The product files have file extensions of:

.IMG – Binary image
.TAB – ASCII format table
.JP2 – JPEG 2000 image product
.XML – XML format metadata file associated with the JP2 product
.JPG – JPEG format image browse product (found in EXTRAS/BROWSE)

6.5 Directory Structure and Contents for MLA CDR/RDR/GDR Data Archive Volume

The following illustration shows the directory structure overview for the MLA CDR/RDR/GDR Data Archive Volume. This volume contains the MLA data products, supporting documentation, and any additional files required for the volume to be compliant with PDS standards. The content of the volume is expected to be updated with periodic releases according to the schedule in the MESSENGER Data Management and Archiving Plan (Applicable Document 2). Revised RDRs and GDRs (if needed) are delivered according to the same schedule. Revised RDRs and GDRs have an incremented version number in the PDS label.

Directory Structure Overview

```
                               <ROOT>
                                 |
                                 |
      ___________________________|__________________________________
      |        |        |        |        |        |        |        |
      |        |        |        |        |        |        |        |
   <LABEL>  <INDEX>  <CATALOG>  <DOCUMENT> <CDR>* <RDR_RADR>  <GDR>   <EXTRAS>
                                 |                 |        |         |
                            <NAVASSMT>**           |     _____|_      |
                       ___________|_______         |     |     |   <BROWSE>
                       |          |       |        |  <IMG>  <JP2>    |
                 <RDR_PLTS>  <SPK_PLOTS>  <SPK>    |                <GDR>
                     |                             |
                _____|_____              __________|_________
                |          |             |      |      |       |
             <2014>     <2015>        <2011> <2012> <2013>   <...>
                |                                              |
           _____|_________                                 ____|__________
           |       |      |                                |       |       |
         <MAY>   <JUN>  <...>                            <JAN>   <FEB>   <...>
```

* The CDR directory is included only in the MESSMLA_2001 volume.
** The NAVASSMT directory is only included in the MESSMLA_2101 volume.

Directory Contents

<ROOT> Directory

This is the top-level directory of the data volume. The following are files contained in the root directory.

AAREADME.TXT - General information file. Provides users with information about the MESSENGER MLA data products. Directs user to other documents on the volume containing more detailed information.

VOLDESC.CAT - PDS file containing the VOLUME object. This gives a high level description of the contents of the volume. Information includes: production date, producer name and institution, volume ID, etc.

ERRATA.TXT - Text file for identifying and describing errors and/or anomalies found in the current volume. Any known errors for the associated volume is documented in this file.

<DOCUMENT> Directory

This subdirectory contains the documentation that is needed in order to understand and analyze the MLA data products. Documents are stored in PDF and HTML format.

DOCINFO.TXT – Identifies and describes the function of each file in the DOCUMENT directory
MLA_RDRSIS.PDF – The MLA RDR Software Interface Specification (this document) in PDF format.
MLA_RDRSIS.TXT – The MLA RDR Software Interface Specification (this document) in text format.
MLA_RDRSIS.LBL – The detached PDS label for the MLA_RDRSIS documents.

MLA_EDR_TO_CDR_TO_RDR-GDR.PDF – The MLA EDR to CDR to RDR/GDR processing description document in PDF format.
MLA_EDR_TO_CDR_TO_RDR-GDR.TXT – The MLA EDR to CDR to RDR/GDR processing description document in text format.
MLA_EDR_TO_CDR_TO_RDR-GDR.LBL – The detached PDS label for the MLA EDR to CDR to RDR/GDR documents.

JP2INFO.TXT – The description of the GDR products in JPEG 2000 format. Contains an attached PDS label.

<DOCUMENT/NAVASSMT> Directory

This subdirectory is included only in the MESSMLA_2101 volume. The NAVASSMT (Navigation Assessment) directory contains documentation and supporting images and data that describe the refinements to the navigation trajectory computed by the MLA team from MLA data. It is organized into further subdirectories. (This directory is included in the MESSMLA_2101only).

<CATALOG> Directory

This subdirectory contains the catalog object files for the entire volume. The following files are included in the catalog subdirectory.

CATINFO.TXT – Identifies and describes of function of each file in the catalog directory**.**

CDR_RDR_DS.CAT– Describes the general content of the CDR/RDR/RADR dataset and includes information about the duration of the mission and the person or group responsible for producing the data. (Included only in the MESSMLA_2001 volume.)

RDR_DS.CAT– Describes the general content of the RDR dataset and includes information about the duration of the mission and the person or group responsible for producing the data. (Included only in the MESSMLA_2101 volume.)

GDR_V1_DS.CAT– Describes the general content of the GDR dataset and includes information about the duration of the mission and the person or group responsible for producing the data. (Included only in the MESSMLA_2001 volume.)

GDR_V2_DS.CAT– Describes the general content of the GDR dataset and includes information about the duration of the mission and the person or group responsible for producing the data. (Included only in the MESSMLA_2101 volume.)

INSTRUMENT.CAT– Describes physical attributes of the MLA instrument and provides relevant references to published literature.

INSTRUMENT_HOST.CAT– Describes the MESSENGER spacecraft.

MISSION.CAT– Describes the scientific goals and objectives of the MESSENGER program. It also identifies key people and institutions.

REF.CAT– Contains the reference objects. These reference additional documents that may be useful to the person using the MLA products.

DSMAP.CAT– Mission-wide description of the projection used in map products. (Included only in the MESSMLA_2001 volume.)

DSMAP_POLAR.CAT – Mission-wide description of the projection used in polar map products.

<INDEX> Directory

This subdirectory contains the indices for the MLA CDR, RDR, and GDR data products. The following files are contained in the index subdirectory.

INDEXINFO.TXT – Identifies and describes the function of each file in the index subdirectory. This includes a description of the structure and contents of each index table in the subdirectory AND usage notes.

INDEX.TAB - The CDR/RDR/GDR index file is organized as a table; there is one entry for each of the data files included in the MLA data sets; the columns contain parameters that describe the data as well as instrument and spacecraft parameters.

INDEX.LBL - Detached PDS label for INDEX.TAB.

MD5.TAB – A file containing a table of MD5 hash values for all files in the volume. This is used for file validation.

MD5.LBL – Detached PDS label for MD5.TAB.

Index Table Contents

There is one index table for the whole CDR/RDR/GDR archive volume. It contains one record (row) for each data product on the volume, and at minimum the following columns:

1. Volume ID
2. Directory path and file name relative to volume root directory
3. Product ID
4. Product version ID
5. Product creation time
6. Data set ID
7. Start time of data acquisition, in UTC
8. Start spacecraft MET clock count

<LABEL> - Label Directory

This subdirectory contains the format files for each of the different CDR product types. The format file describes the format of the Table object in the corresponding CDR or RDR data file.

<CDR> - Data Directory

This is the top level of the directory in which the CDRs are contained. The data directories are organized by year

(YYYY) followed by month in UTC. The CDRs reside in the month folders. (This directory is included in the MESSMLA_2001only).

<RDR_RADR> - Data Directory
The RDRs and RADRs are stored in this directory with the same subdirectory organization as the CDRs. (The MESSMLA_2101 volume directory contains only RDRs).

<GDR> - Data Directory
The GDR products are stored in this directory.

<EXTRAS> - Extras Directory
The EXTRAS directory contains a BROWSE subdirectory which in turn, contains a <GDR> subdirectory. This subdirectory contain viewable, reduce-size browse images of the GDR image products.

<GEOMETRY> - Geometry Directory
The GEOMETRY directory contains a single file, GEOMINFO.TXT, that gives a short summary of the SPICE kernels and a reference to the NAIF PDS node where they are archived.

6.6 Data Volumes

The MLA CDR/RDR/RADR/GDR data products are provided in two volumes. These are MESSMLA_2001 and MESSMLA_2101. MESSMLA_2001 contains all of the products described in this document in two data sets, one for the CDR, RDR, RADR products (MESS-E/V/H-MLA-3/4-CDR/RDR-DATA-V1.0) and one for the GDR products (MESS-E/V/H-MLA-4-GDR-V1.0). MESSMLA_2101 has a structure that mirrors that of the other, but only contains RDR and GDR products in incremented versions of the data sets (MESS-E/V/H-MLA-3/4-CDR/RDR-DATA-V2.0 and MESS-E/V/H-MLA-4-GDR-V2.0). MESSMLA_2101 does not contain CDR or RADR products. These new data sets in this new volume were created to contain reprocessed versions of the RDRs and a new GDR. The reprocessed RDRs were generated using a different spacecraft ephemeris than those in the prior data sets. The products in the V1.0 data sets in volume MESSMLA_2001 were generated using the final mission reconstructed spacecraft ephemeris SPK SPICE kernel (msgr_040803_150430_150430_od431sc_2.bsp). The RDR and GDR products in the V2.0 data sets in volume MESSMLA_2101 were generated using a spacecraft ephemeris computed by the MLA team at GSFC using MLA and Radio Science data (msgr_*yymmdd_yymmdd*_recon_gsfc_0.bsp). For the MLA data and probably other data as well, this is an improved ephemeris. All of the aforementioned SPK kernels are archived at the PDS NAIF node in the MESSSP_1000 volume (data set ID: MESS-E/V/H-SPICE-6-V1.0). The V2.0 data set RDR products supersede, but do not replace the V1.0 RDR products. The earlier RDRs are still scientifically valid and useful and are retained. The CDR, RADR, GDR, and pre-orbit RDR products in V1.0 remain fully valid and are not superseded. The V2.0 GDR is a new product that overlaps the area covered by some V1.0 GDRs, but is based on the V2.0 RDR data.

The directory structure of volume MESSMLA_2101 follows that depicted in section 6.5 , except that it does not contain a CDR directory and the RDR_RADR directory (which contains only RDRs) has subdirectories only for the years during which there were orbital operations (2011-2015).

7 Archive Release Schedule to PDS

The MESSENGER MLA CDR/RDR/GDR archive was transferred from the SOC to the PDS Geosciences Node using the electronic transfer process detailed in section 5.3.3. The transfers took place according to the schedule in the MESSENGER Data Management and Archiving Plan (Applicable Document 2.).

8 Appendices

8.1 Appendix - MLA Science CDR PDS Label

```
PDS_VERSION_ID                = "PDS3"

/*** FILE FORMAT ***/
FILE_RECORDS                  = 9424
RECORD_TYPE                   = FIXED_LENGTH
RECORD_BYTES                  = 384

/*** GENERAL DATA DESCRIPTION PARAMETERS ***/
PRODUCT_ID                    = "MLASCICDR0505111310"
PRODUCT_VERSION_ID            = "V1"
PRODUCT_CREATION_TIME         = 2006-09-28T20:32:12
PRODUCT_TYPE                  = "DATA"
STANDARD_DATA_PRODUCT_ID      = "MLASCIENCECDR"
SOFTWARE_NAME                 = "MLASCICDR"
SOFTWARE_VERSION_ID           = "1.0"
INSTRUMENT_HOST_NAME          = "MESSENGER"
INSTRUMENT_NAME               = "MERCURY LASER ALTIMETER"
INSTRUMENT_ID                 = "MLA"
DATA_SET_ID                   = "MESS-E/V/H-MLA-3/4-CDR/RDR-DATA-V1.0"

MISSION_PHASE_NAME            = "EARTH CRUISE"
TARGET_NAME                   = "CALIBRATION"
START_TIME                    = 2005-05-11T13:10:15.706
STOP_TIME                     = 2005-05-11T13:29:53.581
SPACECRAFT_CLOCK_START_COUNT  = 24304159
SPACECRAFT_CLOCK_STOP_COUNT   = 24305336
^TABLE                        = "MLASCICDR0505111310.TAB"

OBJECT                        = TABLE
COLUMNS                       = 55
INTERCHANGE_FORMAT            = ASCII
ROW_BYTES                     = 384
ROWS                          = 9424
DESCRIPTION                   = "
    This table contains one set of Calibrated MLA Science values, as
    reported by the MESSENGER Mercury Laser Altimeter (MLA). The nominal
    rate is 8 Hz. The column definitions are contained in a structure file
    found in the LABEL directory of the archive disk. Additional details
    are contained in the CDR SIS document."
^STRUCTURE  = "MLASCICDR.FMT"
END_OBJECT                    = TABLE
END
```

8.2 Appendix - MLA Status CDR PDS Label

```
PDS_VERSION_ID                = "PDS3"

/*** FILE FORMAT ***/
FILE_RECORDS                  = 225
RECORD_TYPE                   = FIXED_LENGTH
RECORD_BYTES                  = 504

/*** GENERAL DATA DESCRIPTION PARAMETERS ***/
PRODUCT_ID                    = "MLASTACDR0505311900"
PRODUCT_VERSION_ID            = "V1"
PRODUCT_CREATION_TIME         = 2007-01-01T12:00:00
PRODUCT_TYPE                  = "ANCILLARY"
STANDARD_DATA_PRODUCT_ID      = "MLASTATUSCDR"
SOFTWARE_NAME                 = "MLASTACDR"
SOFTWARE_VERSION_ID           = "1.0"
INSTRUMENT_HOST_NAME          = "MESSENGER"
INSTRUMENT_NAME               = "MERCURY LASER ALTIMETER"
INSTRUMENT_ID                 = "MLA"
DATA_SET_ID                   = "MESS-E/V/H-MLA-3/4-CDR/RDR-DATA-V1.0"

MISSION_PHASE_NAME            = "EARTH CRUISE"
TARGET_NAME                   = "CALIBRATION"
START_TIME                    = 2005-05-31T19:00:05.736
```

```
STOP_TIME                      = 2005-05-31T19:59:49.736
SPACECRAFT_CLOCK_START_COUNT   = 26053149
SPACECRAFT_CLOCK_STOP_COUNT    = 26056733
^TABLE                         = "MLASTACDR0505311900.TAB"

OBJECT                         = TABLE
COLUMNS                        = 116
INTERCHANGE_FORMAT             = ASCII
ROW_BYTES                      = 504
ROWS                           = 225
DESCRIPTION                    = "
  This table contains one set of instrument engineering data as reported by
  the MESSENGER Mercury Laser Altimeter (MLA) status packets. Nominal rate
  is 1 Hz or less. The complete column definitions are contained in a
  structure file found in the LABEL directory of the archive disk.
  Additional details are contained in the CDR SIS document."
^STRUCTURE  = "MLASTACDR.FMT"
END_OBJECT                     = TABLE
END
```

8.3 Appendix - MLA Hardware Diagnostic Lite CDR PDS Label

```
PDS_VERSION_ID                 = "PDS3"

/*** FILE FORMAT ***/
FILE_RECORDS                   = 2608
RECORD_TYPE                    = FIXED_LENGTH
RECORD_BYTES                   = 480

/*** GENERAL DATA DESCRIPTION PARAMETERS ***/
PRODUCT_ID                     = "MLAHADCDR0705260016"
PRODUCT_VERSION_ID             = "V1"
PRODUCT_CREATION_TIME          = 2007-05-29T15:09:57
PRODUCT_TYPE                   = "DATA"
STANDARD_DATA_PRODUCT_ID       = "MLAHDIAGNOSTIC"
SOFTWARE_NAME                  = "MLAHWCDR"
SOFTWARE_VERSION_ID            = "1.0"
INSTRUMENT_HOST_NAME           = "MESSENGER"
INSTRUMENT_NAME                = "MERCURY LASER ALTIMETER"
INSTRUMENT_ID                  = "MLA"
DATA_SET_ID                    = "MESS-E/V/H-MLA-3/4-CDR/RDR-DATA-V1.0"
MISSION_PHASE_NAME             = "VENUS 2 FLYBY"
TARGET_NAME                    = "VENUS"
START_TIME                     = 2007-05-26T00:16:59.000
STOP_TIME                      = 2007-05-26T00:22:25.000
SPACECRAFT_CLOCK_START_COUNT   = 88625947
SPACECRAFT_CLOCK_STOP_COUNT    = 88626273
^TABLE                         = "MLAHADCDR0705260016.TAB"

OBJECT                         = TABLE
COLUMNS                        = 90
INTERCHANGE_FORMAT             = ASCII
ROW_BYTES                      = 480
ROWS                           = 2608
DESCRIPTION                    = "
    This table contains one set of calibrated engineering data as reported by
    the MESSENGER Mercury Laser Altimeter (MLA) hardware diagnostic 'lite'
    packets. The hardware diagnostic 'full' packets are not used in flight.
    The complete column definitions are contained in an structure file
   found in the LABEL directory of the archive disk. Additional details are
    contained in the CDR SIS document. "
^STRUCTURE  = "MLAHADCDR.FMT"
END_OBJECT                     = TABLE

END
```

