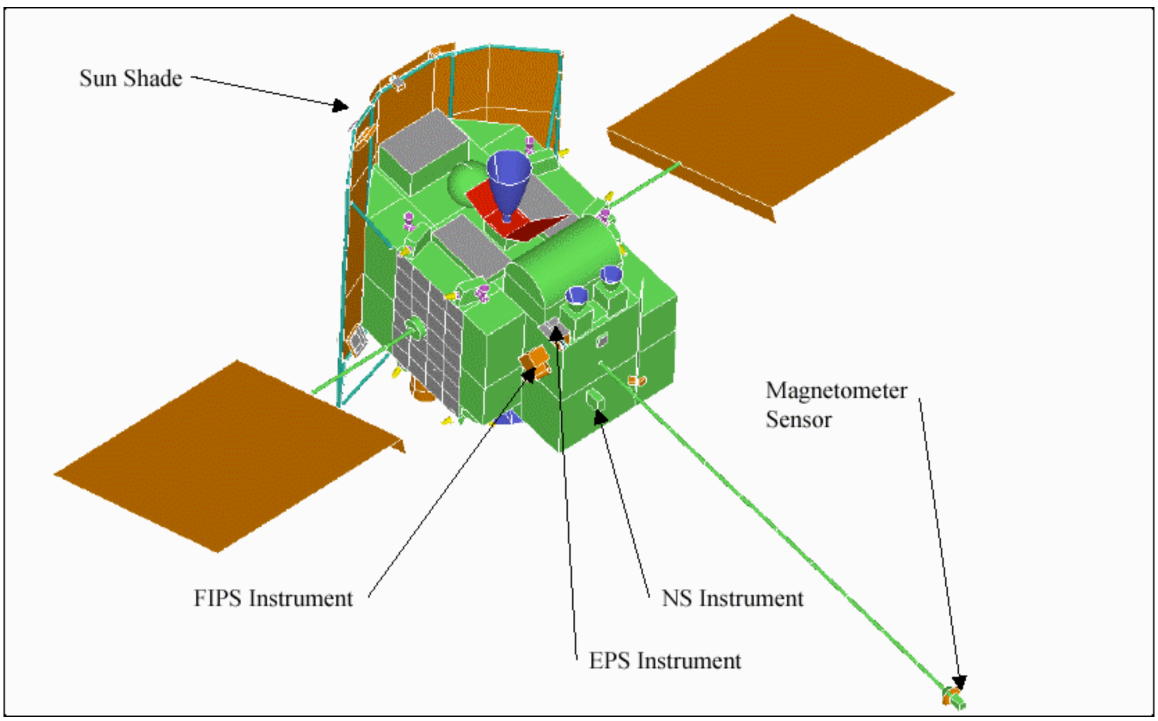
# MESSENGER: Experiment Data Record Software Interface Specification For The MAGNETOMETER

Version 2L




Prepared by:

Raymond Espiritu
Erick Malaret
**Applied Coherent Technology Corporation**
112 Elden St, Suite K
Herndon, VA 22304
http://www.actgate.com

## Document Review

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

Haje Korth, MESSENGER MAG Instrument Scientist, has reviewed and approved this document.

Steve Joy, PDS PPI 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 |
|---|---|---|---|
| 6/14/11 | Change Log | Added change log. | V2G |
| 6/14/11 | Document Title | Added “Experiment Data Record” to document title. | V2G |
| 6/14/11 | Document Review | Replaced signature page with Document Review information | V2G |
| 5/25/2012 | 2, 7 | *Data Management and Archiving Plan* replaces *Data Management and Science Archiving Plan*. Reference that document for PDS delivery schedule and remove schedule table from this document. | V2H |
| 4/17/2014 | 6.2.3 (item 1), Appendix | Updated changes made to Science Header Data and associated PDS labels. | V2I |
| 6/20/2014 | Multiple | Minor edits | V2J |
| 5/28/2015 | 6.5 Archive Volume and File Size | Updated with final archive size and volume | V2K |
| 7/17/2015 | 5.4.2 Time Standards, 6.4 File Naming Conventions, 6.6 Directory Structure And Contents For MAG Documentation Volume | Note use of clock partitions in time tags in product labels following January 8, 2013 S/C clock reset. Update reference to PDS file naming standard (was 27.3 now 36.3), Updated document volume directory structure and contents. | V2L |

# Table of Contents

# 1. Purpose And Scope Of Document

## 1.1 Purpose

This document will serve to provide users of the MESSENGER Magnetometer (MAG) data products with a detailed description of the Magnetometer instrument (see Figure 1: MAG Instrument.) product generation, validation and storage. The MESSENGER Magnetometer 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.