8.4 Appendix – MLA Science RDR PDS Label

```
PDS_VERSION_ID                 = "PDS3"

/*** FILE FORMAT ***/
FILE_NAME                      = "MLASCIRDR1503010457.TAB"
FILE_RECORDS                   = 39015
RECORD_TYPE                    = FIXED_LENGTH
RECORD_BYTES                   = 230
```

```
/*** GENERAL DATA DESCRIPTION PARAMETERS ***/
PRODUCT_ID                      = "MLASCIRDR1503010457.TAB"
PRODUCT_VERSION_ID              = "V4"
PRODUCT_CREATION_TIME           = 2015-12-03T17:26:10
PRODUCT_TYPE                    = "RDR"
STANDARD_DATA_PRODUCT_ID        = "MLA_DATA"
SOFTWARE_NAME                   = "MLA_RDR"
SOFTWARE_VERSION_ID             = "2.8"
SOURCE_PRODUCT_ID               = "MLASCICDR1503010457"
SPICE_FILE_NAME                 = {
               "pck00010_msgr_v21.tpc",
               "naif0010.tls",
               "msgr_de405_de423s.bsp",
               "messenger_2499.tsc",
               "msgr_20040803_20150430_od418sc_0.bsp",
               "msgr20150228.bc",
               "msgr20150301.bc",
               "msgr20150302.bc"
               }
POSITIVE_LONGITUDE_DIRECTION    = EAST
COORDINATE_SYSTEM_NAME          = "PLANETOCENTRIC"
INSTRUMENT_HOST_NAME            = "MESSENGER"
INSTRUMENT_NAME                 = "MERCURY LASER ALTIMETER"
INSTRUMENT_ID                   = "MLA"
DATA_SET_ID                = "MESS-E/V/H-MLA-3/4-CDR/RDR-DATA-V1.0"
DATA_SET_NAME              = "MESSENGER E/V/H MLA 3/4 CDR/RDR DATA V1.0"
MISSION_PHASE_NAME              = "MERCURY ORBIT YEAR 4"
TARGET_NAME                     = "MERCURY"
PRODUCER_ID                     = MESSENGER_MLA_TEAM
PRODUCER_FULL_NAME              = "DAVID E. SMITH"
PRODUCER_INSTITUTION_NAME       = "GODDARD SPACE FLIGHT CENTER"
PRODUCT_RELEASE_DATE            = 2016-05-06
ORBIT_NUMBER                    = 3929
START_TIME                      = 2015-03-01T04:58:10
STOP_TIME                       = 2015-03-01T05:30:57
SPACECRAFT_CLOCK_START_COUNT    = "2/67509886"
SPACECRAFT_CLOCK_STOP_COUNT     = "2/67511852"
INSTRUMENT_MODE_ID              = {"SC_RANGE"}

^HEADER                         = ("MLASCIRDR1503010457.TAB",1)
OBJECT = HEADER
  BYTES = 230
  RECORDS = 1
  HEADER_TYPE = TEXT
  DESCRIPTION = "Column headings"
END_OBJECT = HEADER
^TABLE                          = ("MLASCIRDR1503010457.TAB",2)
OBJECT                          = TABLE
  COLUMNS                       = 24
  INTERCHANGE_FORMAT            = ASCII
  ROW_BYTES                     = 230
  ROWS                          = 39014
  DESCRIPTION                   = "
    This product contains time-ordered, calibrated,
    geolocated altimetry data reduced by the Mercury Laser Altimeter (MLA)
    Science Team at the NASA Goddard Space Flight Center and
    the JHU Applied Physics Laboratory."
  ^STRUCTURE  = "MLASCIRDR.FMT"
END_OBJECT                      = TABLE
END
```

8.5 Appendix – MLA Radiometric Active Data Record (RADR) PDS Label

```
PDS_VERSION_ID                 = "PDS3"

/*** FILE FORMAT ***/
FILE_RECORDS                  = 7024
RECORD_TYPE                   = FIXED_LENGTH
RECORD_BYTES                  = 180

/*** GENERAL DATA DESCRIPTION PARAMETERS ***/

PRODUCT_ID                      = "MLARADR1503010457"
```

```
PRODUCT_VERSION_ID             = "V4"
PRODUCT_CREATION_TIME          = 2016-03-12T22:27:39
PRODUCT_TYPE                   = "RDR"
STANDARD_DATA_PRODUCT_ID       = "MLA_DATA"
SOFTWARE_NAME                  = "CDR2SCIPAIR"
SOFTWARE_VERSION_ID            = "2.6"
SOURCE_PRODUCT_ID              = "MLASCICDR1503010457"
SPICE_FILE_NAME                = {
               "pck00010_msgr_v21.tpc",
               "naif0010.tls",
               "msgr_de405_de423s.bsp",
               "messenger_2499.tsc",
               "msgr_20040803_20150430_od418sc_0.bsp",
               "msgr20150228.bc",
               "msgr20150301.bc",
               "msgr20150302.bc"
               }
POSITIVE_LONGITUDE_DIRECTION   = EAST
INSTRUMENT_HOST_NAME           = "MESSENGER"
INSTRUMENT_NAME                = "MERCURY LASER ALTIMETER"
INSTRUMENT_ID                  = "MLA"
DATA_SET_ID                    = "MESS-E/V/H-MLA-3/4-CDR/RDR-DATA-V1.0"
DATA_SET_NAME                  = "MESSENGER E/V/H MLA 3/4 CDR/RDR DATA V1.0"
MISSION_PHASE_NAME             = "MERCURY ORBIT YEAR 4"
COORDINATE_SYSTEM_NAME         = "PLANETOCENTRIC"
TARGET_NAME                    = "MERCURY"
PRODUCER_ID                    = MESSENGER_MLA_TEAM
PRODUCER_FULL_NAME             = "DAVID E. SMITH"
PRODUCER_INSTITUTION_NAME      = "GODDARD SPACE FLIGHT CENTER"
PRODUCT_RELEASE_DATE           = 2016-03-07
ORBIT_NUMBER                   = 3929
START_TIME                     = 2015-03-01T04:58:10
STOP_TIME                      = 2015-03-01T05:30:57
SPACECRAFT_CLOCK_START_COUNT   = "2/67509886"
SPACECRAFT_CLOCK_STOP_COUNT    = "2/67511852"
INSTRUMENT_MODE_ID             = {"SC_RANGE"}
^TABLE                         = "MLARADR1503010457.TAB"
OBJECT                         = TABLE
  COLUMNS                      = 18
  INTERCHANGE_FORMAT           = ASCII
  ROW_BYTES                    = 180
  ROWS                         = 7024
  DESCRIPTION                  = "
    This product contains time-ordered, calibrated, geolocated
    active radiometric data of the Mercury Laser Altimeter (MLA)."
  ^STRUCTURE  = "MLARADR.FMT"
END_OBJECT                     = TABLE
END
```

8.6 Appendix – MLA Gridded Data Record PDS Label

```
PDS_VERSION_ID            = "PDS3"
PRODUCT_VERSION_ID        = "V2.0"
DATA_SET_ID               = "MESS-E/V/H-MLA-4-GDR-V1.0"
PRODUCT_ID                = "HDEM_45N_1000M"
INSTRUMENT_HOST_NAME      = "MESSENGER"
INSTRUMENT_NAME           = "MERCURY LASER ALTIMETER"
INSTRUMENT_ID             = "MLA"
MISSION_PHASE_NAME        = {"MERCURY 1 FLYBY","MERCURY 2 FLYBY",
                            "MERCURY ORBIT","MERCURY ORBIT YEAR 2",
                            "MERCURY ORBIT YEAR 3","MERCURY ORBIT YEAR 4",
                            "MERCURY ORBIT YEAR 5"}
TARGET_NAME               = MERCURY
START_TIME                = 2008-01-14
STOP_TIME                 = 2015-04-30
PRODUCT_CREATION_TIME     = 2016-04-11
PRODUCER_ID               = MESSENGER_MLA_TEAM
PRODUCER_FULL_NAME        = "DAVID E. SMITH"
PRODUCER_INSTITUTION_NAME = "GODDARD SPACE FLIGHT CENTER"
DESCRIPTION               = "This data product is a shape map (radius)
   of Mercury at a resolution of 1000m/pix by 1000m/pix, true at the
   pole in polar stereographic (spherical) projection, based on altimetry
   data acquired by the MLA instrument.  The MLA Laser data through
   Mercury Orbit Year 5 are the source for this gridded product.
```

```
   The ground tracks are interpolated using the Generic Mapping Tools
   programs 'mapproject', 'blockmedian' and 'surface'. The map is in the
   form of a binary table.  Map values are relative to a radius of 2439.4 km.

   This label describes an IMG file in the form of a binary resampling with
   pixel registration.  "

OBJECT                     = UNCOMPRESSED_FILE
FILE_NAME                  = "HDEM_45N_1000M.IMG"
RECORD_TYPE                = FIXED_LENGTH
FILE_RECORDS               = 4096
RECORD_BYTES               = 8192
^IMAGE                     = "HDEM_45N_1000M.IMG"
  OBJECT                   = IMAGE
    NAME                   = HEIGHT
    DESCRIPTION            = "Each sample represents height relative to a
      reference radius (OFFSET) and is generated using altimetry data
      produced by the MLA team."
    LINES                  = 4096
    LINE_SAMPLES           = 4096
    MINIMUM                = -11188
    MAXIMUM                = 7952
    MISSING_CONSTANT       = -32768
    SAMPLE_TYPE            = LSB_INTEGER
    SAMPLE_BITS            = 16
    UNIT                   = METER
    SCALING_FACTOR         = 0.5
    OFFSET                 = 2439400

/* NOTE:                                                                    */
/* Conversion from Digital Number to HEIGHT, i.e. elevation in meters, is: */
/* HEIGHT = (DN * SCALING_FACTOR).                                          */
/* The conversion from Digital Number to PLANETARY_RADIUS in meters is:    */
/* PLANETARY_RADIUS = (DN * SCALING_FACTOR) + OFFSET                        */
/* where OFFSET is the radius of a reference sphere.                        */
/* The planetopotential TOPOGRAPHY is PLANETARY_RADIUS - GEOID_RADIUS,     */
/* where GEOID_RADIUS is derived from a gravitational equipotential model. */
/* By convention, the average GEOID_RADIUS at the equator is OFFSET.       */

  END_OBJECT               = IMAGE
END_OBJECT                 = UNCOMPRESSED_FILE

OBJECT                     = IMAGE_MAP_PROJECTION
 ^DATA_SET_MAP_PROJECTION      = "DSMAP_POLAR.CAT"
 MAP_PROJECTION_TYPE           = "POLAR STEREOGRAPHIC"
 KEYWORD_LATITUDE_TYPE         = "PLANETOCENTRIC"
 MAP_RESOLUTION                = 42.586 <pix/deg>
 A_AXIS_RADIUS                 = 2439.4 <km>
 B_AXIS_RADIUS                 = 2439.4 <km>
 C_AXIS_RADIUS                 = 2439.4 <km>
 FIRST_STANDARD_PARALLEL       = 'N/A'
 SECOND_STANDARD_PARALLEL      = 'N/A'
 POSITIVE_LONGITUDE_DIRECTION  = "EAST"
 CENTER_LATITUDE               = 90 <deg>
 CENTER_LONGITUDE              = 0 <deg>
 REFERENCE_LATITUDE            = 'N/A'
 REFERENCE_LONGITUDE           = 'N/A'
 LINE_FIRST_PIXEL              = 1
 LINE_LAST_PIXEL               = 4096
 SAMPLE_FIRST_PIXEL            = 1
 SAMPLE_LAST_PIXEL             = 4096
 MAP_PROJECTION_ROTATION       = 0.0
 MAP_SCALE                     = 1000 <m/pix>
 MAXIMUM_LATITUDE              = 90 <deg>
 MINIMUM_LATITUDE              = 45 <deg>
 WESTERNMOST_LONGITUDE         = 'N/A'
 EASTERNMOST_LONGITUDE         = 'N/A'
 LINE_PROJECTION_OFFSET        = 2047.5 <pix>
 SAMPLE_PROJECTION_OFFSET      = 2047.5 <pix>
 COORDINATE_SYSTEM_TYPE        = "BODY-FIXED ROTATING"
 COORDINATE_SYSTEM_NAME        = "PLANETOCENTRIC"
END_OBJECT                     = IMAGE_MAP_PROJECTION

END
```

8.7 Appendix – MLA Gridded Data Record JPEG 2000 PDS Label

```
PDS_VERSION_ID            = "PDS3"

/*** This label describes a compressed image file, its corresponding XML    */
/*** file, and map projection information.                                  */
/*** The files described have the same name as this label but different     */
/*** extensions. They are:                                                  */
/***    .JP2 - A compressed image file corresponding to the uncompressed IMG*/
/***           file, stored with JPEG2000 compression                       */
/***    .XML - An auxiliary text file in XML, provided to aid display of    */
/***           the JPEG2000 image with certain image processing software    */
/*** The map projection information includes parameters that are specific  */
/*** to this image. They are intended to be used with the general map       */
/*** projection descriptions in the file indicated by the keyword           */
/*** ^DATA_SET_MAP_PROJECTION. That file is found in the CATALOG directory  */
/*** of this archive.                                                       */

/*** GENERAL DATA DESCRIPTION PARAMETERS ***/

PRODUCT_VERSION_ID        = "V2.0"
DATA_SET_ID               = "MESS-E/V/H-MLA-4-GDR-V1.0"
STANDARD_DATA_PRODUCT_ID  = "MLASCIENCEGDR"
INSTRUMENT_HOST_NAME      = "MESSENGER"
INSTRUMENT_NAME           = "MERCURY LASER ALTIMETER"
INSTRUMENT_ID             = "MLA"
PRODUCT_ID                = "HDEM_45N_1000M_JP2"

MISSION_PHASE_NAME        = {"MERCURY 1 FLYBY","MERCURY 2 FLYBY",
                            "MERCURY ORBIT","MERCURY ORBIT YEAR 2",
                            "MERCURY ORBIT YEAR 3","MERCURY ORBIT YEAR 4",
                            "MERCURY ORBIT YEAR 5"}
TARGET_NAME               = MERCURY
START_TIME                = 2008-01-14
STOP_TIME                 = 2015-04-30
PRODUCT_CREATION_TIME     = 2016-04-08
PRODUCT_RELEASE_DATE      = 2016-03-07
PRODUCER_ID               = MESSENGER_MLA_TEAM
PRODUCER_FULL_NAME        = "DAVID E. SMITH"
PRODUCER_INSTITUTION_NAME = "GODDARD SPACE FLIGHT CENTER"
DESCRIPTION               = "This data product is a map of data counts
   for the gridded data product of the corresponding filename.
   This grid has a resolution of 1000m/pix by 1000m/pix, true at the pole
   in polar stereographic (spherical) projection, and based on altimetry
   data acquired by the MLA instrument through Mercury Orbit Year 5.
   The gridded topographic data product is the source for this data set,
   which contains the number of observations per pixel used to produce it.
   Map values are relative to a radius of 2439.4 km.

   This label describes three objects.  The first is a JP2 file of
   the corresponding uncompressed .IMG file. A jpeg 2000 compression is used
   to render the image.  The second is the uncompressed IMG file.  The third
   is an auxiliary xml file that contains extensible markup language that is
   interpreted by GDAL readers (www.gdal.org).
"

OBJECT                    = COMPRESSED_FILE
FILE_NAME                 = "HDEM_45N_1000M.JP2"
RECORD_TYPE               = UNDEFINED
FILE_RECORDS              = UNK
ENCODING_TYPE             = "JP2"
  INTERCHANGE_FORMAT      = BINARY
  UNCOMPRESSED_FILE_NAME  = "HDEM_45N_1000M.IMG"
  REQUIRED_STORAGE_BYTES  = "14967502"
  ^DESCRIPTION            = "JP2INFO.TXT"
END_OBJECT                = COMPRESSED_FILE

OBJECT                    = UNCOMPRESSED_FILE
  FILE_NAME               = "HDEM_45N_1000M.IMG"
RECORD_TYPE               = FIXED_LENGTH
FILE_RECORDS              = 4096
RECORD_BYTES              = 8192
^IMAGE                    = "HDEM_45N_1000M.IMG"
  OBJECT                  = IMAGE
    NAME                  = HEIGHT
    DESCRIPTION           = "Each sample represents height relative to a
```

```
      reference radius (OFFSET) and is generated using altimetry data
      produced by the MLA team."
    LINES                  = 4096
    LINE_SAMPLES           = 4096
    MINIMUM                = -11188
    MAXIMUM                = 7952
    SAMPLE_TYPE            = LSB_INTEGER
    SAMPLE_BITS            = 16
    UNIT                   = METER
    SCALING_FACTOR         = 0.5
    OFFSET                 = 2439400
  END_OBJECT               = IMAGE
END_OBJECT                 = UNCOMPRESSED_FILE

OBJECT                     = AUX_FILE
  FILE_NAME                = "HDEM_45N_1000M_AUX.XML"
  RECORD_TYPE              = STREAM
  FILE_RECORDS             = UNK
  DESCRIPTION              = "This is an auxiliary file accompanying
     the JPEG2000 file. It contains metadata in XML format that
     is useful for displaying the image using a GDAL supported tool."
END_OBJECT                 = AUX_FILE

OBJECT                     = IMAGE_MAP_PROJECTION
 ^DATA_SET_MAP_PROJECTION      = "DSMAP_POLAR.CAT"
 MAP_PROJECTION_TYPE           = "POLAR STEREOGRAPHIC"
 KEYWORD_LATITUDE_TYPE         = "PLANETOCENTRIC"
 MAP_RESOLUTION                = 42.586 <pix/deg>
 A_AXIS_RADIUS                 = 2439.4 <km>
 B_AXIS_RADIUS                 = 2439.4 <km>
 C_AXIS_RADIUS                 = 2439.4 <km>
 FIRST_STANDARD_PARALLEL       = 'N/A'
 SECOND_STANDARD_PARALLEL      = 'N/A'
 POSITIVE_LONGITUDE_DIRECTION = "EAST"
 CENTER_LATITUDE               = 90 <deg>
 CENTER_LONGITUDE              = 0 <deg>
 REFERENCE_LATITUDE            = 'N/A'
 REFERENCE_LONGITUDE           = 'N/A'
 LINE_FIRST_PIXEL              = 1
 LINE_LAST_PIXEL               = 4096
 SAMPLE_FIRST_PIXEL            = 1
 SAMPLE_LAST_PIXEL             = 4096
 MAP_PROJECTION_ROTATION       = 0.0
 MAP_SCALE                     = 1000 <m/pix>
 MAXIMUM_LATITUDE              = 90 <deg>
 MINIMUM_LATITUDE              = 45 <deg>
 WESTERNMOST_LONGITUDE         = 'N/A'
 EASTERNMOST_LONGITUDE         = 'N/A'
 LINE_PROJECTION_OFFSET        = 2047.5 <pix>
 SAMPLE_PROJECTION_OFFSET      = 2047.5 <pix>
 COORDINATE_SYSTEM_TYPE        = "BODY-FIXED ROTATING"
 COORDINATE_SYSTEM_NAME        = "PLANETOCENTRIC"
END_OBJECT                     = IMAGE_MAP_PROJECTION

END
```