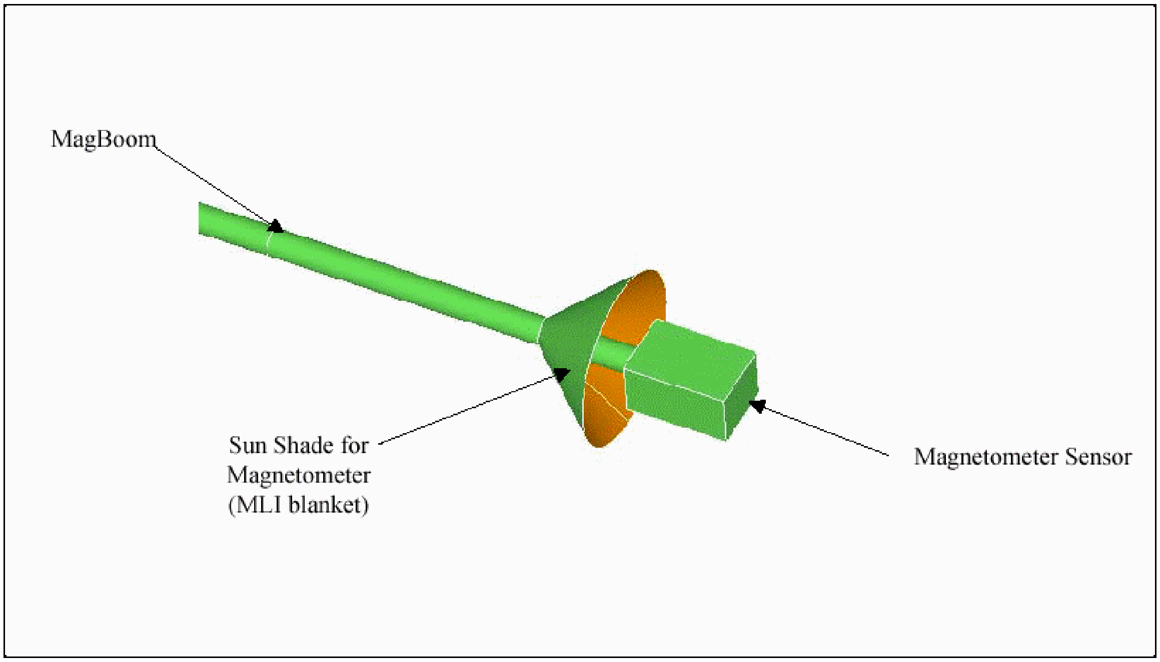



**Figure 1: MAG Instrument.**

## 1.2 Scope

This Software Interface Specification (SIS) is useful to those who wish to understand the format and content of the MESSENGER Magnetometer Experiment Data Record (EDR) data products. Typically, these individuals include software engineers, data analysts, and planetary scientists. The SIS applies to EDR data products produced during the course of the MESSENGER mission. Calibrated and Reduced Data Records (CDRs and RDRs) are outside the scope of this SIS and are described in a separate SIS document – the MAG RDR SIS.

In addition this SIS describes the MAG documentation volume, which will contain products related to the EDR, CDR and RDR level archives. The contents of the documentation volume will provide the information needed to understand and the EDRs as well as to use the CDR and RDR archives for science analysis. Sufficient information to allow investigators to generate CDR and RDR data from the EDR data will be provided. This includes calibration conversion tables, time latency correction values and offset corrections as well as descriptions of the algorithms for their use, possibly including key sections of high level source code to accurately capture critical logic or routine call sequences. The information specifically excludes software that must be executed to be useful. The documentation volume is described in greater detail in section 6.5.

The EDR magnetic field data are only the initial level of processed data and higher levels of processing are performed for the CDR and RDR data. The EDR magnetic field data are not converted to physical units. Conversion to physical units for the magnetic field data and identification of data quality indicated by a data quality flag are applied to CDR data. Processing to CDR records also applies offset corrections to the magnetic field data, applies time conversions from spacecraft mission elapsed time (MET) to UTC including all necessary time latency corrections (see Magnetometer Timing Latencies Appendix, Table 1, below), and provides magnetic field data in spacecraft coordinates. Processing to RDR records includes coordinate transformation from MESSENGER spacecraft coordinates to various relevant geophysical reference frames. All of the CDR and RDR processing steps and algorithms not described herein will be described in appropriate documents in the MAG documentation volume not later than delivery of the corresponding CDR and RDR volumes. Appropriate updates to the MAG documentation volume such as tables of calibration parameters required to convert to CDR or RDR products from EDR data, will be made as they are derived and validated.