8.8 Appendix – MLA Polar DEM PDS Label

```
PDS_VERSION_ID             = "PDS3"
PRODUCT_VERSION_ID         = "V2.0"
DATA_SET_ID                = "MESS-E/V/H-MLA-4-GDR-V1.0"
PRODUCT_ID                 = "MSGR_DEM_MLA_NP_V01"
INSTRUMENT_HOST_NAME       = "MESSENGER"
INSTRUMENT_NAME            = "MERCURY LASER ALTIMETER"
INSTRUMENT_ID              = "MLA"
MISSION_PHASE_NAME         = {"MERCURY 1 FLYBY","MERCURY 2 FLYBY",
                             "MERCURY ORBIT","MERCURY ORBIT YEAR 2",
                             "MERCURY ORBIT YEAR 3","MERCURY ORBIT YEAR 4",
                             "MERCURY ORBIT YEAR 5"}
TARGET_NAME                = MERCURY
START_TIME                 = 2008-01-14
STOP_TIME                  = 2015-04-30
PRODUCT_CREATION_TIME      = 2016-04-11
PRODUCER_ID                = MESSENGER_MLA_TEAM
PRODUCER_FULL_NAME         = "DAVID E. SMITH"
```

```
PRODUCER_INSTITUTION_NAME = "GODDARD SPACE FLIGHT CENTER"
DESCRIPTION               = "This data product is a shape map (radius)
   of the north pole of Mercury at a resolution of 665.24 m/pix by
   665.24 m/pix, roughly 64 pixels per degree, true at the
   pole in polar stereographic (spherical) projection, based on altimetry
   data acquired by the MLA instrument.  The MLA Laser data through
   Mercury Orbit Year 5 are the source for this gridded product.

   This particular resolution has been chosen for correspondence with the
   USGS DEM product MSGR_DEM_USG_NP_J_V01.

   The ground tracks are interpolated using the Generic Mapping Tools
   programs 'mapproject', 'nearneighbor' and 'surface'. The map is in the
   form of a binary table.  Map values are relative to a radius of 2439.4 km.

   This label describes an IMG file, which is composed of a set of pixels
   that represent finite areas, and not discrete points. "

OBJECT                    = UNCOMPRESSED_FILE
FILE_NAME                 = "MSGR_DEM_MLA_NP_V01.IMG"
RECORD_TYPE               = FIXED_LENGTH
FILE_RECORDS              = 4800
RECORD_BYTES              = 9600
^IMAGE                    = "MSGR_DEM_MLA_NP_V01.IMG"
  OBJECT                  = IMAGE
    NAME                  = HEIGHT
    DESCRIPTION           = "Each sample represents height relative to a
      reference radius (OFFSET) and is generated using altimetry data
      produced by the MLA team."
    LINES                 = 4800
    LINE_SAMPLES          = 4800
    MINIMUM               = -10028
    MAXIMUM               = 6089
    MISSING_CONSTANT      = -32768
    SAMPLE_TYPE           = LSB_INTEGER
    SAMPLE_BITS           = 16
    UNIT                  = METER
    SCALING_FACTOR        = 0.5
    OFFSET                = 2439400

/* NOTE:                                                                  */
/* Conversion from Digital Number to HEIGHT, i.e. elevation in meters, is: */
/* HEIGHT = (DN * SCALING_FACTOR).                                        */
/* The conversion from Digital Number to PLANETARY_RADIUS in meters is:   */
/* PLANETARY_RADIUS = (DN * SCALING_FACTOR) + OFFSET                      */
/* where OFFSET is the radius of a reference sphere.                      */
/* The planetopotential TOPOGRAPHY is PLANETARY_RADIUS - GEOID_RADIUS,    */
/* where GEOID_RADIUS is derived from a gravitational equipotential model. */
/* By convention, the average GEOID_RADIUS at the equator is OFFSET.      */

  END_OBJECT              = IMAGE
END_OBJECT                = UNCOMPRESSED_FILE

OBJECT                    = IMAGE_MAP_PROJECTION
 ^DATA_SET_MAP_PROJECTION     = "DSMAP_POLAR.CAT"
 MAP_PROJECTION_TYPE          = "POLAR STEREOGRAPHIC"
 KEYWORD_LATITUDE_TYPE        = "PLANETOCENTRIC"
 MAP_RESOLUTION               = 64 <pix/deg>
 A_AXIS_RADIUS                = 2439.4 <km>
 B_AXIS_RADIUS                = 2439.4 <km>
 C_AXIS_RADIUS                = 2439.4 <km>
 FIRST_STANDARD_PARALLEL      = 'N/A'
 SECOND_STANDARD_PARALLEL     = 'N/A'
 POSITIVE_LONGITUDE_DIRECTION = "EAST"
 CENTER_LATITUDE              = 90 <deg>
 CENTER_LONGITUDE             = 0 <deg>
 REFERENCE_LATITUDE           = 'N/A'
 REFERENCE_LONGITUDE          = 'N/A'
 LINE_FIRST_PIXEL             = 1
 LINE_LAST_PIXEL              = 4800
 SAMPLE_FIRST_PIXEL           = 1
 SAMPLE_LAST_PIXEL            = 4800
 MAP_PROJECTION_ROTATION      = 0.0
 MAP_SCALE                    = 665.243152705 <m/pix>
 MAXIMUM_LATITUDE             = 90 <deg>
 MINIMUM_LATITUDE             = 53.7587111233 <deg>
```

```
 WESTERNMOST_LONGITUDE        = 'N/A'
 EASTERNMOST_LONGITUDE        = 'N/A'
 LINE_PROJECTION_OFFSET       = 2399.5 <pix>
 SAMPLE_PROJECTION_OFFSET     = 2399.5 <pix>
 COORDINATE_SYSTEM_TYPE       = "BODY-FIXED ROTATING"
 COORDINATE_SYSTEM_NAME       = "PLANETOCENTRIC"
END_OBJECT                    = IMAGE_MAP_PROJECTION

END
```

8.9 Appendix - Contents of MLASCICDR.FMT

```
/* Definition:                                                          */
/* T0 is the electronic event which starts the range measurement timer.  */
/* The laser pulse typically occurs ~820 microseconds after T0. See      */
/* the MLA Instrument paper [CAVANAUGHETAL2007] for details regarding    */
/* instrument event timing.                                             */

OBJECT        = COLUMN
   NAME           = ET
   COLUMN_NUMBER  = 1
   BYTES          = 16
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 1
   FORMAT         = "F16.6"
   UNIT           = "SECOND"
   DESCRIPTION    = "The independent variable of the equations of motion,
     in seconds from the J2000 epoch, at the shot timing origin T0.
     In the past this variable has been referred to at JPL as Ephemeris Time
     and at MIT, later at the Center for Astrophysics, as Coordinate Time.
     Its practical realization is the project-supplied clock kernel,
     applied to the Spacecraft Clock Mission Elapsed Time (MET) count
     that is transmitted to MESSENGER subsystems by the Integrated
     Electronics Module corresponding to the 1 PPS signal. The NAIF
     SPICE spacecraft clock (SCLK) kernel determines a corresponding
     Terrestrial Dynamic Time. These times are synchronous with respect
     to an observer at the Solar System barycenter in a relativistic sense.
     The SPICE library routine SCS2E performs the conversion to
     Ephemeris Time as used by the Project-supplied ephemeris files."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = UTC
   COLUMN_NUMBER  = 2
   BYTES          = 24
   DATA_TYPE      = TIME
   START_BYTE     = 18
   DESCRIPTION    = "Shot timing origin T0,
     converted to Coordinated Universal Time (UTC).
     The project-supplied clock kernel and NAIF routines convert MET into
     Terrestrial Dynamical Time (TDT) seconds past the J2000 epoch, and by
     accounting for leap seconds and the 32.184 s offset between TDT
     and UTC, to a standard calendar representation of UTC."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = MET
   COLUMN_NUMBER  = 3
   BYTES          = 9
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 43
   DESCRIPTION    = "Mission elapsed time in seconds at the last 1 PPS tick."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SHOT_NUMBER
   COLUMN_NUMBER  = 4
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 53
   DESCRIPTION    = "Number of 8 Hz shot or minor frame, 0-7"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = VGA_GAIN
```

```
   COLUMN_NUMBER  = 5
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 55
   FORMAT         = "F6.3"
   DESCRIPTION    = "Commanded value for VGA gain."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CH1_HI_THLD
   COLUMN_NUMBER  = 6
   BYTES          = 7
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 62
   FORMAT         = "F7.4"
   UNIT           = "VOLT"
   DESCRIPTION    = "The threshold setting for channel 1 high."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = NOISE_CH1_HI
   COLUMN_NUMBER  = 7
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 70
   FORMAT         = "I5"
   DESCRIPTION    = "Number of noise hits detected on Channel 1 high, summed
     over 4 shots, from plog4.4 compressed value."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CH1_LO_THLD
   COLUMN_NUMBER  = 8
   BYTES          = 7
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 76
   FORMAT         = "F7.4"
   UNIT           = "VOLT"
   DESCRIPTION    = "The threshold setting for channel 1 low,
                     volts."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = NOISE_CH1_LO
   COLUMN_NUMBER  = 9
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 84
   FORMAT         = "I5"
   DESCRIPTION    = "Number of noise hits detected on Channel 1 low,
     summed over 4 shots, from plog4.4 compressed value."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CH2_THLD
   COLUMN_NUMBER  = 10
   BYTES          = 7
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 90
   FORMAT         = "F7.4"
   UNIT           = "VOLT"
   DESCRIPTION    = "The threshold setting for channel 2,
                     volts."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = NOISE_CH2
   COLUMN_NUMBER  = 11
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 98
   FORMAT         = "I5"
   DESCRIPTION    = "Number of noise hits detected on Channel 2,
     summed over 4 shots, from plog4.4 compressed value."
END_OBJECT    = COLUMN
```

```
OBJECT        = COLUMN
   NAME           = CH3_THLD
   COLUMN_NUMBER  = 12
   BYTES          = 7
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 104
   FORMAT         = "F7.4"
   UNIT           = "VOLT"
   DESCRIPTION    = "The threshold setting for channel 3,
                     volts."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = NOISE_CH3
   COLUMN_NUMBER  = 13
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 112
   FORMAT         = "I5"
   DESCRIPTION    = "Number of noise hits detected on Channel 3,
     summed over 4 shots, from plog4.4 compressed value."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = TX_ENERGY
   COLUMN_NUMBER  = 14
   BYTES          = 4
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 118
   FORMAT         = "F4.1"
   UNIT           = "MILLIJOULE"
   DESCRIPTION    = "Transmitted laser pulse energy."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = STARTPLS_TIME
   COLUMN_NUMBER  = 15
   BYTES          = 9
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 123
   FORMAT         = "F9.1"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Time of leading edge of transmit laser pulse
     relative to T0."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
  NAME             = STARTPLS_WIDTH
  COLUMN_NUMBER    = 16
  BYTES            = 4
  DATA_TYPE        = ASCII_REAL
  START_BYTE       = 133
  FORMAT           = "F4.1"
  UNIT             = "nanosecond"
  MISSING_CONSTANT = 99.9
  DESCRIPTION      = "Width of transmit laser pulse in nanoseconds, used
    to determine centroid time of outgoing pulse. A value of 99.9
    denotes a measurement whose pulse width is invalid."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = RANGE_GATE_START
   COLUMN_NUMBER  = 17
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 138
   FORMAT         = "I5"
   DESCRIPTION    = "Range gate start from RMU; units of 30 meters."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = RANGE_GATE_STOP
   COLUMN_NUMBER  = 18
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 144
```

```
   FORMAT         = "I5"
   DESCRIPTION    = "Range gate stop from RMU; units of 30 meters."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SC_RANGE
   COLUMN_NUMBER  = 18
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 150
   FORMAT         = "I5"
   DESCRIPTION    = "The spacecraft range value used by the science task for
      algorithm calculations, in units of 30 meters per count.
      This value is calculated in real time by the spacecraft using its
      attitude and position knowledge relative to the planet. The range
      is provided to the instrument asynchronously at one second intervals.
      As soon as the science task receives a range message, it begins using
      the new range in its calculations. This value is an estimate only.
      The spacecraft range reported in telemetry may NOT be the one used
      throughout the entire second of algorithm calculations."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CH1_HI_RX_TIME
   COLUMN_NUMBER  = 20
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 156
   FORMAT         = "F10.1"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Time of leading edge of high threshold received
     laser pulse relative to T0."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
  NAME             = CH1_HI_RX_WIDTH
  COLUMN_NUMBER    = 21
  BYTES            = 4
  DATA_TYPE        = ASCII_REAL
  START_BYTE       = 167
  FORMAT           = "F4.1"
  UNIT             = "nanosecond"
  MISSING_CONSTANT = 99.9
  DESCRIPTION      = "Width of high threshold received laser pulse, used
     determine centroid time of return pulse. A value of 99.9 denotes
     a measurement whose pulse width is invalid."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = WIDE_FILT_RX_CNT
   COLUMN_NUMBER  = 22
   BYTES          = 2
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 172
   FORMAT         = "I2"
   DESCRIPTION    = "Total number of wide filter low returns downlinked,
     a maximum is 10 (although the hardware can record up to 15 triggers).
     The use of multiple triggers is described in [CAVANAUGHETAL2007].
     In order to compress data for telemetry, a variable length packet
     is issued, and this record may contain none, or up to 10, groups of
     event ids, times, and pulse widths. The leading and trailing event times
     consist of a coarse time count and a fine time count.
     The trailing event coarse time is downlinked as the four
     least significant bits of the coarse time difference. This difference
     should normally be zero or one depending on the phase of the return
     with respect to the coarse clock. The difference is sometimes one count
     greater than the actual difference, for reasons that are unclear, and
     the difference is reduced by one count, or 200 ns.
     If all 4 least significant bits of the coarse time difference are set,
     the pulse width is invalid and is set to zero. A nominal offset should
     be used to approximate the centroid time. Otherwise, the difference
     LOW_RX_WIDTH_n between leading and trailing edge event time is returned.
     The nominal centroid time is the leading edge time plus 1/2 this width.
     The FSW determines whether returns contain signal and downlinks only
     those low returns that are likely to be ground returns.
     If signal is not found by the FSW algorithm, it downlinks all triggers.
```

```
     Each of the triggers has a 3-bit leading and trailing edge id of 1, 2,
     or 4, corresponding to discriminators on filter channels 1, 2, and 3.
     The LOW_RX_ID_n is the logical AND of the leading and trailing ids.
     The RMU may occasionally issue multiple id's for an event, but the
     event id is that of the first valid filter channel discriminator, i.e.,
                    =0 invalid pulse, or lead and trail ID do not match.
                    =1 channel 1 low
                    =2 channel 2 low
                    =4 channel 3 low.
                    =5 pad values follow

     Values greater than 5 denote low returns classified as non-ground, i.e.,
     noise returns, resulting from an editing procedure. Such returns are
     ignored by the subsequent Science geolocation software.
     The ten or fewer WIDE_FILT_RX_CNT groups of events now follow."
END_OBJECT    = COLUMN

***** DEFINITION OF TEN GROUPS OF THREE OBJECTS

OBJECT        = COLUMN
   NAME           = LOW_RX_ID_1
   COLUMN_NUMBER  = 23
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 175
   FORMAT         = "I1"
   DESCRIPTION    = "ID for low return pulse 1."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_TIME_1
   COLUMN_NUMBER  = 24
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 177
   FORMAT         = "F10.1"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Leading edge time for low return pulse 1, if valid,
      relative to T0."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_WIDTH_1
   COLUMN_NUMBER  = 25
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 188
   FORMAT         = "F6.1"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Time difference between leading and trailing edge of low
      pulse 1, used to determine centroid time and spread of return pulse."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_ID_2
   COLUMN_NUMBER  = 26
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 195
   FORMAT         = "I1"
   DESCRIPTION    = "ID for low return pulse 2."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_TIME_2
   COLUMN_NUMBER  = 27
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 197
   FORMAT         = "F10.1"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Leading edge time for low return pulse 2, if valid,
      relative to T0."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
```

```
   NAME           = LOW_RX_WIDTH_2
   COLUMN_NUMBER  = 28
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 208
   FORMAT         = "F6.1"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Time difference between leading and trailing edge of low
      pulse 2, used to determine centroid time and spread of return pulse."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_ID_3
   COLUMN_NUMBER  = 29
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 215
   FORMAT         = "I1"
   DESCRIPTION    = "ID for low return pulse 3."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_TIME_3
   COLUMN_NUMBER  = 30
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 217
   FORMAT         = "F10.1"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Leading edge time for low return pulse 3, if valid,
      relative to T0."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_WIDTH_3
   COLUMN_NUMBER  = 31
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 228
   FORMAT         = "F6.1"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Time difference between leading and trailing edge of low
      pulse 3, used to determine centroid time and spread of return pulse."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_ID_4
   COLUMN_NUMBER  = 32
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 235
   FORMAT         = "I1"
   DESCRIPTION    = "ID for low return pulse 4."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_TIME_4
   COLUMN_NUMBER  = 33
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 237
   FORMAT         = "F10.1"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Leading edge time for low return pulse 4, if valid,
      relative to T0."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_WIDTH_4
   COLUMN_NUMBER  = 34
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 248
   FORMAT         = "F6.1"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Time difference between leading and trailing edge of low
```

```
      pulse 4, used to determine centroid time and spread of return pulse."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_ID_5
   COLUMN_NUMBER  = 35
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 255
   FORMAT         = "I1"
   DESCRIPTION    = "ID for low return pulse 5."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_TIME_5
   COLUMN_NUMBER  = 36
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 257
   FORMAT         = "F10.1"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Leading edge time for low return pulse 5, if valid,
      relative to T0."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_WIDTH_5
   COLUMN_NUMBER  = 37
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 268
   FORMAT         = "F6.1"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Time difference between leading and trailing edge of low
      pulse 5, used to determine centroid time and spread of return pulse."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_ID_6
   COLUMN_NUMBER  = 38
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 275
   FORMAT         = "I1"
   DESCRIPTION    = "ID for low return pulse 6."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_TIME_6
   COLUMN_NUMBER  = 39
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 277
   FORMAT         = "F10.1"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Leading edge time for low return pulse 6, if valid,
      relative to T0."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_WIDTH_6
   COLUMN_NUMBER  = 40
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 288
   FORMAT         = "F6.1"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Time difference between leading and trailing edge of low
      pulse 6, used to determine centroid time and spread of return pulse."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_ID_7
   COLUMN_NUMBER  = 41
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
```

```
   START_BYTE     = 295
   FORMAT         = "I1"
   DESCRIPTION    = "ID for low return pulse 7."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_TIME_7
   COLUMN_NUMBER  = 42
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 297
   FORMAT         = "F10.1"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Leading edge time for low return pulse 7, if valid,
      relative to T0."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_WIDTH_7
   COLUMN_NUMBER  = 43
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 308
   FORMAT         = "F6.1"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Time difference between leading and trailing edge of low
      pulse 7, used to determine centroid time and spread of return pulse."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_ID_8
   COLUMN_NUMBER  = 44
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 315
   FORMAT         = "I1"
   DESCRIPTION    = "ID for low return pulse 8."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_TIME_8
   COLUMN_NUMBER  = 45
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 317
   FORMAT         = "F10.1"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Leading edge time for low return pulse 8, if valid,
      relative to T0."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_WIDTH_8
   COLUMN_NUMBER  = 46
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 328
   FORMAT         = "F6.1"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Time difference between leading and trailing edge of low
      pulse 8, used to determine centroid time and spread of return pulse."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_ID_9
   COLUMN_NUMBER  = 47
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 335
   FORMAT         = "I1"
   DESCRIPTION    = "ID for low return pulse 9."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_TIME_9
   COLUMN_NUMBER  = 48
```

```
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 337
   FORMAT         = "F10.1"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Leading edge time for low return pulse 9, if valid,
      relative to T0."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_WIDTH_9
   COLUMN_NUMBER  = 49
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 348
   FORMAT         = "F6.1"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Time difference between leading and trailing edge of low
      pulse 9, used to determine centroid time and spread of return pulse."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_ID_10
   COLUMN_NUMBER  = 50
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 355
   FORMAT         = "I1"
   DESCRIPTION    = "ID for low return pulse 10."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_TIME_10
   COLUMN_NUMBER  = 51
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 357
   FORMAT         = "F10.1"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Leading edge time for low return pulse 10, if valid,
      relative to T0."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_RX_WIDTH_10
   COLUMN_NUMBER  = 52
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 368
   FORMAT         = "F6.1"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Time difference between leading and trailing edge of low
      pulse 10, used to determine centroid time and spread of return pulse."
END_OBJECT    = COLUMN

/*** SIGNAL PROCESSING INFO updated every 10-s superframe ***/

OBJECT        = COLUMN
   NAME           = ALGORITHM_MODE
   COLUMN_NUMBER  = 53
   BYTES          = 2
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 375
   FORMAT         = "I2"
   DESCRIPTION    = " "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SIGNAL_FOUND
   COLUMN_NUMBER  = 54
   BYTES          = 2
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 378
   FORMAT         = "I2"
   DESCRIPTION    = " "
END_OBJECT    = COLUMN
```

```
OBJECT        = COLUMN
   NAME           = SIG_FRAM_PER_SUPER
   COLUMN_NUMBER  = 55
   BYTES          = 2
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 381
   FORMAT         = "I2"
   DESCRIPTION    = " "
END_OBJECT    = COLUMN
```

8.10 Appendix - Contents of MLASTACDR.FMT

```
/* Version 1.2 with comma-delimiters beginning with time */
OBJECT        = COLUMN
   NAME           = ET
   COLUMN_NUMBER  = 1
   BYTES          = 16
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 1
   FORMAT         = "F16.6"
   UNIT           = "SECOND"
   DESCRIPTION    = "The independent variable of the equations of motion,
     in seconds from the J2000 epoch, at the shot timing origin T0.
     In the past this variable has been referred to at JPL as Ephemeris Time
     and at MIT, later at the Center for Astrophysics, as Coordinate Time.
     Its practical realization is the project-supplied clock kernel,
     applied to the Spacecraft Clock Mission Elapsed Time (MET) count
     that is transmitted to MESSENGER subsystems by the Integrated
     Electronics Module corresponding to the 1 PPS signal. The NAIF
     SPICE spacecraft clock (SCLK) kernel determines a corresponding
     Terrestrial Dynamic Time. These times are synchronous with respect
     to an observer at the Solar System barycenter in a relativistic sense.
     The SPICE library routine SCS2E performs the conversion to
     Ephemeris Time as used by the Project-supplied ephemeris files."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = UTC
   COLUMN_NUMBER  = 2
   BYTES          = 24
   DATA_TYPE      = TIME
   START_BYTE     = 18
   DESCRIPTION    = "Spacecraft clock (MET) converted to Coordinated Universal
                     Time (UTC) using the project-supplied conversion from MET
                     into Terrestrial Dynamical Time (TDT) seconds past the
                     J2000 epoch, and by accounting for leap seconds and the
                     offset between atomic time and UTC,
                     into to an ISO standard calendar representation of UTC."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = MET
   COLUMN_NUMBER  = 3
   BYTES          = 9
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 43
   DESCRIPTION    = "Spacecraft clock count, the Mission Elapsed Time in
                     seconds, transmitted to subsystems by the Integrated
                     Electronics Module, corresponding to the 1 PPS signal."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = RMU_DATA_SIZE
   COLUMN_NUMBER  = 4
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 53
   DESCRIPTION    = "RMU supports two interfaces in reading the RMU shot data
     after every RUPT: byte mode and nibble mode. The nibble mode is not
     supported by flight software, therefore this telemetry point should
     always read 0, for byte mode."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
```

```
   NAME           = RMU_TEST_PATTERN
   COLUMN_NUMBER  = 5
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 55
   DESCRIPTION    = "Test pattern used to fill RMU shot data.
      0,6,7: real data, 1: LFSR, 2: 0xAA, 3: 0x55, 4: Counter, 5: ~Counter
   "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = RMU_DATA_TYPE
   COLUMN_NUMBER  = 6
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 57
   DESCRIPTION    = "Identifies shot data as real or test data.
     =0 real data, =1 test data."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = RMU_RATE_SELECT
   COLUMN_NUMBER  = 7
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 59
   DESCRIPTION    = "RMU Rate selected. =0, 1Hz, =1 6Hz, =2 8Hz, =3 10Hz"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CANNED_DATA
   COLUMN_NUMBER  = 8
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 61
   DESCRIPTION    = "Designates whether flight software is using a collection
     of RMU shot data or fake data as input to the science algorithms.
      =0 Real Data, =1 Fake Data
    "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = RMU_1PPS_SYNC
   COLUMN_NUMBER  = 9
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 63
   DESCRIPTION    = "RMU synchronized with 1PPS flag.
    =0, not synchronized, =1 synchronized"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = RMU_TRANSFER_MODE
   COLUMN_NUMBER  = 10
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 65
   DESCRIPTION    = "Data Transfer mode commanded to RMU. Does not reflect
      the state of the RMU but rather the state of the software and how the
      software is reading the RMU. It is possible after an RMU reset to have
      this telemetry point not coincide with RMU_DATA_SIZE.
      =0 byte mode, =1 low nibble, =2 high nibble
   "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DETECTOR_CH3
   COLUMN_NUMBER  = 11
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 67
   DESCRIPTION    = "Status of detector channel 3:
     =0 enabled, =1 disabled."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
```

```
    NAME           = DETECTOR_CH2
    COLUMN_NUMBER  = 12
    BYTES          = 1
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 69
    DESCRIPTION    = "Status of detector channel 2:
      =0 enabled, =1 disabled."
  END_OBJECT    = COLUMN

  OBJECT        = COLUMN
    NAME           = DETECTOR_CH1LO
    COLUMN_NUMBER  = 13
    BYTES          = 1
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 71
    DESCRIPTION    = "Status of detector channel 1 low:
      =0 enabled, =1 disabled."
  END_OBJECT    = COLUMN

  OBJECT        = COLUMN
    NAME           = DETECTOR_CH1HI
    COLUMN_NUMBER  = 14
    BYTES          = 1
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 73
    DESCRIPTION    = "Status of detector channel 1 high:
      =0 enabled, =1 disabled."
  END_OBJECT    = COLUMN

  OBJECT        = COLUMN
    NAME           = DUMP_ACTIVE
    COLUMN_NUMBER  = 15
    BYTES          = 1
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 75
    DESCRIPTION    = "Designates whether software is performing a memory dump.
       =0 not performing memory dump
       =1 currently performing memory dump"
  END_OBJECT    = COLUMN

  OBJECT        = COLUMN
    NAME           = RMU_CLOCK_SELECT
    COLUMN_NUMBER  = 16
    BYTES          = 1
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 77
    DESCRIPTION    = "Clock configuration for the RMU. This drives the entire
       operation of the RMU. RMU has 4 different 5MHz clocks available to it,
       two internal to the RMU board and two external from the spacecraft.
       =0 Oscillator A, =1 Internal 40%, =2 Internal 50%, =3 Oscillator B"
  END_OBJECT    = COLUMN

  OBJECT        = COLUMN
    NAME           = RMU_CYCLE_RESET_TOF
    COLUMN_NUMBER  = 17
    BYTES          = 1
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 79
    DESCRIPTION    = "RMU uses TOF chips to measure in fine detail the return
       pulses coming back from a laser fire. The chips are prone to lockup if
       flooded with input. If the flight software detects that they are locked
       up, it will automatically configure the RMU to reset the TOF chips for
       one shot. Unfortunately the rate at which this telemetry point is
       monitored means that it is very unlikely that this event will ever be
       reflected in this telemetry point.
       =0 TOF chips are not reset after each shot.
       =1 TOF chips are reset after each shot."
  END_OBJECT    = COLUMN

  OBJECT        = COLUMN
    NAME           = RMU_CAL_SELECT
    COLUMN_NUMBER  = 18
    BYTES          = 1
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 81
    DESCRIPTION    = "Indicates which calibration setting was applied to the
```

```
      RMU during ground testing, if enabled:
      00=0ns, 01=200ns, 10=400ns, 11=200ns"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = RMU_CAL_ENABLE
   COLUMN_NUMBER  = 19
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 83
   DESCRIPTION    = "Indicates whether RMU will output a fixed test pattern
      during ground testing as selected by RMU_CAL_SELECT:
      00,01,10=Real Data from instrument, 11=TOF-A calibration data"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = OVR_THRESHOLD_CH3
   COLUMN_NUMBER  = 20
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 85
   DESCRIPTION    = "Indicates whether the science task has overridden (via
    command) the channel 3 threshold value written as a DAC to the
    hardware. =0 not overridden, =1 overridden"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = OVR_THRESHOLD_CH2
   COLUMN_NUMBER  = 21
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 87
   DESCRIPTION    = "Indicates whether the science task has overridden (via
      command) the channel 2 threshold value written as a DAC to the
      hardware. =0 not overridden, =1 overridden"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = OVR_THRESHOLD_CH1LO
   COLUMN_NUMBER  = 22
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 89
   DESCRIPTION    = "Indicates whether the science task has overridden (via
      command) the channel 1 low threshold value written as a DAC to the
       hardware. =0 not overridden, =1 overridden"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = OVR_THRESHOLD_CH1HI
   COLUMN_NUMBER  = 23
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 91
   DESCRIPTION    = "Indicates whether the science task has overridden (via
      command) the channel 1 high threshold value written as a DAC to the
      hardware. =0 not overridden, =1 overridden
  "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = OVR_CHAN_DISABLES
   COLUMN_NUMBER  = 24
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 93
   DESCRIPTION    = "Indicates whether channel disables mask used by
      science algorithms has been overridden. This mask is used to enable
      and disable the return channels (1hi, 1low, 2, 3).
      =0 not overridden, =1 overridden.
 "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = OVR_GAIN
   COLUMN_NUMBER  = 25
```

```
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 95
   DESCRIPTION    = "Indicates whether the science task has overridden (via
      command) the gain value written as a DAC to the hardware.
      =0 not overridden, =1 overridden.
 "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = OVR_RANGE_WINDOW
   COLUMN_NUMBER  = 26
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 97
   DESCRIPTION    = "Indicates whether the science task has overridden (via
      command) the range window vlaue used to write the RMU range gate
      start and stop. =0 not overridden, =1 overridden.
  "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = OVR_RANGE_DELAY
   COLUMN_NUMBER  = 27
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 99
   DESCRIPTION    = "Indicates whether the science task has overridden (via
      command) the range delay value used to write the RMU range gate start
       and stop. =0 not overridden, =1 overridden.
  "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = V2DOT5_MON
   COLUMN_NUMBER  = 28
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 101
   DESCRIPTION    = "The ADC of the +2.5 volt monitor."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = V5_MON
   COLUMN_NUMBER  = 29
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 105
   DESCRIPTION    = "The ADC of the +5 volt monitor."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = V5NEG_MON
   COLUMN_NUMBER  = 30
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 109
   DESCRIPTION    = "The ADC of the -5 volt monitor."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = V12_MON
   COLUMN_NUMBER  = 31
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 113
   DESCRIPTION    = "The ADC of the +12 volt monitor."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = V32DOT5_MON
   COLUMN_NUMBER  = 32
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 117
   DESCRIPTION    = "The ADC of the +32.5 volt monitor."
```

```
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = V550_MON
   COLUMN_NUMBER  = 33
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 121
   DESCRIPTION    = "The ADC of the +550 volt monitor."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = VOLT2DOT5
   COLUMN_NUMBER  = 34
   BYTES          = 4
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 125
   FORMAT         = "F4.2"
   UNIT           = "VOLT"
   DESCRIPTION    = "The voltage of the +2.5 volt monitor."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = VOLT5
   COLUMN_NUMBER  = 35
   BYTES          = 4
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 130
   FORMAT         = "F4.2"
   UNIT           = "VOLT"
   DESCRIPTION    = "The voltage of the +5 volt monitor."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = VOLT5NEG
   COLUMN_NUMBER  = 36
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 135
   FORMAT         = "F6.2"
   UNIT           = "VOLT"
   DESCRIPTION    = "The voltage of the -5 volt monitor."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = VOLT12
   COLUMN_NUMBER  = 37
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 142
   FORMAT         = "F6.2"
   UNIT           = "VOLT"
   DESCRIPTION    = "The voltage of the +12 volt monitor."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = VOLT32DOT5
   COLUMN_NUMBER  = 38
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 149
   FORMAT         = "F6.2"
   UNIT           = "VOLT"
   DESCRIPTION    = "The voltage of the +32.5 volt monitor."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = VOLT550
   COLUMN_NUMBER  = 39
   BYTES          = 5
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 156
   FORMAT         = "F5.1"
   UNIT           = "VOLT"
   DESCRIPTION    = "The voltage of the +550 volt monitor."
END_OBJECT    = COLUMN
```

```
OBJECT        = COLUMN
   NAME           = LASER_TX_THRESHOLD
   COLUMN_NUMBER  = 40
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 162
   DESCRIPTION    = "The ADC of the laser Tx threshold which is commanded
      by the science task automatically every shot, via a DAC write, using a
      table value."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = VOLT_LASER_TX_THRESHOLD
   COLUMN_NUMBER  = 41
   BYTES          = 7
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 166
   FORMAT         = "F7.4"
   UNIT           = "VOLT"
   DESCRIPTION    = "The voltage of the laser Tx threshold which is commanded
      by the science task automatically every shot, via a DAC write, using a
      table value."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = AEM_LATCHUP_CTR
   COLUMN_NUMBER  = 42
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 174
   DESCRIPTION    = "Count of the number of times the flight software
      responds to an AEM latch-up. It is important to note that this counter
      does not reflect the number of AEM latch-ups, but rather the number of
      times the software responds to a latch-up. Because the AEM is not able
      to remove the latch-up condition fast enough, the software will attempt
      to acknoweldge the same latch-up multiple times. Because of this, the
      software limits the number of latch-up acknowledgements a second to 2.
      In practice, for every AEM latch-up this counter will increment by 2."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DETECTOR_BOARD_TEMP
   COLUMN_NUMBER  = 43
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 178
   DESCRIPTION    = "The ADC of the detector board temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = ALTIMETER_DET_TEMP
   COLUMN_NUMBER  = 44
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 182
   DESCRIPTION    = "The ADC of the altimeter detector temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = ANALOG_BOARD_TEMP
   COLUMN_NUMBER  = 45
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 186
   DESCRIPTION    = "The ADC of the analog board temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = RMU_BOARD_TEMP
   COLUMN_NUMBER  = 46
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 190
   DESCRIPTION    = "The ADC of the RMU board temperature."
END_OBJECT    = COLUMN
```

```
OBJECT        = COLUMN
   NAME           = XTAL_OSCILLATOR_TEMP
   COLUMN_NUMBER  = 47
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 194
   DESCRIPTION    = "The ADC of the crystal oscillator temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CPU_BOARD_TEMP
   COLUMN_NUMBER  = 48
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 198
   DESCRIPTION    = "The ADC of the CPU board temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LASER_ELEC_TEMP
   COLUMN_NUMBER  = 49
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 202
   DESCRIPTION    = "The ADC of the laser electronics temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LASER_AMP_TEMP
   COLUMN_NUMBER  = 50
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 206
   DESCRIPTION    = "The ADC of the laser amplifier temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LASER_OSCILLATOR_TEMP
   COLUMN_NUMBER  = 51
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 210
   DESCRIPTION    = "The ADC of the laser oscillator temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = PCA_TEMP
   COLUMN_NUMBER  = 52
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 214
   DESCRIPTION    = "The ADC of the PCA temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = BEAM_XPAND_TOP_TEMP
   COLUMN_NUMBER  = 53
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 218
   DESCRIPTION    = "The ADC of the beam expander top temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = BEAM_XPAND_BASE_TEMP
   COLUMN_NUMBER  = 54
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 222
   DESCRIPTION    = "The ADC of the beam expander base temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = RX_TUBELENS_TOP_TEMP
   COLUMN_NUMBER  = 55
```

```
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 226
   DESCRIPTION    = "The ADC of the receiver tube lens temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = MLA_HOUSING_TEMP
   COLUMN_NUMBER  = 56
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 230
   DESCRIPTION    = "The ADC of the MLA housing temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CAL_LO_TEMP
   COLUMN_NUMBER  = 57
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 234
   DESCRIPTION    = "The ADC of the low calibration temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CAL_HI_TEMP
   COLUMN_NUMBER  = 58
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 238
   DESCRIPTION    = "The ADC of the high calibration temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DEG_DETECTOR_BOARD_TEMP
   COLUMN_NUMBER  = 59
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   FORMAT         = "F6.2"
   UNIT           = "degC"
   START_BYTE     = 242
   DESCRIPTION    = "The detector board temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DEG_ALTIMETER_DET_TEMP
   COLUMN_NUMBER  = 60
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   FORMAT         = "F6.2"
   UNIT           = "degC"
   START_BYTE     = 249
   DESCRIPTION    = "The altimeter detector temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DEG_ANALOG_BOARD_TEMP
   COLUMN_NUMBER  = 61
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   FORMAT         = "F6.2"
   UNIT           = "degC"
   START_BYTE     = 256
   DESCRIPTION    = "The analog board temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DEG_RMU_BOARD_TEMP
   COLUMN_NUMBER  = 62
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   FORMAT         = "F6.2"
   UNIT           = "degC"
   START_BYTE     = 263
   DESCRIPTION    = "The RMU board temperature."
END_OBJECT    = COLUMN
```

```
OBJECT        = COLUMN
   NAME           = DEG_XTAL_OSCILLATOR_TEMP
   COLUMN_NUMBER  = 63
   BYTES          = 6
   FORMAT         = "F6.2"
   DATA_TYPE      = ASCII_REAL
   UNIT           = "degC"
   START_BYTE     = 270
   DESCRIPTION    = "The crystal oscillator temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DEG_CPU_BOARD_TEMP
   COLUMN_NUMBER  = 64
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   FORMAT         = "F6.2"
   UNIT           = "degC"
   START_BYTE     = 277
   DESCRIPTION    = "The CPU board temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DEG_LASER_ELEC_TEMP
   COLUMN_NUMBER  = 65
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   FORMAT         = "F6.2"
   UNIT           = "degC"
   START_BYTE     = 284
   DESCRIPTION    = "The laser electronics temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DEG_LASER_AMP_TEMP
   COLUMN_NUMBER  = 66
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   FORMAT         = "F6.2"
   UNIT           = "degC"
   START_BYTE     = 291
   DESCRIPTION    = "The laser amplifier temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DEG_LASER_OSCILLATOR_TEMP
   COLUMN_NUMBER  = 67
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 298
   FORMAT         = "F6.2"
   UNIT           = "degC"
   DESCRIPTION    = "The laser oscillator temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DEG_PCA_TEMP
   COLUMN_NUMBER  = 68
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   FORMAT         = "F6.2"
   UNIT           = "degC"
   START_BYTE     = 305
   DESCRIPTION    = "The PCA temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DEG_BEAM_XPAND_TOP_TEMP
   COLUMN_NUMBER  = 69
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   FORMAT         = "F6.2"
   UNIT           = "degC"
   START_BYTE     = 312
   DESCRIPTION    = "The beam expander top temperature."
```

```
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DEG_BEAM_XPAND_BASE_TEMP
   COLUMN_NUMBER  = 70
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   FORMAT         = "F6.2"
   UNIT           = "degC"
   START_BYTE     = 319
   DESCRIPTION    = "The beam expander base temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DEG_RX_TUBELENS_TOP_TEMP
   COLUMN_NUMBER  = 71
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   FORMAT         = "F6.2"
   UNIT           = "degC"
   START_BYTE     = 326
   DESCRIPTION    = "The receiver tube lens temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DEG_MLA_HOUSING_TEMP
   COLUMN_NUMBER  = 72
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   FORMAT         = "F6.2"
   UNIT           = "degC"
   START_BYTE     = 333
   DESCRIPTION    = "The MLA housing temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DEG_CAL_LO_TEMP
   COLUMN_NUMBER  = 73
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   FORMAT         = "F6.2"
   UNIT           = "degC"
   START_BYTE     = 340
   DESCRIPTION    = "The low calibration temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DEG_CAL_HI_TEMP
   COLUMN_NUMBER  = 74
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   FORMAT         = "F6.2"
   UNIT           = "degC"
   START_BYTE     = 347
   DESCRIPTION    = "The high calibration temperature."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = TELEMETRY_VOLUME
   COLUMN_NUMBER  = 75
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 354
   DESCRIPTION    = "Telemetry volume counter. Increments by 1 for every
      1KB of data output by the telemetry framer task since the last software
      boot."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CHECKSUM_ENABLED
   COLUMN_NUMBER  = 76
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 360
   DESCRIPTION    = "An integer representation of the 16-bit mask that
     shows which tables in memory are being checksummed. Each bit in the
```

```
     mask corresponds to the table ID of the same number (bit 4 in the mask
     corresponds to table 4). Convert back to binary notation before
     evaluating the checksumenabled mask:
     =0 table is not being checksummed, =1 table is being checksummed."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CHECKSUM_STATUS
   COLUMN_NUMBER  = 77
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 366
   DESCRIPTION    = "An integer representation of the 16-bit mask that shows
     whether the checksum of a table in memory is correct or incorrect.
     Each bit in the mask corresponds to the table ID of the same number
     (bit 4 in the mask corresponds to table 4). Convert back to binary
     notation before evaluating the checksumstatus mask:
     =0 Checksum is correct, =1 checksum is incorrect"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = TOF_LOCKUP_CNTR
   COLUMN_NUMBER  = 78
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 372
   DESCRIPTION    = "There are 6 TOF chips in the RMU. The RMU uses them
     to time stamp the Tx pulse, the high return, and the low returns. Every
     16 shots the software analyzes the state of the TOFs. If during the past
     16 shots the fine time (least significant 10 bits) on a RMU time stamp
     has not changed at all, and the coarse time has changed at least once,
     then a TOF lockup is detected and this telemetry point is incremented,
     and for the next shot, the TOF chips are configured to be reset. The
     software will immediately begin monitoring for the next 16 shots. The
     software only monitors the TOF lockups in Standby and Science modes."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = TELEM_RATE_CONFIG
   COLUMN_NUMBER  = 79
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 376
   DESCRIPTION    = "Indicates whether the TELEMETRY_VOLUME counter is
    derived from the FSW or from a test source: 0=Oper, 1=Test."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SDHWDIAG_LITESWITCH
   COLUMN_NUMBER  = 80
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 378
   DESCRIPTION    = "=0 The MLA_HWDiagLite packet is off.
                     =1 The MLA_HwDiagLite packet is on.
    "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SI_TIMING_VALID
   COLUMN_NUMBER  = 81
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 380
   DESCRIPTION    = "Check of timing integrity at rate of once per second.
        Three checks are performed:
             1. Has MET message from S/C been received
             2. Has the 1PPS signal from the S/C been received
             3. Is the phase lock to the 1PPS off by more than 5 us
            If any of the checks fail then the timing integrity is in
             question.
             =0 Timing integrity fine,
             =1 Timing integrity under question."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
```