# 2. Applicable Documents

The MAG SIS is responsive to the following Documents:

- 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
- Planetary Data System Standards Reference, August 1, 2003, Version 3.6. JPL D-7669, Part-2.
- MESSENGER Data Management and Archiving Plan, The Johns Hopkins University, APL. Document ID number 7384-9019
- [PLR] Appendix 7 to the discovery program Plan; Program Level Requirement for the MESSENGER Discovery project; June 20, 2001.

# 3. Relationships with other Interfaces

The MAG EDR data products are stored on hard disk and in SQL (Structured Query Language) relational databases for rapid mission access during mission operations. The data products will be electronically transferred to the PDS Planetary Plasma Interactions (PPI) Node according to the delivery schedule in the MESSENGER Data Management and Archiving Plan. The data in the EDR files themselves will be stored in a PDS ASCII TABLE object.

# 4. Roles and Responsibilities

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

# 5. Data Product Characteristics and Environment

## *5.1 Overview*

The primary objective for the MAG instrument is to gather data for determining the structure and nature of Mercury's magnetic field. To meet this objective, the instrument will take comprehensive measurements to understand the strength and geometry of the magnetic field. Further, the data gathered is intended to resolve fields due to magnetosphere currents. The secondary objective is to determine the structure and dynamics of Mercury's magnetosphere. Finally, the MAG data gathered is intended to support particle measurements of volatiles. An overview of the MAG instrument is provided in the Appendix – MAG Instrument Overview.

## *5.2 Data Product Overview*

This SIS document only contains information on the Experiment Data Record (EDR) data products. The Calibrated Data Record (CDR) SIS document was developed separately by the MESSENGER Project. There are eight EDR products that will be created for the MAG instrument. They are the Status, Science, Science Header, AC, Low-Rate Housekeeping (LRHK), LRHK Header, Burst, and Burst Log EDRs. Each MAG EDR data product consists of two files. One file contains the data itself, and is arranged in ASCII table fixed format with string fields enclosed in double quotes. The other file is a detached PDS label file which describes the contents of the ASCII table file. The label file defines the start and end time of the observation, product creation time, the structure of the ASCII table and each of the different fields within the table.

All EDR data products, with the exception of Burst and Burst Log, contain the observations collected on a given UTC day. Each Burst EDR contains the data from one burst observation. The Burst Log EDR contains the statistical information for every burst observed during the entire mission.

### 5.2.1 Status EDR

This EDR contains MAG instrument status information, temperatures, voltage, command status counts as well as low resolution (14-bit) 3-axis magnetic field samples as recorded by A/D converters integral to the Low Voltage Power Supply (LVPS).

### 5.2.2 Science EDR

The Science EDR provides the primary science MAG data and consists of 3-axis field samples from the magnetometer at the commanded sample rate.

### 5.2.3 Science Header EDR

The Science Header EDR captures the instrument state (health and mode) as reported by the science packet. This information only changes on packet boundaries so it is kept in a separate EDR, minimizing repetition of information. Each row in the Science Header EDR corresponds to the information extracted from one science packet.

### 5.2.4 AC EDR

The AC EDR product contains alternating current (AC) level values at the commanded sample rate. To conserve telemetry the vector sampling will usually be less than the maximum rate, 20 sample/s. To provide a record of the amplitude of fluctuations for frequencies higher than 1 Hz, an AC amplitude is calculated from the internally sampled 20/s data for the sensor axis commanded as the AC_AXIS. Thus, in addition to the vector samples data, a 1 Hz to 10 Hz bandpass average amplitude is evaluated for the commanded sensor axis, selected by command, and recorded as a log AC value with a 4-bit mantissa of the four most significant non-zero bits and a 4-bit power of two exponent of the $4^{th}$ (least significant) bit of the mantissa. This is called the logAC value. It is created once per second and saved for telemetry at that rate or at the commanded science rate, whichever is less frequent.

The Science and AC EDR products will be used for detailed science analysis of Mercury's intrinsic magnetic field and of its magnetospheric configuration and dynamics.

### 5.2.5 LRHK EDR

This EDR product contains magnetometer low rate housekeeping data at the commanded sample rate of 50, 500 or 2000 seconds. This includes the 3-axis field values (received from the filter and subsampling logic) and the corresponding AC values.