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   NAME           = CHECKSUM_EN_FLAG
   COLUMN_NUMBER  = 82
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 382
   DESCRIPTION    = "=0 checksumming of tables is disabled.
                     =1 checksumming of tables is enabled."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = ONE_PPS_OCCURRED
   COLUMN_NUMBER  = 83
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 384
   DESCRIPTION    = "Each second the spacecraft sends a 1PPS signal to the
      MLA instrument. The flight software uses this signal to synchronize.
      =0 1PPS did not occur, =1 1PPS occured."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SDHWDIAG_FULLSWITCH
   COLUMN_NUMBER  = 84
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 386
   DESCRIPTION    = "=0 MLA_HwDiagnostic packet is off.
      =1 MLA_HwDiagnostic packet is on."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = OS_EPROM_VERSION
   COLUMN_NUMBER  = 85
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 388
   DESCRIPTION    = "There are two banks of EEPROM that the software is
      stored in.  When the instrument is turned on, or any time the CPU board
      is rebooted, the code stored in EEPROM is copied out of one of the two
      banks, into RAM and executed there.  This telemetry point says which
      bank of EEPROM the code was copied out of.
      =0 EEPROM Bank 0 - Non Write-Protected
      =1 EEPROM Bank 1 - Write-Protected"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SIDIRECT_THRES_OVR
   COLUMN_NUMBER  = 86
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 390
   DESCRIPTION    = "The science task allows the thresholds applied to
      each of the channels to be overridden.  The science algorithms specify
      that the value commanded for them to be overridden with must be scaled
      by a function of the gain, and range window. For testing purposes, it
      was necessary to have the ability to directly apply the threshold given
      in the threshold override command.
      =0 thresholds are scaled as prescribed in science algorithm.
      =1 thresholds are directly applied"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = IDLE_CHECKIN
   COLUMN_NUMBER  = 87
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 392
   DESCRIPTION    = "By default, the flight software requires certain
     critical tasks to 'check in' in order for the watchdog to be kicked.
     In diagnosing a problem it might be necessary to disable that behavior.
      =0 critical tasks do NOT have to check in.
      =1 critical tasks DO have to check in."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = IDLE_MET_CHECKIN
```

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   COLUMN_NUMBER  = 88
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 394
   DESCRIPTION    = "By default, the software checks that the MET is being
      received while in Science mode. If the MET is missing for a preset
      amount of time, then the software will execute the Mla_Safe script which
      will transition the software to Keep Alive mode. This telemetry point
      reflects whether or not the software is actively checking if the MET is
      being received.
      =0 MET not being checked.
        =1 MET being checked."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SISC_TIME_BIAS
   COLUMN_NUMBER  = 89
   BYTES          = 8
   DATA_TYPE      = ASCII_REAL
   FORMAT         = "F8.3"
   UNIT           = "SECOND"
   START_BYTE     = 396
   DESCRIPTION    = "The difference between the s/c ranging data alignment to
   the value of the MET, used in Science algorithm mode 1. Value is a B8
   fraction."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SISC_RANGE_BIAS
   COLUMN_NUMBER  = 90
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 405
   DESCRIPTION    = "The difference between the s/c ranging data alignment to
     the range value, used in Science algorithm mode 1 to account for orbital
     error and other biases. Value is a signed integer number of counts."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SI_TRANSMIT_THRESHOLD
   COLUMN_NUMBER  = 91
   BYTES          = 4
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 411
   DESCRIPTION    = "The transmit start detector threshold value commanded by
     the Science task (currently defaults to 15 counts)."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = VOLT_SI_TRANSMIT_THRESHOLD
   COLUMN_NUMBER  = 92
   BYTES          = 7
   DATA_TYPE      = ASCII_REAL
   FORMAT         = "F7.4"
   UNIT           = "VOLT"
   START_BYTE     = 416
   DESCRIPTION    = "The transmit start detector threshold voltage.
   "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SD_AEM_ERROR_COUNT
   COLUMN_NUMBER  = 93
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 424
   DESCRIPTION    = "Once a second, the flight software performs a series
      of ADCs on the temperatures and voltages.  After every RUPT, the flight
      software performs a series of ADCs on all the items that can be written
      to via a DAC. If any ADC fails, due to a time out (the software pends on
      the AEM asserting that it is finished the ADC), then this counter is
      incremented."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SI_RMU_ERROR_COUNT
```

```
   COLUMN_NUMBER  = 94
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 430
   DESCRIPTION    = "Every shot when the software is in Science mode, the
      science task writes the values of the range gates (start and stop). At
      that time it also reads the values back and compares them to the values
      it wrote. If those two values do not agree then the science task
      increments this counter."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CMD_ACCEPT_CTR
   COLUMN_NUMBER  = 95
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 436
   DESCRIPTION    = "Counter increments every time a command is sent and
      the software executes that command to completion without any errors."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CMD_OPCODE
   COLUMN_NUMBER  = 96
   DATA_TYPE      = CHARACTER
   BYTES          = 4
   START_BYTE     = 442
   DESCRIPTION    = "The opcode of the last command that was processed, as a
     hexadecimal value."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CMD_RESULTCODE
   COLUMN_NUMBER  = 97
   BYTES          = 4
   DATA_TYPE      = CHARACTER
   START_BYTE     = 450
   DESCRIPTION    = "The error code generated by the last command executed.
      If the last command executed did not generate an error, then this value
      is zero. The error code is a hexadecimal value."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = ALARM_ID
   COLUMN_NUMBER  = 98
   BYTES          = 4
   DATA_TYPE      = CHARACTER
   START_BYTE     = 458
   DESCRIPTION    = "The ID of the last alarm issued by the flight software.
     The id is a hexadecimal value."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = ALARM_COUNT
   COLUMN_NUMBER  = 99
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 464
   DESCRIPTION    = "Counter is incremented every time an alarm is issued
      by the flight software. The flight software treats the reset message as
      an alarm, therefore value is one at boot up. However the actual integer
      range of values is from 129 to 255 because the most significant bit
      of the telemetry point is used as a flag that is always set to 1."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CMD_REJECT_COUNT
   COLUMN_NUMBER  = 100
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 468
   DESCRIPTION    = "Counter increments every time the flight software fails
      to execute a command."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
```

```
   NAME           = ITF_REJECT_COUNT
   COLUMN_NUMBER  = 101
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 472
   DESCRIPTION    = "Counter is incremented every time the flight software
      receives an ITF and the ITF is either invalid or unable to be processed.
      The four cases for which this counter increments are:
        Not enough memory available to allocate a software bus packet;
        Invalid command format;
        Incorrect checksum;
        Synch pattern incorrect."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = WATCHDOG_COUNT
   COLUMN_NUMBER  = 102
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 476
   DESCRIPTION    = "Increments on reset of the flight software watchdog."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CPURESET_COUNT
   COLUMN_NUMBER  = 103
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 480
   DESCRIPTION    = "Increments on every reset of the flight software CPU.
      A CPU reset can occur one of two ways:
       Software was directly commanded to reset;
       Software erroneously branched to an unused memory address and executed
       a 0xFF instruction."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = RESET_CAUSE
   COLUMN_NUMBER  = 104
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 484
   DESCRIPTION    = "Every time the flight software reboots, registers in
      the CPU board FPGA are examined in order to determine the cause of the
      reboot:
      =0 Power On, =1 CPU Reset, =2 Watchdog, =3 Invalid."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = MLA_MODE
   COLUMN_NUMBER  = 105
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 486
   DESCRIPTION    = "Flight software mode:
      =0 Keep Alive, =1 Standby, =2 Science"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DPU_SELECTION
   COLUMN_NUMBER  = 106
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 488
   DESCRIPTION    = "The S/C has two DPUs that can interface to the MLA
      instrument. Only one of them can be active at a time.
               =0 DPU A, =1 DPU B"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = WATCHDOG_ENABLED
   COLUMN_NUMBER  = 107
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 490
   DESCRIPTION    = "=1 Watchdog enabled.
```

```
      =0 Watchdog disabled. Flight software will still
      continue to service the watchdog but it will have no affect, nor will
      there be any effect if the software fails to service the watchdog."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = PCA_POWER_MODE
   COLUMN_NUMBER  = 108
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 492
   DESCRIPTION    = "The PCA controls the power on the MLA instrument.
      There are two power modes. Under normal operation, Keep Alive software
      mode configures the PCA to low power mode. Standby and Science software
      modes configure the PCA to high power mode.
      =0 low power mode, =1 high power mode."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = PCA_LASER_ENABLED
   COLUMN_NUMBER  = 109
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 494
   DESCRIPTION    = "The laser on the MLA instrument can be directly turned
      on and off. Under normal operations the laser is automatically
      configured to be on in Science mode and automatically configured to be
      off in all other modes.
      =0 laser is OFF, =1 laser is ON."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = ALGORITHM_MODE
   COLUMN_NUMBER  = 110
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 496
   DESCRIPTION    = "The currently designated science algorithm mode.
      Only modes 0 and 1 were implemented in FSW at launch.
      =0 Mode 0 or Fixed, =1 Mode 1 or Scraft Range, =2 Closed Loop."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = RANGE_MODE
   COLUMN_NUMBER  = 111
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 498
   DESCRIPTION    = "The currently designated range tracking mode:
         0= Don't use the s/c range data
         1= Use s/c range in tracking algorithm
         2= Reserved for future use in Algorithm Mode 2."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = HWDIAG_TLM_CONFIG
   COLUMN_NUMBER  = 112
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 500
   DESCRIPTION    = "=0 neither MLA_HwDiagnostic nor MLA_HwDiagLite is on.
       =1, one of the hardware diagnostic packets is on.
   "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SWDIAG_TLM_CONFIG
   COLUMN_NUMBER  = 113
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 502
   DESCRIPTION    = "=0 The Mla_SwDiagnostic packet is OFF
                     =1 The Mla_SwDiagnostic packet is ON"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
```

```
   NAME           = MET_FREE_RUN
   COLUMN_NUMBER  = 114
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 504
   DESCRIPTION    = "Every second the flight software checks to see if it
      has received a MET message from the spacecraft. If it did not receive
      the MET message it will free run off an internal clock until the MET
      message is received again. When using GSEOS build 4 or lower, the MET
      message is not consistently issued, and therefore this telemetry point
      will show the software free running often; this is fine.  There is one
      known error condition for this telemetry point and that is when the
      science task overruns and delays the telemetry framer task for a
      considerable period of time (over 50ms). It is possible in that case
      that the MET was received, but because the task that monitors the MET
      was delayed, the software believes it is free running and will flag this
      telemetry point.
      =0 the flight software did receive a MET message
        =1 the flight software did NOT receive an MET message"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = MEM_WRITE_ENABLE
   COLUMN_NUMBER  = 115
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 506
   DESCRIPTION    = "=0 memory is not write enabled
    =1 memory is write enabled."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SD_PARITY_ERROR
   COLUMN_NUMBER  = 116
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 508
   DESCRIPTION    = "Every time the RUPT is generated, the flight
      software reads 166 bytes from the RMU (the shot data).  The last byte of
      the data read from the RMU is a parity byte (XOR over entire block). The
      flight software also computes a parity for the data read from the RMU.
      If the two parities do not equal each other this telemetry point
      increments. This value should never be anything but 0."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPARE
   COLUMN_NUMBER  = 117
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 510
   DESCRIPTION    = "Spare column."
END_OBJECT    = COLUMN
```

8.11 Appendix - Contents of MLAHADCDR.FMT

```
OBJECT        = COLUMN
   NAME           = ET
   COLUMN_NUMBER  = 1
   BYTES          = 16
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 1
   FORMAT         = "F16.6"
   UNIT           = "SECOND"
   DESCRIPTION    = "The independent variable of the equations of motion,
     in seconds from the J2000 epoch, at the shot timing origin T0.
     In the past this variable has been referred to at JPL as Ephemeris Time
     and at MIT, later at the Center for Astrophysics, as Coordinate Time.
     Its practical realization is the project-supplied clock kernel,
     applied to the Spacecraft Clock Mission Elapsed Time (MET) count
     that is transmitted to MESSENGER subsystems by the Integrated
     Electronics Module corresponding to the 1 PPS signal. The NAIF
     SPICE spacecraft clock (SCLK) kernel determines a corresponding
     Terrestrial Dynamic Time. These times are synchronous with respect
     to an observer at the Solar System barycenter in a relativistic sense.
```

```
     The SPICE library routine SCS2E performs the conversion to
     Ephemeris Time as used by the Project-supplied ephemeris files."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = UTC
   COLUMN_NUMBER  = 2
   BYTES          = 24
   DATA_TYPE      = TIME
   START_BYTE     = 18
   DESCRIPTION    = "Spacecraft clock (MET) converted to Coordinated Universal
                     Time (UTC) using the project-supplied conversion from MET
                     into Terrestrial Dynamical Time (TDT) seconds past the
                     J2000 epoch, and by accounting for leap seconds and the
                     offset between atomic time and UTC,
                     into to an ISO standard calendar representation of UTC."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = MET
   COLUMN_NUMBER  = 3
   BYTES          = 9
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 43
   DESCRIPTION    = "Spacecraft clock count, the Mission Elapsed Time in
                     seconds, transmitted to subsystems by the Integrated
                     Electronics Module, corresponding to the 1 PPS signal."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SHOT_NUMBER
   COLUMN_NUMBER  = 4
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 53
   DESCRIPTION    = "Number of 8 Hz shot or minor frame, 0-7"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SUBSECONDS
   COLUMN_NUMBER  = 5
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 55
   DESCRIPTION    = "Fraction of second from 1PPS to Packet Close, 0-65535"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DATA_XFER_MODE
   COLUMN_NUMBER  = 6
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 61
   DESCRIPTION    = "Science Data Transfer Mode. =0 byte, =1 nibble."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = TEST_PATTERN
   COLUMN_NUMBER  = 7
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 63
   DESCRIPTION    = "Test Pattern Selection, =1 LFSR, =2 AA, =3 55,
           =4 Counter, =5 Counter Inverse"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = TEST_DATA_SELECT
   COLUMN_NUMBER  = 8
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 65
   DESCRIPTION    = "Test data select. =0 Real data, =1 Test Data pattern.
         Defaults to 1."
END_OBJECT    = COLUMN
```

```
OBJECT        = COLUMN
   NAME           = RATE_SELECT
   COLUMN_NUMBER  = 9
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 67
   DESCRIPTION    = "Rate select flag. =0 One Hz, =1 Six Hz, =2 Eight Hz,
                      =3 Ten Hz."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CYCLE_RESET_TOF
   COLUMN_NUMBER  = 10
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 69
   DESCRIPTION    = "Reset Time of Flight timing chips. With reset enabled
      the RMU will automatically reset the TOF after every RUPT until
      configured to do otherwise."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CAL_SELECT
   COLUMN_NUMBER  = 11
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 71
   DESCRIPTION    = "Calibration mode selected. =0 0ns, =1 200ns, =2 400ns,
      =3 200ns."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CAL_ENABLE
   COLUMN_NUMBER  = 12
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 73
   DESCRIPTION    = "Enable calibration. =0,1,2 Real Data. =3 TOF-A
      calibration data."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CLOCK_SELECT
   COLUMN_NUMBER  = 13
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 75
   DESCRIPTION    = "Clock selected. =0 Internal(40%),
      =1 OSC_B (external clock), =2 OSC_A (external clock),=3 Internal(50%)"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SYNCH_TO_PPS
   COLUMN_NUMBER  = 14
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 77
   DESCRIPTION    = "Synchronize the RMU to the 1PPS. =0 inhibited,
                     =1 enabled"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CYCLE_SLIP
   COLUMN_NUMBER  = 15
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 79
   DESCRIPTION    = "CPU Cycle slip. (=0 no slip, =1 slip)."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CH1_NOISE_H1
   COLUMN_NUMBER  = 16
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 81
```

```
   DESCRIPTION    = "Background noise counter for channel 1 high"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CH1_NOISE_LO
   COLUMN_NUMBER  = 17
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 87
   DESCRIPTION    = "Background noise counter for channel 1 low"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CH2_NOISE
   COLUMN_NUMBER  = 18
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 93
   DESCRIPTION    = "Background noise counter for channel 2"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CH3_NOISE
   COLUMN_NUMBER  = 19
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 99
   DESCRIPTION    = "Background noise counter for channel 3"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LASER_TX_THRESHOLD_AEM
   COLUMN_NUMBER  = 20
   BYTES          = 7
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 105
   FORMAT         = "F7.4"
   UNIT           = "VOLT"
   DESCRIPTION    = "Laser start detector threshold (volts)"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DETECTOR_VGA_GAIN
   COLUMN_NUMBER  = 21
   BYTES          = 7
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 113
   FORMAT         = "F7.4"
   UNIT           = "N/A"
   DESCRIPTION    = "Detector VGA setting (pure number)"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DET_CH1_HI_THRESHOLD_AEM
   COLUMN_NUMBER  = 22
   BYTES          = 7
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 121
   FORMAT         = "F7.4"
   UNIT           = "VOLT"
   DESCRIPTION    = "AEM readback Ch. 1 high threshold setting (volts)"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DET_CH1_LO_THRESHOLD_AEM
   COLUMN_NUMBER  = 23
   BYTES          = 7
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 129
   FORMAT         = "F7.4"
   UNIT           = "VOLT"
   DESCRIPTION    = "AEM readback Ch. 1 low threshold setting (volts)"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DET_CH2_THRESHOLD_AEM
```

```
   COLUMN_NUMBER  = 24
   BYTES          = 7
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 137
   FORMAT         = "F7.4"
   UNIT           = "VOLT"
   DESCRIPTION    = "AEM readback Ch. 2 threshold setting (volts)"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DET_CH3_THRESHOLD_AEM
   COLUMN_NUMBER  = 25
   BYTES          = 7
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 145
   FORMAT         = "F7.4"
   UNIT           = "VOLT"
   DESCRIPTION    = "AEM readback Ch. 3 threshold setting (volts)"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME          = START_PULSE_PID
   COLUMN_NUMBER = 26
   BYTES         = 1
   DATA_TYPE     = ASCII_INTEGER
   START_BYTE    = 153
   DESCRIPTION   = "Pulse ids for valid start pulse should be 0."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME          = START_PULSE_BEGIN_VALID
   COLUMN_NUMBER = 27
   BYTES         = 1
   DATA_TYPE     = BOOLEAN
   START_BYTE    = 155
   DESCRIPTION   = "Validity bit of start pulse leading edge,
                    =T if edge is valid, =F if invalid"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME          = START_PULSE_END_VALID
   COLUMN_NUMBER = 28
   BYTES         = 1
   DATA_TYPE     = BOOLEAN
   START_BYTE    = 157
   DESCRIPTION   = "Validity bit of start pulse trailing edge,
                    =T if edge is valid, =F if invalid"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME          = START_PULSE_BEGIN_COARSE
   COLUMN_NUMBER = 29
   BYTES         = 5
   DATA_TYPE     = ASCII_INTEGER
   START_BYTE    = 159
   DESCRIPTION   = "RMU start pulse leading edge coarse counter,
                    200 ns ticks"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME          = START_PULSE_BEGIN_FINE
   COLUMN_NUMBER = 30
   BYTES         = 3
   DATA_TYPE     = ASCII_INTEGER
   START_BYTE    = 165
   DESCRIPTION   = "RMU leading edge fine counter, ~400 ps ticks"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME          = START_PULSE_END_COARSE
   COLUMN_NUMBER = 31
   BYTES         = 5
   DATA_TYPE     = ASCII_INTEGER
   START_BYTE    = 169
   DESCRIPTION   = "RMU start pulse trailing edge coarse counter,
                    200 ns ticks"
```

```
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME          = START_PULSE_END_FINE
   COLUMN_NUMBER = 32
   BYTES         = 3
   DATA_TYPE     = ASCII_INTEGER
   START_BYTE    = 175
   DESCRIPTION   = "RMU trailing edge fine counter, ~400 ps ticks"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME          = CH1_HI_PULSE_PID
   COLUMN_NUMBER = 33
   BYTES         = 1
   DATA_TYPE     = ASCII_INTEGER
   START_BYTE    = 179
   DESCRIPTION   = "Pulse ids for Ch.1 high pulse are always 0."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME          = CH1_HI_PULSE_BEGIN_VALID
   DATA_TYPE     = BOOLEAN
   COLUMN_NUMBER = 34
   BYTES         = 1
   DATA_TYPE     = BOOLEAN
   START_BYTE    = 181
   DESCRIPTION   = "Validity bit of Ch.1 high pulse leading edge,
                     =T if edge is valid, =F if invalid"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME          = CH1_HI_PULSE_END_VALID
   DATA_TYPE     = BOOLEAN
   COLUMN_NUMBER = 35
   BYTES         = 1
   DATA_TYPE     = BOOLEAN
   START_BYTE    = 183
   DESCRIPTION   = "Validity bit of Ch.1 high pulse trailing edge,
                     =T if edge is valid, =F if invalid"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME          = CH1_HI_PULSE_BEGIN_COARSE
   COLUMN_NUMBER = 36
   BYTES         = 5
   DATA_TYPE     = ASCII_INTEGER
   START_BYTE    = 185
   DESCRIPTION   = "RMU Ch.1 high pulse leading edge coarse counter,
                    200 ns ticks"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME          = CH1_HI_PULSE_BEGIN_FINE
   COLUMN_NUMBER = 37
   BYTES         = 3
   DATA_TYPE     = ASCII_INTEGER
   START_BYTE    = 191
   DESCRIPTION   = "RMU Ch.1 high leading edge fine counter, ~400 ps ticks"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME          = CH1_HI_PULSE_END_COARSE
   COLUMN_NUMBER = 38
   BYTES         = 5
   DATA_TYPE     = ASCII_INTEGER
   START_BYTE    = 195
   DESCRIPTION   = "RMU Ch.1 high trailing edge coarse counter, 200 ns ticks"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME          = CH1_HI_PULSE_END_FINE
   COLUMN_NUMBER = 39
   BYTES         = 3
   DATA_TYPE     = ASCII_INTEGER
   START_BYTE    = 201
```

```
   DESCRIPTION    = "RMU Ch.1 high trailing edge fine counter, ~400 ps ticks"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOWPULSE_1_BEGIN_PID
   COLUMN_NUMBER  = 40
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 205
   DESCRIPTION    = "Identifies channel of low return 1 if valid.
                     =1 Channel 1, =2 Channel 2, =4 Channel 3."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOWPULSE_1_BEGIN_VALID
   COLUMN_NUMBER  = 41
   BYTES          = 1
   DATA_TYPE      = BOOLEAN
   START_BYTE     = 207
   DESCRIPTION    = "Validity bit for the leading edge of the low pulse 1;
                     =T if pulse is valid, =F if invalid"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOWPULSE_1_END_VALID
   COLUMN_NUMBER  = 42
   BYTES          = 1
   DATA_TYPE      = BOOLEAN
   START_BYTE     = 209
   DESCRIPTION    = "Validity bit for the trailing edge of the low pulse 1;
                     =T if pulse is valid, =F if invalid"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOWPULSE_1_BEGIN_COARSE
   COLUMN_NUMBER  = 43
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 211
   DESCRIPTION    = "RMU leading edge coarse counter, 200 ns ticks"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOWPULSE_1_BEGIN_FINE
   COLUMN_NUMBER  = 44
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 217
   DESCRIPTION    = "RMU leading edge fine counter, ~400 ps ticks"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOWPULSE_1_END_COARSE
   COLUMN_NUMBER  = 45
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 221
   DESCRIPTION    = "RMU trailing edge coarse counter, 200 ns ticks"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOWPULSE_1_END_FINE
   COLUMN_NUMBER  = 46
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 227
   DESCRIPTION    = "RMU trailing edge fine counter, ~400 ps ticks"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOWPULSE_2_BEGIN_PID
   COLUMN_NUMBER  = 47
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 231
   DESCRIPTION    = "Identifies pulse channel of low return 2 if valid.
```

```
                    =1 Channel 1, =2 Channel 2, =4 Channel 3."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOWPULSE_2_BEGIN_VALID
   COLUMN_NUMBER  = 48
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 233
   DESCRIPTION    = "Validity bit for the leading edge of the low pulse 2;
                    =1 if pulse is valid, =0 if invalid"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOWPULSE_2_END_VALID
   COLUMN_NUMBER  = 49
   BYTES          = 1
   DATA_TYPE      = BOOLEAN
   START_BYTE     = 235
   DESCRIPTION    = "Validity bit for the trailing edge of the low pulse 2;
                    =T if pulse is valid, =F if invalid"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOWPULSE_2_BEGIN_COARSE
   COLUMN_NUMBER  = 50
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 237
   DESCRIPTION    = "RMU leading edge coarse counter, 200 ns ticks"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOWPULSE_2_BEGIN_FINE
   COLUMN_NUMBER  = 51
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 243
   DESCRIPTION    = "RMU leading edge fine counter, ~400 ps ticks"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOWPULSE_2_END_COARSE
   COLUMN_NUMBER  = 52
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 247
   DESCRIPTION    = "RMU trailing edge coarse counter, 200 ns ticks"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOWPULSE_2_END_FINE
   COLUMN_NUMBER  = 53
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 253
   DESCRIPTION    = "RMU trailing edge fine counter, ~400 ps ticks"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOWPULSE_3_BEGIN_PID
   COLUMN_NUMBER  = 54
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 257
   DESCRIPTION    = "Identifies pulse channel of low return 3 if valid.
                    =1 Channel 1, =2 Channel 2, =4 Channel 3."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOWPULSE_3_BEGIN_VALID
   COLUMN_NUMBER  = 55
   BYTES          = 1
   DATA_TYPE      = BOOLEAN
   START_BYTE     = 259
   DESCRIPTION    = "Validity bit for the leading edge of the low pulse 3;
```

```
                     =T if pulse is valid, =F if invalid"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOWPULSE_3_END_VALID
   COLUMN_NUMBER  = 56
   BYTES          = 1
   DATA_TYPE      = BOOLEAN
   START_BYTE     = 261
   DESCRIPTION    = "Validity bit for the trailing edge of the low pulse 3;
                     =T if pulse is valid, =F if invalid"

OBJECT        = COLUMN
   NAME           = LOWPULSE_3_BEGIN_COARSE
   COLUMN_NUMBER  = 57
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 263
   DESCRIPTION    = "RMU leading edge coarse counter, 200 ns ticks"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOWPULSE_3_BEGIN_FINE
   COLUMN_NUMBER  = 58
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 269
   DESCRIPTION    = "RMU leading edge fine counter, ~400 ps ticks"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOWPULSE_3_END_COARSE
   COLUMN_NUMBER  = 59
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 273
   DESCRIPTION    = "RMU trailing edge coarse counter, 200 ns ticks"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOWPULSE_3_END_FINE
   COLUMN_NUMBER  = 60
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 279
   DESCRIPTION    = "RMU trailing edge fine counter, ~400 ps ticks"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = RANGE_GATE_START
   COLUMN_NUMBER  = 61
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 283
   DESCRIPTION    = "Range Gate start time in units of 200 ns"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = RANGE_GATE_STOP
   COLUMN_NUMBER  = 62
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 289
   DESCRIPTION    = "Range Gate stop time in units of 200 ns."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CH1_BEGIN_EVENT_COUNT
   COLUMN_NUMBER  = 63
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 295
   DESCRIPTION    = "RMU pulse begin triggers on Ch. 1"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
```

```
   NAME           = CH1_END_EVENT_COUNT
   COLUMN_NUMBER  = 64
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 299
   DESCRIPTION    = "RMU pulse end triggers on Ch. 1"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CH2_BEGIN_EVENT_COUNT
   COLUMN_NUMBER  = 65
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 303
   DESCRIPTION    = "RMU pulse begin triggers on Ch. 2"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CH2_END_EVENT_COUNT
   COLUMN_NUMBER  = 66
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 307
   DESCRIPTION    = "RMU pulse end triggers on Ch. 2"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CH3_BEGIN_EVENT_COUNT
   COLUMN_NUMBER  = 67
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 311
   DESCRIPTION    = "RMU pulse begin triggers on Ch. 3"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CH3_END_EVENT_COUNT
   COLUMN_NUMBER  = 68
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 315
   DESCRIPTION    = "RMU pulse end triggers on Ch. 3"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LASER_TX_THRESHOLD
   COLUMN_NUMBER  = 69
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 319
   DESCRIPTION    = "Laser start detector threshold (counts)"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DETECTOR_GAIN
   COLUMN_NUMBER  = 70
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 323
   DESCRIPTION    = "Detector VGA setting (counts)"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DET_CH1_HI_THRESHOLD
   COLUMN_NUMBER  = 71
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 327
   DESCRIPTION    = "AEM readback Ch. 0 threshold setting"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DET_CH1_LO_THRESHOLD
   COLUMN_NUMBER  = 72
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
```

```
   START_BYTE     = 331
   DESCRIPTION    = "AEM readback Ch. 1 threshold setting"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DET_CH2_THRESHOLD
   COLUMN_NUMBER  = 73
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 335
   DESCRIPTION    = "AEM readback Ch. 2 threshold setting"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DET_CH3_THRESHOLD
   COLUMN_NUMBER  = 74
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 339
   DESCRIPTION    = "AEM readback Ch. 3 threshold setting"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = TX_PULSE_ENERGY
   COLUMN_NUMBER  = 75
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 343
   DESCRIPTION    = "Laser pickoff transmit energy monitor"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LASER_DIODE_CUR
   COLUMN_NUMBER  = 76
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 347
   DESCRIPTION    = "Laser diode pump current"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LASER_PULSE_WIDTH
   COLUMN_NUMBER  = 77
   BYTES          = 3
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 351
   DESCRIPTION    = "Laser diode pulse width (counts)"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = HZ_TO_RUPT
   COLUMN_NUMBER  = 78
   BYTES          = 6
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 355
   DESCRIPTION    = "8 MHz Ticks from 1PPS signal to T_0"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LASER_ENERGY
   COLUMN_NUMBER  = 79
   BYTES          = 5
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 362
   FORMAT         = "F5.2"
   UNIT           = "MILLIJOULE"
   DESCRIPTION    = "Laser pulse transmit energy"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = START_TIME
   COLUMN_NUMBER  = 80
   BYTES          = 12
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 368
   FORMAT         = "F12.2"
```

```
   UNIT           = "nanosecond"
   DESCRIPTION    = "Transmit pulse leading edge time, from T_0."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = START_WIDTH
   COLUMN_NUMBER  = 81
   BYTES          = 7
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 381
   FORMAT         = "F7.2"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Transmit pulse width, between leading and
                     trailing edge."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = HIGH_EVENT
   COLUMN_NUMBER  = 82
   BYTES          = 12
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 389
   FORMAT         = "F12.2"
   UNIT           = "nanosecond"
   DESCRIPTION    = "High threshold event leading edge time, from T_0."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = HIGH_WIDTH
   COLUMN_NUMBER  = 83
   BYTES          = 7
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 402
   FORMAT         = "F7.2"
   UNIT           = "nanosecond"
   DESCRIPTION    = "High threshold event pulse width, between leading
                     and trailing edge."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_EVENT1
   COLUMN_NUMBER  = 84
   BYTES          = 12
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 410
   FORMAT         = "F12.2"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Low threshold event 1 leading edge time, from T_0."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_WIDTH1
   COLUMN_NUMBER  = 85
   BYTES          = 7
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 423
   FORMAT         = "F7.2"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Low threshold event 1 pulse width, between leading
                     and trailing edge."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_EVENT2
   COLUMN_NUMBER  = 86
   BYTES          = 12
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 431
   FORMAT         = "F12.2"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Low threshold event 2 leading edge time, from T_0."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_WIDTH2
   COLUMN_NUMBER  = 87
```

```
   BYTES          = 7
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 444
   FORMAT         = "F7.2"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Low threshold event 2 pulse width, between leading
                     and trailing edge."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_EVENT3
   COLUMN_NUMBER  = 88
   BYTES          = 12
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 452
   FORMAT         = "F12.2"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Low threshold event 3 leading edge time, from T_0."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LOW_WIDTH3
   COLUMN_NUMBER  = 89
   BYTES          = 7
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 465
   FORMAT         = "F7.2"
   UNIT           = "nanosecond"
   DESCRIPTION    = "Low threshold event 3 pulse width, between leading
                     and trailing edge."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = BACKGROUND_POWER
   COLUMN_NUMBER  = 90
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 473
   FORMAT         = "F6.2"
   UNIT           = "NANOWATT"
   DESCRIPTION    = "Solar background power at 1064 nm within the
    detector field of view, averaged over the 8-Hz frame. CH1_NOISE_LO
    counts and DET_CH1_LO_THRESHOLD_AEM are the source of this measurement.
    The calibration of noise counts to power is preliminary."
END_OBJECT    = COLUMN
```