### 5.2.6 LHRK Header EDR

The LHRK Header EDR contains the instrument state (health and mode) as reported by the LRHK packet. This changes only on packet boundaries so it is kept in a separate EDR, minimizing repetition of information. Each row in the LHRK Header EDR corresponds to information extracted from one LHRK packet.

### 5.2.7 Burst EDR

This EDR product contains snapshots of vector samples, or 'burst' sampling, over a time span of 8 minutes, at a rate of 20 samples per second for a total of 9600 vector samples. The burst data give information about waves and turbulent phenomena expected to occur at the magnetospheric boundaries and elsewhere in association with pickup processes of volatile species as they are photo-ionized. Typically one burst period will be recorded every day of orbit operations.

### 5.2.8 Burst Log EDR

The Burst Log EDR is a cumulative file for the entire mission. The purpose of the file is to keep a time log of bursts recorded by the instrument, as well as the number of burst packets recorded for each Burst EDR.

## 5.3 Data Processing

### 5.3.1 Data Processing Level

There will be one MAG documentation volume and one MAG EDR data volume. The data volume includes level 2 CODMAC (Committee on Data Management and Computation) data products, also known as EDRs. Each product will have a unique file name and conform to the file naming convention in section 6.4. All EDR products will be stored at the Applied Physics Laboratory/Science Operations Center (APL/SOC). Level-1 CODMAC data will be received at the SOC where it will be ingested via an automatic data processing system and stored in a database reserved for the MAG sensor. Bundled with the time series of magnetic field values will be scientific and engineering housekeeping data sampled by the MAG instrument. Data downlink is telemetered through NASA's Deep Space Network (DSN) managed by the Jet Propulsion Laboratory in Pasadena, CA, and then forwarded to APL. Inputs to the SOC will consist of telemetry in the form of CCSDS packets. Level-0 MAG raw time series and engineering data is then broken out of the data stream and stored online at the SOC. The SOC will produce early version of the data products using SPICE kernels to give 'quick-look' displays of time series, orbit geometry, and data coverage.

### 5.3.2 Data Product Generation

The MAG EDR files will be produced by the MESSENGER SOC, operated jointly by APL and ACT. The 'PIPE-MAG2EDR' software converts the data to the proper PDS labeled format. The EDR 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 6.7 for transmittal to the PPI Node. The transmittal process is described in the following section, Data Flow. An initial release of the documentation volume will accompany the initial release of the EDR data archive. Thereafter, there will be updates to the documentation volume whenever the MAG team determines that they have a sufficiently improved calibration to warrant a new release. PDS will then provide public access to the data products through its online distribution system. These products will be used for engineering support, direct science analysis, and construction of other science products.

### 5.3.3 Data Flow

The MESSENGER SOC operates under the auspices of the MESSENGER Project Scientist to plan data acquisition, 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 Johns Hopkins University/Applied Physics Lab (JHU/APL). The SOC will produce early versions of products that can be used by the science and instrument teams. These "quick look" products, by their nature, may contain partial data which has been only recently downloaded from the MESSENGER spacecraft. It is expected that the EDR products delivered to PDS will contain the full range of data as specified in this SIS. Example: A quick look product generated for -day of year 126, 2006 may contain only partial data due to partial download from the spacecraft. It is expected that by the time it is delivered to PDS the EDR will contain all the data from observations taken on day of year 126, 2006.

The Data Flow diagram in **Error! Reference source not found.** shows the general flow of data within the MESSENGER project and data flow to 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 validates the EDRs and notifies the SOC if corrections are needed. Documentation, EDRs, and science products are delivered to the PDS Planetary Plasma Interactions (PPI) node. SPICE Kernels are delivered to the PDS Navigation and Ancillary Information (NAIF) node.

The MESSENGER SOC will deliver data for the MAG EDR data volume to the PDS Planetary Plasma Interactions (PPI) node in standard product packages. Each package will comprise data and ancillary data files, organized into directory structures consistent with the volume design described in section 6.7. The initial release will also contain the documents and required files for the MAG documentation volume, organized into directory structures as described in section 6.6. Subsequent releases to the MAG documentation volume will be at the discretion of the MAG team and delivered whenever the MAG team determines that they have a sufficiently improved calibration to warrant a new release.

The following describes the electronic transfer process of releasing data to PDS for both the data volume and the documentation volume. This transfer process will be used for the first PDS delivery. Future data deliveries will be assumed to follow the same process unless otherwise noted in an update of this document. Given the long duration of the mission the project is reserving the option of exploring alternate data delivery methods for subsequent deliveries. As such, the method of electronic transfer may change and will be revised accordingly in the SIS. Any changes to the delivery process will be noted in an update to the SIS document and will include the specific dates which will use the new delivery process. The delivery of products to the data volume will follow the schedule in the MESSENGER Data Management and Archiving Plan. The delivery date for updates to the documentation volume will be determined as needed at the discretion of the MAG team.

In the week prior to the delivery date the directory structure will be compressed into a single “zip archive” file for transmittal to the PDS node. The zip archive preserves the directory structure internally so that it can be recreated after electronic delivery to the PDS node. The zip archive file is transmitted to the PDS node via FTP to an account set up by the receiving node. Also transmitted will be a checksum file created using the MD5 algorithm. This provides an independent method of verifying the integrity of the zip file after it has been sent. Within days of transmittal the PDS node will acknowledge receipt of the archive and checksum file. If acknowledgement is not received, or if problems are reported, the MESSENGER SOC will immediately take corrective action to effect successful transmittal.

After transmittal the PDS node will uncompress the zip archive file and check for data integrity using the checksum file. The node will then perform any additional verification and validation of the data provided and will report any discrepancies or problems to the

MESSENGER SOC. It is expected that the node will perform these checks in about two weeks. After inspection has been completed to the satisfaction of the PDS node, the node will issue to the MESSENGER SOC acknowledgement of successful receipt of the data.

Following receipt of a data delivery the PDS node will organize the data into a PDS volume archive structure within its online data system. Newly delivered data will be made available publicly from PDS once accompanying labels and other documentation have been validated.