8.12 Appendix - Contents of MLASCIRDR.FMT

```
/***************************************************************************/
/* MLASCIRDR.FMT V8.2                                                      */
/*            edited 13 Aug 2014 gan fixed double quote 12/31/14           */
/* Revised 21 May 2015 CHANID = A, B, C for ground triggers whose          */
/*  pulse width is invalid but may have usable range/reflectance.          */
/* Revised 17 September 2015 for new Planetary Constant definitions and    */
/* to use absolute radius rather than height above a spherical datum       */
/***************************************************************************/
OBJECT        = COLUMN
   NAME           = LONGITUDE
   COLUMN_NUMBER  = 1
   BYTES          = 9
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 1
   FORMAT         = "F9.5"
   DESCRIPTION    = "The planetocentric longitude of the laser bounce point
     producing a trigger on a given channel."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LATITUDE
   COLUMN_NUMBER  = 2
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 11
   FORMAT         = "F10.5"
```

```
   DESCRIPTION    = "The planetocentric latitude of the laser bounce point
     producing a trigger on a given channel."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = RADIUS
   COLUMN_NUMBER  = 3
   BYTES          = 9
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 22
   FORMAT         = "F9.4"
   UNIT           = "KM"
   DESCRIPTION    = "The planetary radius at the laser bounce point. Altitude
     was previously measured with respect to a reference sphere about the
     center of mass, but is now the total planetary radius."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = ET_FIRE
   COLUMN_NUMBER  = 4
   BYTES          = 17
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 32
   FORMAT         = "F17.6"
   UNIT           = "SECOND"
   DESCRIPTION    = "The independent variable of the equations of motion in
     the Solar System Barycentric frame at the laser fire time, in ET seconds
     from the J2000 epoch, also known as Ephemeris Time or Coordinate Time.
     Its practical realization is the project-supplied clock kernel, applied
     to the Spacecraft Clock Mission Elapsed Time (MET_SECONDS) that is
     transmitted to MESSENGER subsystems by the Integrated Electronics Module
     at the time of the 1 PPS signal. The NAIF SPICE spacecraft clock (SCLK)
     kernel determines a corresponding Terrestrial Dynamic Time. These times
     are synchronous with respect to an observer at the Solar System
     barycenter.  The SPICE library routine SCS2E performs the conversion
     to Ephemeris Time as used by the JPL Planetary Ephemeris."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   COLUMN_NUMBER  = 5
   BYTES          = 10
   START_BYTE     = 50
   NAME           = MET_SECONDS
   DATA_TYPE      = ASCII_INTEGER
   FORMAT         = "I10"
   DESCRIPTION    = "Spacecraft mission elapsed time."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SHOT_NUMBER
   COLUMN_NUMBER  = 6
   BYTES          = 2
   START_BYTE     = 61
   DATA_TYPE      = ASCII_INTEGER
   FORMAT         = "I2"
   DESCRIPTION    = "Number of 8 Hz shot or minor frame, 0-7"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CHANID
   COLUMN_NUMBER  = 7
   BYTES          = 2
   DATA_TYPE      = ASCII_INTEGER
   FORMAT         = "I2"
   START_BYTE     = 64
   DESCRIPTION    = "Receiver channel of ground or noise trigger -
                     =0 channel 1 high threshold.
                     =1 channel 1 low
                     =2 channel 2 low
                     =3 ambiguous, assigned to channel 1 low
                     =4 channel 3 low.
                     =5 channel 1 high noise trigger
                     =6 channel 1 low noise trigger
                     =7 channel 2 low noise trigger
                     =8 unassigned noise trigger
                     =9 channel 3 low noise trigger.
```

```
                     =A channel 1 high trigger with
                        invalid STARTPLS_WIDTH.
                     =B channel 1 low ground trigger with
                        invalid STARTPLS_WIDTH.
                     =C channel 2 low ground trigger with
                        invalid STARTPLS_WIDTH."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = PULSE_WIDTH
   COLUMN_NUMBER  = 8
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 67
   FORMAT         = "F6.1"
   DESCRIPTION    = "Received pulse width, nanoseconds."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = THRESHOLD
   COLUMN_NUMBER  = 9
   BYTES          = 7
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 74
   UNIT           = "VOLT"
   FORMAT         = "F7.4"
   DESCRIPTION    = "Discriminator threshold on receiver channel CHANID."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = VGA_GAIN
   COLUMN_NUMBER  = 10
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 82
   FORMAT         = "F6.3"
   DESCRIPTION    = "Variable gain amplifier gain factor."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = RANGE
   COLUMN_NUMBER  = 11
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 89
   UNIT           = "KM"
   FORMAT         = "F10.4"
   DESCRIPTION    = "Range from spacecraft center of mass
        to bounce point, km.
        The time of flight from the laser transmit start pulse to
        the bounce point on Mercury, as seen by an observer at the
        Solar System barycenter, is calculated iteratively from
        the two-way time of flight using the spacecraft and planetary
        ephemerides in an inertial frame, and multiplied by the
        speed of light constant, 299,792.458 km/s. The range has been
        corrected for the offset of the laser zero-range point to the
        S/C COM  in the boresight direction."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = EMISSION_ANGLE
   COLUMN_NUMBER  = 12
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 100
   FORMAT         = "F6.2"
   DESCRIPTION    = "Angle at a surface bounce point between a vector to
     MLA, and a radial vector from the center of mass."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = TX_ENERGY
   COLUMN_NUMBER  = 13
   BYTES          = 5
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 107
```

```
   UNIT           = "MILLIJOULE"
   FORMAT         = "F5.1"
   DESCRIPTION    = "The measured transmitted pulse energy
       for the current SHOT_NUMBER."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = UTC
   COLUMN_NUMBER  = 14
   BYTES          = 25
   DATA_TYPE      = TIME
   START_BYTE     = 113
   DESCRIPTION    = "Laser shot time origin T0,
     converted to Coordinated Universal Time (UTC).
     The project-supplied clock kernel and NAIF routines convert MET into
     Terrestrial Dynamical Time (TDT) seconds past the J2000 epoch, and by
     accounting for leap seconds and the 32.184 s offset between TDT
     and UTC, to a standard calendar representation of UTC. The laser fire
     occurs about 0.97 to 1 ms after T0."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = TIME_OF_FLIGHT
   COLUMN_NUMBER  = 15
   BYTES          = 11
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 139
   UNIT           = "NANOSECOND"
   FORMAT         = "F11.1"
   DESCRIPTION    = "Two-way time of flight, corrected for zero-range
     delay to spacecraft center of mass, in ET nanoseconds."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SAT_LONGITUDE
   COLUMN_NUMBER  = 16
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 151
   FORMAT         = "F10.5"
   DESCRIPTION    = "The planetocentric longitude of MESSENGER
     at the time of fire."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SAT_LATITUDE
   COLUMN_NUMBER  = 17
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 162
   FORMAT         = "F10.5"
   DESCRIPTION    = "The planetocentric latitude of MESSENGER
     at the time of fire."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SAT_ALTITUDE
   COLUMN_NUMBER  = 18
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 173
   FORMAT         = "F10.5"
   UNIT           = "KM"
   DESCRIPTION    = "The altitude of MESSENGER with respect to a
     reference surface about the center of mass, currently a sphere
     of 2440 km radius."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = OFFNADIR_ANGLE
   COLUMN_NUMBER  = 19
   BYTES          = 8
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 184
   FORMAT         = "F8.3"
   DESCRIPTION    = "Angle between a vector from MLA to the bounce
```

```
     point, and a vector from MLA to the center of mass."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = PHASE_ANGLE
   COLUMN_NUMBER  = 20
   BYTES          = 8
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 193
   FORMAT         = "F8.3"
   DESCRIPTION    = "Solar phase angle at the bounce point."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SOLAR_INCIDENCE_ANGLE
   COLUMN_NUMBER  = 21
   BYTES          = 7
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 202
   FORMAT         = "F7.2"
   DESCRIPTION    = "Angle at a surface bounce point between a vector to
     Sun and a radial vector from the center of mass."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SC_RANGE
   COLUMN_NUMBER  = 22
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 210
   FORMAT         = "I6"
   DESCRIPTION    = "The spacecraft range value used by the science task for
      algorithm calculations, in units of approximately 30 meters per count.
      This value is calculated in real time by the spacecraft using its
      attitude and position knowledge relative to the planet. The range
      is provided to the instrument asynchronously at one second intervals.
      As soon as the science task receives a range message, it begins using
      the new range in its calculations. This value is an estimate only.
      The spacecraft range reported in telemetry may NOT be the one used
      throughout the entire second of algorithm calculations."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SEQUENCE_ID
   COLUMN_NUMBER  = 23
   BYTES          = 6
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 217
   FORMAT         = "I6"
   DESCRIPTION    = "Unique sequential identifier for triggers recorded by
     the range measurement unit in the Calibrated Data Record. Many triggers
     lie well outside the normal slant range window and are discarded. The
     SEQUENCE_ID allows ground/noise editing to be transferred from previous
     processing versions."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
  NAME             = STARTPLS_WIDTH
  COLUMN_NUMBER    = 24
  BYTES            = 4
  DATA_TYPE        = ASCII_REAL
  START_BYTE       = 225
  FORMAT           = "F4.1"
  UNIT             = "nanosecond"
  MISSING_CONSTANT = 99.9
  DESCRIPTION      = "Width of transmit laser pulse in nanoseconds, used
    to determine centroid time of outgoing pulse. A value of 99.9
    denotes a measurement whose pulse width is invalid. In addition,
    this value is set to indicate an uncertain start time, leading to
    highly degraded range accuracy."
END_OBJECT    = COLUMN
```