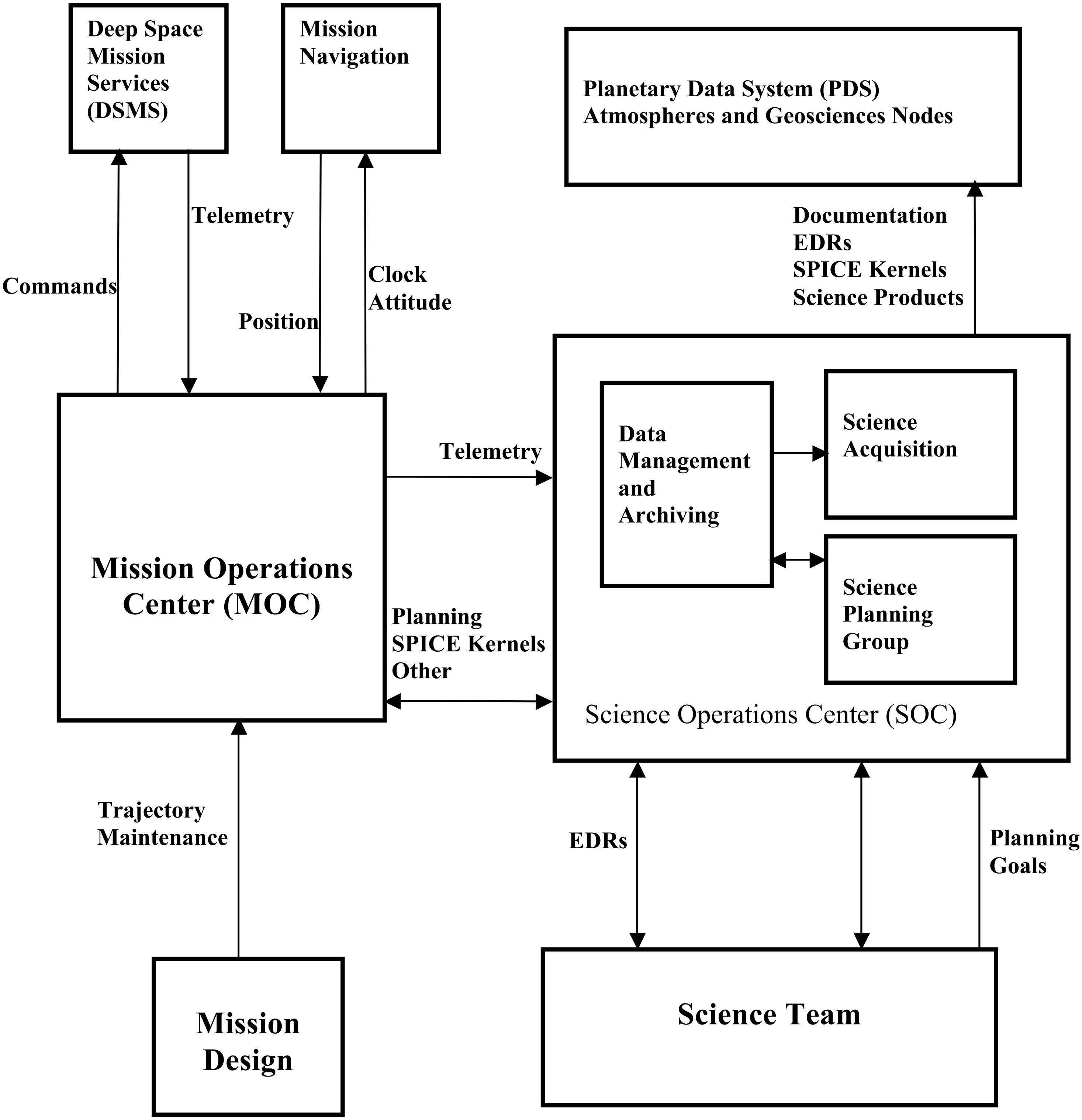



**Figure 2. MESSENGER data flow**

#### 5.3.4 Labeling and Identification

The label area of the data file conforms to the PDS version 3.6 standards. For more information on this standard consult the PDS Standards Reference Document. The purpose of the PDS label is to describe the data product and provide ancillary information about the data product. The label file is detached and separate from the EDR data file. The data file itself will contain the data in an ASCII table format. There will be one detached PDS label file for every data file. There are eight standard data products, described in section 5.2. The data products are identified via the STANDARD_DATA_PRODUCT_ID keyword and the file naming convention (section 6.4). Example label files for each EDR data product are shown in the Appendix. Details about the table structure for each data file are specified later in section 6.2.

### *5.4 Standards Used in Generating Data Products*

#### 5.4.1 PDS Standards

The MAG EDR data products are constructed according to the data object concepts developed by the PDS. By adopting the PDS format, the MAG EDR data products are consistent in content and organization with other planetary data collections. In the PDS standard, the EDR data file is grouped into objects with PDS labels describing the objects. Each EDR data product consists of two files:

- A data file containing an ASCII table object (the primary data), in fixed field and comma separated value (CSV) format. This makes the data extremely easy to read by many commercial off-the-shelf programs.
- A label file which serves as a high-level description of the parameters of which correspond to the data file.

#### 5.4.2 Time Standards

The time fields in the EDR table objects may reference the Mission Elapsed Time (MET). This MET is the spacecraft time in integer seconds that is transmitted to the MESSENGER subsystems by the Integrated Electronics Module (IEM). MET = 0 is August 3, 2004 05:59:16 UTC, which is 1000 seconds prior to 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[1] 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/). For this reason the MESSENGER spacecraft clock coefficients file is archived at the PDS Navigation and Ancillary Information Facility (NAIF) Node. This file is used in conjunction with the leapseconds kernel file in order to calculate the conversion between MET and UTC. A description of how to

[1] See instrument host catalog file in MAG document volume for more information on MESSENGER spacecraft clock reset.

perform the conversion including both instrument latency corrections and the required calls using the SPICE toolkit is included in the Appendix: Magnetometer Timing Latencies.

#### 5.4.3 Data Storage Conventions

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

### *5.5 Data Validation*

The MAG EDR data archive volume set will include all data acquired during the MESSENGER mission. The archive validation procedure described in this section applies to data products generated during all post launch phases of the mission. To be clear, there is one and only one documentation volume and one and only one MAG EDR data archive volume created over the whole mission. Initial releases of both volumes will occur during the first EDR delivery date and updates to the data volume will occur according to the schedule in the MESSENGER Data Management and Archiving Plan. Updates to the documentation volume will occur at the discretion of the MAG team.

PDS standards recommend that all data included in the formal archive be validated through a peer-review process. This process is designed to ensure that both the data and documentation are of sufficient quality to be useful to future generations of scientists. The schedule of PDS data deliveries, however, necessitate some modification of the normal PDS review process since it is impractical to convene a review panel to examine the archive volume for every PDS data delivery. The following describes the modified validation process. The process is presented as several steps, most of which occur in the PDS peer review. This peer review is conducted before any volumes are produced and released to PDS.

The peer review panel consists of members of the MAG team, members of ACT, the PPI node of PDS, and at least one outside scientist actively working in the field of planetary, terrestrial or interplanetary magnetic fields research. The PDS personnel are responsible for validating that the volumes are fully compliant with PDS standards. The instrument team, ACT, and outside reviewer(s) are responsible for verifying the content of the data set, the completeness of the documentation, and the usability of the data in its archive format.

The peer review will validate the documentation and data archive volumes via a two step process. First the panel reviews this document and verifies that the volumes and EDRs produced to this specification will be useful. Next the panel reviews the initial release of the data and documentation volumes to verify that the volumes meet this specification and are acceptable. Once automated production begins, software provided by ACT produce a summary of each data product and software provided by the PPI node verifies that all the files required by PDS are present and the files themselves conform to PDS standards. If an error is detected by either of the above programs, the error is corrected, if possible, before the update to the volume is delivered. Otherwise the correction will occur at the next scheduled delivery date. If an error in a data file is uncorrectable, (i.e. an error in the downlink data file) the error is described in the cumulative errata file that is included in the data archive volume.

The peer review will also validate the MAG EDR data in a two step process. The first step consists of reviewing a sample data set for compliance with the PDS standards. The sample data set is delivered and reviewed in conjunction with delivery and review of this SIS document. The second step is examination of the data to ensure usability and completeness. The PDS personnel will be responsible for validating that the EDR data set is fully compliant with PDS standards. The instrument team, ACT, and the outside science reviewer(s) will be responsible for verifying the content of the data set, the completeness of the documentation, and the usability of the data in its archive format.

Any deficiencies in the archive data or documentation volumes will be recorded as liens against the product by the review panel. The sample data set is created using software provided by ACT. Once the sample data is validated, and all liens placed against the product or product generation software are resolved, the same software will be used to generate subsequent data products in an automated fashion.

Once automated production begins, the data file content will be spot checked by members of the MAG team. “Quick look” products generated by software provided by ACT and the MAG team will be produced routinely and examined by members of the MAG team. In addition, the data will be actively used by team members to perform their analysis. Any discrepancies in the data noted during these activities will be investigated. If the discrepancy is a data error, the response will depend on the source of the error. If the error is in the software producing the data product, the error will be corrected and the data produced affected will be reproduced. If there is a correctable error in a data file, the file will be replaced. If an error in a data file is uncorrectable, the error will be described in the cumulative errata file included in the archive volume. The structure of data files and labels will be spot checked by the PPI node for compliance with PDS standards and this SIS.

# 6. Detailed Data Product Specifications

## *6.1 Data Product Structure And Organization*

The MESSENGER MAG EDR data set will be archived at the PDS PPI Node as a data archive volume. The EDR dataset in the data archive volume is intended to store the data in a form that faithfully reflects the raw telemetry data received from the spacecraft. The automated production and release of the EDRs thereby lends itself to a regular release schedule as shown in the MESSENGER Data Management and Archiving Plan. If errors are discovered, the data will be replaced with corrected EDRs on the next scheduled delivery date.

Calibration tables and calibration procedures will be required to properly analyze the EDRs. These ancillary data will be archived at the PDS PPI Node as the MAG documentation volume. The MAG documentation volume will also be referenced by the MAG CDR and RDR data archive volumes. As such, the MAG documentation will contain the MAG EDR SIS, the MAG CDR SIS and the MAG RDR SIS and will contain the calibration tables, procedures, and documents applicable to these data archive volumes. A first release of the MAG documentation volume will accompany the initial release of the EDR data archive. The initial release will only contain the EDR level documentation and the parameters derived from the ground calibration tests. After the initial release, there will be updates to the documentation volume whenever the MAG team determines that they have a sufficiently improved calibration to warrant a new release.

### 6.1.1 Handling Errors

The possibility exists that errors may be introduced into the archive even with validation procedures applied to the archive volumes. Errors in the data files may be discovered as detailed in section 5.5. An ERRATA report file is maintained to track and document all discovered uncorrectable errors that may occur during the mission. Correctable errors, such as revised EDRs or EDRs that were missing from a previous PDS delivery will be provided at the next scheduled PDS delivery or at the final delivery date (schedule in the MESSENGER Data Management and Archiving Plan). PDS will then replace the outdated files with the revised EDR files in the data directories of the archive volume. The ERRATA report file is archived in the ROOT directory of the MAG documentation volume.

## *6.2 Data Format Description*

Data is stored in ASCII table format. A detached PDS label file will provide a detailed description of the structure of the ASCII table. The following tables present the structure of the data tables in a user-friendly format. The fields are numbered according to their column order in the table. Data_Type refers to the PDS standards data type for a particular column in the table.

### 6.2.1 MAG Status EDR ASCII Table

1. **TIME_TAG**
   Bytes: 12 Data_Type: ASCII_INTEGER

The Mission Elapsed Time (MET) in seconds when the LVPS X, Y, Z axis samples were collected.