8.13 Appendix - Contents of MLARADR.FMT

```
/*****************************************************************************/
```

```
/* MLARADR.FMT v6  March 8, 2016                                          */
/*             edited for accuracy 9/14/12 k. jha                         */
/*             3 data columns added 10/03/12 k. jha                       */
/*             updated 3/08/16 to planetocentric reference /gan/          */
/*             add VGA column 3/12/16, 180 byte records  /gan/            */
/*************************************************************************/
OBJECT        = COLUMN
   NAME           = LONGITUDE
   COLUMN_NUMBER  = 1
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 1
   FORMAT         = "F10.5"
   DESCRIPTION    = "The planetocentric longitude of the laser spot
     producing dual triggers on channel 1."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LATITUDE
   COLUMN_NUMBER  = 2
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 11
   FORMAT         = "F10.5"
   DESCRIPTION    = "The planetocentric latitude of the laser spot
     producing dual triggers on channel 1."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = REFLECTANCE
   COLUMN_NUMBER  = 3
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 21
   FORMAT         = "F10.4"
   DESCRIPTION    = "The calibrated reflectance (geometric albedo)
     derived from channel 1 low/high threshold return pairs."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = PULSE_STD
   COLUMN_NUMBER  = 4
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 31
   FORMAT         = "F10.3"
   DESCRIPTION    = "Pulse width standard deviation, nanoseconds."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = ALTITUDE
   COLUMN_NUMBER  = 5
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 41
   FORMAT         = "F10.4"
   UNIT           = "KM"
   DESCRIPTION    = "The radius of the laser bounce point with respect to
     the center of mass of Mercury."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = PULSE_WIDTH_HI
   COLUMN_NUMBER  = 6
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 51
   FORMAT         = "F10.1"
   DESCRIPTION    = "Received high threshold pulse width, nanoseconds."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = PULSE_WIDTH_LO
   COLUMN_NUMBER  = 7
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
```

```
   START_BYTE     = 61
   FORMAT         = "F10.1"
   DESCRIPTION    = "Received low threshold pulse width, nanoseconds."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = THRESHOLD_HI
   COLUMN_NUMBER  = 8
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 71
   UNIT           = "VOLT"
   FORMAT         = "F10.4"
   DESCRIPTION    = "Discriminator high threshold on receiver channel 1."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = THRESHOLD_LO
   COLUMN_NUMBER  = 9
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 81
   UNIT           = "VOLT"
   FORMAT         = "F10.4"
   DESCRIPTION    = "Discriminator low threshold on receiver channel 1."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = RANGE
   COLUMN_NUMBER  = 10
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 91
   UNIT           = "KM"
   FORMAT         = "F10.3"
   DESCRIPTION    = "Range from spacecraft center of mass
     to bounce point, km."
END_OBJECT    = COLUMN

/* # the leading-edge time difference tle */
OBJECT        = COLUMN
   NAME           = LEADING_EDGE
   COLUMN_NUMBER  = 11
   BYTES          = 8
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 101
   UNIT           = "NANOSECONDS"
   FORMAT         = "F8.1"
   DESCRIPTION    = "The time from the low threshold discriminator
     trigger to the leading-edge high threshold trigger."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = TX_ENERGY
   COLUMN_NUMBER  = 12
   BYTES          = 8
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 109
   UNIT           = "MILLIJOULE"
   FORMAT         = "F8.1"
   DESCRIPTION    = "The measured transmitted pulse energy
       for the current SHOT_NUMBER."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = EMISSION_ANGLE
   COLUMN_NUMBER  = 13
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 117
   FORMAT         = "F6.2"
   DESCRIPTION    = "Angle at a surface bounce point between a vector to
     MLA, and a radial vector from the center of mass."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
```

```
   NAME           = ET_FIRE
   COLUMN_NUMBER  = 14
   BYTES          = 14
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 123
   FORMAT         = "F14.3"
   UNIT           = "SECOND"
   DESCRIPTION    = "The independent variable of the equations of motion in
     the Solar System Barycentric frame at the laser fire time, in seconds
     from the J2000 epoch, also known as Ephemeris Time or Coordinate Time.
     Its practical realization is the project-supplied clock kernel, applied
     to the Spacecraft Clock Mission Elapsed Time (MET_SECONDS) that is
     transmitted to MESSENGER subsystems by the Integrated Electronics Module
     at the time of the 1 PPS signal. The NAIF SPICE spacecraft clock (SCLK)
     kernel determines a corresponding Terrestrial Dynamic Time. These times
     are synchronous with respect to an observer at the Solar System
     barycenter.  The SPICE library routine SCS2E performs the conversion
     to Ephemeris Time as used by the JPL Planetary Ephemeris."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = MET_SECONDS
   COLUMN_NUMBER  = 15
   BYTES          = 10
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 137
   FORMAT         = "I10"
   UNIT           = "SECOND"
   DESCRIPTION    = " Spacecraft Clock Mission Elapsed Time (MET_SECONDS),
     that is transmitted to MESSENGER subsystems by the Integrated
     Electronics Module at the time of the 1 PPS signal."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = FRAME
   COLUMN_NUMBER  = 16
   BYTES          = 2
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 147
   FORMAT         = "I2"
   DESCRIPTION    = " Minor frame (0-7) of the 8-Hz data.  MET and FRAME
     together provide the epoch of packet formation, such that each packet
     has a unique identifier."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = UTC
   COLUMN_NUMBER  = 17
   BYTES          = 24
   DATA_TYPE      = TIME
   START_BYTE     = 149
   DESCRIPTION    = "Laser shot time origin T0, converted to Coordinated
     Universal Time (UTC).
     The project-supplied clock kernel and NAIF routines convert MET into
     Terrestrial Dynamical Time (TDT) seconds past the J2000 epoch, and by
     accounting for leap seconds and the 32.184 s offset between TDT
     and UTC, to a standard calendar representation of UTC. The laser fire
     occurs about 0.97 to 1 ms after T0."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = VGA_GAIN
   COLUMN_NUMBER  = 18
   BYTES          = 6
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 173
   FORMAT         = "F6.3"
   DESCRIPTION    = "Variable gain amplifier gain factor."
END_OBJECT    = COLUMN
```

8.14 Appendix - SPICE Kernel Files Used in MESSENGER Data Products

The following SPICE kernel files are used to compute the UTC time and any geometric quantities found in the PDS labels. Kernel files are generated throughout the mission with a file-naming convention specified by the MESSENGER project.

***.bsp:**
MESSENGER spacecraft ephemeris file. Also known as the Planetary Spacecraft Ephemeris Kernel (SPK) file.

***.bc:**
MESSENGER spacecraft orientation file. Also known as the Attitude C-Kernel (CK) file.

***.tf:**
MESSENGER reference frame file. Also known as the Frames Kernel. Contains the MESSENGER spacecraft, science instrument, and communications antennae frame definitions.

***.ti:**
MESSENGER instrument kernel (I-kernel). Contains references to mounting alignment, operation modes, and timing as well as internal and field of view geometry for the MLA instrument.

***.tsc:**
MESSENGER spacecraft clock coefficients file. Also known as the Spacecraft Clock Kernel (SCLK) file.

***.tpc:**
Planetary constants file. Also known as the Planetary Constants Kernel (PcK) file. The current release uses the file pck00010_msgr_v21.tpc.

***.tls:**
NAIF leapseconds kernel file. Used in conjunction with the SCLK kernel to convert between Universal Time Coordinated (UTC) and MESSENGER Mission Elapsed Time (MET). Also called the Leap Seconds Kernel (LSK) file.

8.15 Appendix - Data Archive Terms

Definition of Terms:

Archive	An archive consists of one or more data sets along with all the documentation and ancillary information needed to understand and use the data. An archive is a logical construct independent of the medium on which it is stored.
Archive Volume, Archive Volume Set	A volume is a unit of medium on which data products are stored; for example, one DVD. An archive volume is a volume containing all or part of an archive, that is, data products plus documentation and ancillary files. When an archive spans multiple volumes, they are called an archive volume set. Usually the documentation and some ancillary files are repeated on each volume of the set, so that a single volume can be used alone.

Data Product	A labeled grouping of data resulting from a scientific observation, usually stored in one file. A product label identifies, describes, and defines the structure of the data. An example of a data product is a planetary image, a spectrum table, or a time series table.
Data Set	An accumulation of data products. A data set together with supporting documentation and ancillary files is an archive.
Experiment Data Records	NASA Level 0 data for a given instrument; raw data. Same as CODMAC level2.
Calibrated and Reduced Data Records	Science data that have been processed from raw data to NASA Level 1 or higher. See section 8.13 for definitions of processing levels. Reduced data are geolocated and filtered for noise.
Standard Data Product	A data product that has been defined during the proposal and selection process and that is contractually promised by the PI as part of the investigation. Standard data products are generated in a predefined way, using well-understood procedures, and processed in "pipeline" fashion.

8.16 Appendix - CODMAC and NASA Data Levels

CODMAC/NASA Definition of processing levels for science data sets

CODMAC Level	Proc. Type	Data Processing Level Description
1	Raw Data	Telemetry data stream as received at the ground station, with science and engineering data embedded. Corresponds to NASA packet data.
2	Edited Data	Instrument science data (e.g., raw voltages, counts) at full resolution, time ordered, with duplicates and transmission errors removed. Referred to in the MESSENGER program as Experimental Data Records (EDRs). Corresponds to NASA Level 0 data.
3	Calibrated Data	Edited data that are still in units produced by the instrument, but have been transformed (e.g., calibrated, rearranged) in a reversible manner and packaged with needed ancillary and auxiliary data (e.g., radiances with calibration equations applied). Referred to in the MESSENGER Program as Calibrated Data Records (CDRs). In some cases these also qualify as derived data products (DDRs). Corresponds to NASA Level 1A.
4	Resampled data	Irreversibly transformed (e.g., resampled, remapped, calibrated) values of the instrument measurements (e.g., radiances, magnetic field strength). Referred to in the MESSENGER program as either derived data products

		(DDPs) or derived analysis products (DAPs). Corresponds to NASA Level 1B.
5	Derived Data	Derived results such as maps, reports, graphics, etc. Corresponds to NASA Levels 2 through 5
6	Ancillary Data	Non-Science data needed to generate calibrated or resampled data sets. Consists of instrument gains, offsets, pointing information for scan platforms, etc.
7	Corrective Data	Other science data needed to interpret space-borne data sets. May include ground based data observations such as soil type or ocean buoy measurements of wind drift.
8	User Description	Description of why the data were required, any peculiarities associated with the data sets, and enough documentation to allow a secondary user to extract information from the data.

The above is based on the National Research Council Committee on Data Management and Computation (CODMAC) data levels.

8.17 Appendix - Acronyms

ACT	Applied Coherent Technology Corporation
ADC	Analog-to-Digital Converter
AEM	Analog Electronics Module
APL	The Johns Hopkins University Applied Physics Laboratory
ASCII	American Standard Code for Information Interchange
CCSDS	Consultative Committee for Space Data Systems
CDR	Calibrated Data Record
CK	C-Kernels (SPICE)
CODMAC	Committee on Data Management and Computation
Co-I	Co-Investigator
DAC	Digital-to-Analog Converter
DAP	Derived Analysis Product
DDP	Derived Data Product
DPU	Data Processing Unit
DSN	Deep Space Network
EDR	Experimental Data Records
EK	Event Kernel
EPPS	Energetic Particle and Plasma Spectrometer
ET	Ephemeris Time
FIPS	Fast Imaging Plasma Spectrometer
FITS	Flexible Image Transport System ?
FOV	Field-of-View
FTP	File Transfer Protocol
GRNS	Gamma-Ray and Neutron Spectrometer
GSFC	Goddard Space Flight Center
HSI	High Speed Input; measures laser pump pulse duration
I&T	Integration and Test
IK	Instrument Measurement Kernel (SPICE)
LFSR	Linear Feedback Shift Register
LSK	Leap seconds Kernel (SPICE)
MAG	Magnetometer
MASCS	Mercury Atmospheric and Surface Composition Spectrometer
MDIS	Mercury Dual Imaging System
MESSENGER	MErcury, Surface, Space ENvironment, Geochemistry, and Ranging
MET	Mission Elapsed Time

MLA	Mercury Laser Altimeter
NAIF	Navigation and Ancillary Information Facility
NASA	Navigation Aeronautics and Space Administration
PCK	Planetary Constant Kernel (SPICE)
PDS	Planetary Data System
PPS	Pulse Per Second
RDR	Reduced Data Record
RMU	Range Measurement Unit
RUPT	Interrupt to FSW tasks whose timing is traceable to spacecraft 1PPS clock tick
SCLK	Space Clock Kernel (SPICE)
SIS	Software Interface Specification
SOC	MESSENGER Science Operations Center
SPICE	Spacecraft, Planet, Instrument, C-matrix Events
SPK	Spacecraft and Planets Kernel (SPICE)
SQL	Structured Query Language
TOF	Time-of-flight ASIC
UTC	Coordinated Universal Time
VGA	Variable Gain Amplifier
XM	Extended Mission
XM1	First Extended Mission
XRS	X-Ray Spectrometer

8.18 Appendix - MLA Instrument Overview

The MErcury Surface, Space ENvironment, Geochemistry, and Ranging (MESSENGER) mission entered orbit around Mercury in March 2011 following two flybys each of Venus and Mercury. It launched on August 3, 2004 and used one flyby of Earth, two flybys of Venus and three of Mercury to achieve an orbit insertion around Mercury on March 18, 2011. The use of planetary flybys enables the mission to save fuel, but lengthens the duration of cruise. Initial data collection will begin during the three flybys of Mercury, and will primarily consist of global mapping and measurements of the surface, atmosphere, and magnetosphere composition. MESSENGER remained in orbit for the rest of the nominal mission, which ended in March 2012. This was followed by two extended missions. The MESSENGER mission finally ended on April 30, 2015 when the spacecraft impacted into Mercury as planned. (Once in orbit around Mercury it began a series of observations using multiple instruments. These observations provided data to answer questions about the nature and composition of Mercury's crust, tectonic history, the structure of the atmosphere and magnetosphere, and the nature of the polar regions.

Most of the instruments are fixed-mounted, so that coverage of Mercury is obtained by spacecraft motion over the planet. The instruments are co-located on a science deck facing Mercury while the spacecraft is shielded from direct sunlight by a lightweight sunshade, (Figure A-1) below.

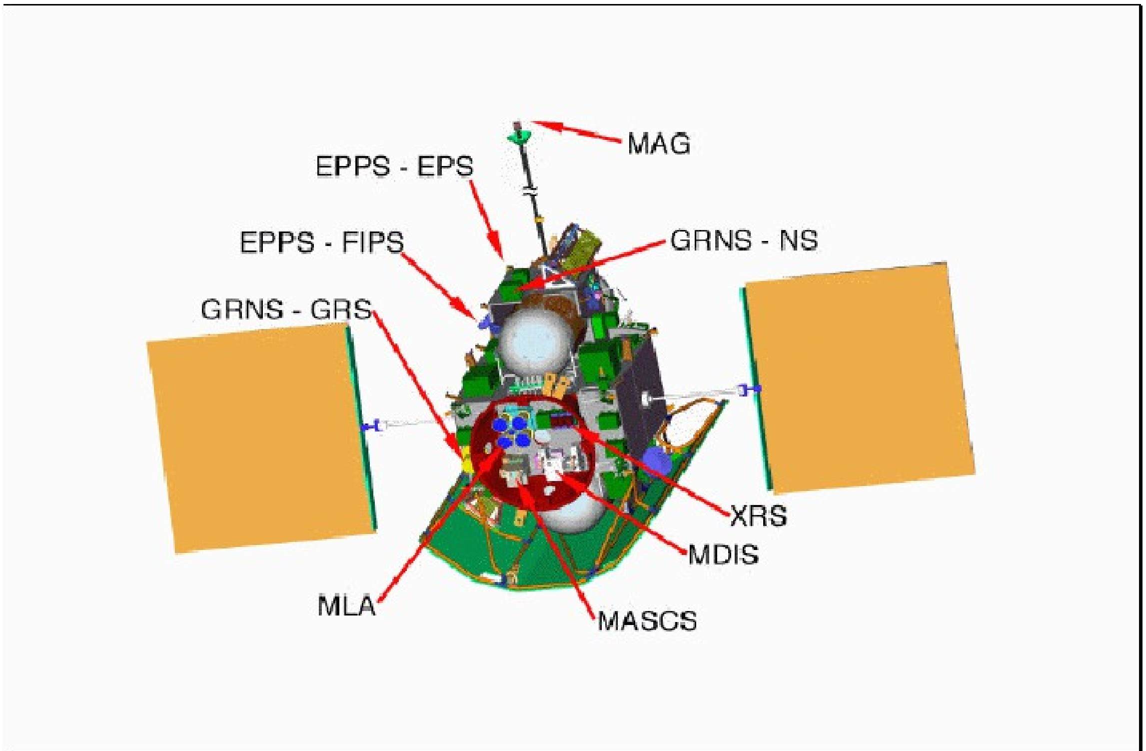

Figure A-1 Spacecraft with Instrument Locations.

The Mercury Laser Altimeter (MLA) uses a solid-state pulsed laser to measure the distance between the spacecraft and the surface of Mercury. This will allow the science team to take detailed measurements of Mercury's shape and surface structure. The MLA is a bi-static system, meaning that it consists of separate transmitter and receiver systems.

General Specifications:

Mass : 7.25kg (Allocated)
Power: 25.6 W Science. Mode (Allocated).
20W Orbit average.
Volume ~ 0.027m^3 (1ft^3); 33cm height limit (13")

The transmitter generates a brief laser pulse, and the instrument measures the time required for the light to reach the surface and return. The MLA data complements the visible and near infrared imaging that will also be performed on Mercury. Unlike the imager, the MLA does not rely on solar illumination and can make measurements over the entire surface of Mercury including the dark side. The MLA complements imaging because the direct range measurements enable unambiguous determinations of topography that will improve the interpretation of images. The MLA can also be operated as a laser transponder using the transmit and receiver subsystems independently.

The laser output is sensed by a diode pickoff, and its energy is recorded. A leading and trailing edge start pulse time is recorded by comparators within the range measurement unit (RMU), as well as the time of the reflected pulse, as described below. To accommodate surfaces of greater slope and roughness, the received signal is passed through each of three matched filters into separate comparators within the RMU. These filter channels have response times of 10, 60, and 270 ns. A sufficiently strong return pulse will trigger comparators on one of the three lower threshold channels (channel 1, 2, 3), whose arrival is measured by a common pair (leading, trailing edge) time-of-flight chip, or TOF. Pulses that trigger a separate high threshold on the 10-ns channel (Channel 1 high, also known as channel 0) are measured by an additional pair of TOFs. Thresholds are set independently for each channel by means of flight software and programmable digital-to-analog converters, in response to changing numbers of noise counts issued by the comparators, so as to maintain a preset average rate of false alarms in face of varying background illumination. The RMU stores up to 15 returns, of which up to 10 are returned by the flight software after signal processing. The FSW Science task tracks the surface so as to eliminate most noise returns, and outputs a variable-length packet. The RMU counts consist of coarse and fine times. Each of the six dedicated TOFs has a series of gates that generate a fine range count at the leading or trailing edge of a pulse. Thus each 200-ns interval generated by the 5 MHz clock is subdivided into approximately 500 subintervals of roughly 400 ps. Individual timing calibrations for each TOF are applied from a lookup table since each gate has a slightly different delay.

Additionally, the MLA can perform active and passive radiometric measurements in a narrow spectral band centered at 1064 nm. The active measurement employs a dual-threshold measurement of pulse width to infer the area and width of the return pulse. The pulse area, together with a transmit energy monitor, provides the reflectivity of the target within a 0.08-mrad-diameter laser spot. Thus MLA may search for volatile deposits that exhibit high albedo within the permanently shadowed polar regions. Active measurements require sufficient signal to trigger the detector at both low and higher threshold settings on the lowest matched filter setting, 10 ms. The passive measurement employs the noise counters and threshold settings on the detector subsystem to infer radiance from a 0.4-mrad-diameter field of view. The passive mode is enabled in Science Mode, wherein the noise counts are summed over 0.5-s intervals. The Hardware Diagnostic packets may be enabled in Standby Mode to provide 8-Hz passive measurements.