2. **ACTUAL_RANGE**
   Bytes:1 Data_Type: ASCII_INTEGER

Actual Range used by MAG.
=0 1530 nT, =1 51300

3. **STATUS_CNT_SENSOR_X**
   Bytes:5 Data_Type: ASCII_INTEGER

The LVPS X-axis sample. X axis field value in signed integer counts. If DN value is greater than 8192 then this value is DN - 16384. DN is the telemetry value stored in the downloaded packet.

4. **STATUS_CNT_SENSOR_Y**
   Bytes:5 Data_Type: ASCII_INTEGER

The LVPS Y-axis sample. Y axis field value in signed integer counts. If DN value is greater than 8192 then this value is DN - 16384. DN is the telemetry value stored in the downloaded packet.

5. **STATUS_CNT_SENSOR_Z**
   Bytes:5 Data_Type: ASCII_INTEGER

The LVPS Z-axis sample. Z axis field value in signed integer counts. If DN value is greater than 8192 then this value is DN - 16384. DN is the telemetry value stored in the downloaded packet.

6. **MAG_DC_DC_CURR**
   Bytes:8 Data_Type: ASCII_REAL

The derived MAG DC/DC current; used the following formula:
If the DN value is less than 128,
MAG_DC_DC_CURR = DN/64
else
MAG_DC_DC_CURR = (DN-256)/64. Where DN is the telemetry value.

7. **MAG_ELEC_TEMP**
   Bytes:9 Data_Type: ASCII_REAL

The derived MAG electronics temperature; used the following formula:
MAG_ELEC_TEMP = (155*DN/127) - 55
Where DN is the telemetry value.

8. **MAG_PROBE_TEMP**
   Bytes:9 Data_Type: ASCII_INTEGER

The raw telemetry counts for the MAG probe temperature.

**9. FSW_VERSION**
Bytes:3 Data_Type: ASCII_INTEGER

The Flight Software (FSW) version number.

**10. LVPS_PLUS5V**
Bytes:3 Data_Type: ASCII_INTEGER

The raw integer counts for LVPS +5 voltage counter. The values for this column are set to an N/A value of 999 when FSW_VERSION is less than 9; the measurement did not exist in prior flight software versions.

**11. LVPS_MINUS5V**
Bytes:3 Data_Type: ASCII_INTEGER

The raw integer counts for LVPS -5 voltage counter. The values for this column are set to an N/A value of 999 when FSW_VERSION is less than 9; the measurement did not exist in prior flight software versions.

**12. LVPS_PLUS12V**
Bytes:3 Data_Type: ASCII_INTEGER

The raw integer counts for LVPS +12 voltage counter. The values for this column are set to an N/A value of 999 when FSW_VERSION is less than 9; the measurement did not exist in prior flight software versions.

**13. LVPS_MINUS12V**
Bytes:3 Data_Type: ASCII_INTEGER

The raw integer counts for LVPS -12 voltage counter. The values for this column are set to an N/A value of 999 when FSW_VERSION is less than 9; the measurement did not exist in prior flight software versions.

**14. LVPS_PLUS5I**
Bytes:3 Data_Type: ASCII_INTEGER

The raw integer counts for LVPS +5 current counter. The values for this column are set to an N/A value of 999 when FSW_VERSION is less than 9; the measurement did not exist in prior flight software versions.

**15. LVPS_MINUS5I**
Bytes:3 Data_Type: ASCII_INTEGER

The raw integer counts for LVPS -5 current counter. The values for this column are set to an N/A value of 999 when FSW_VERSION is less than 9; the measurement did not exist in prior flight software versions.

**16. LVPS_PLUS12I**
Bytes:3 Data_Type: ASCII_INTEGER

The raw integer counts for LVPS +12 current counter. The values for this column are set to an N/A value of 999 when FSW_VERSION is less than 9; the measurement did not exist in prior flight software versions.

**17. LVPS_MINUS12I**
Bytes:3 Data_Type: ASCII_INTEGER

The raw integer counts for LVPS -12 current counter. The values for this column are set to an N/A value of 999 when FSW_VERSION is less than 9; the measurement did not exist in prior flight software versions.

**18. HEATER_DUTY_CYCLE**
Bytes:5 Data_Type: ASCII_INTEGER

The heater duty cycle. The values for this column are set to an N/A value of 999 when FSW_VERSION is less than 9; the measurement did not exist in prior flight software versions.

### 6.2.2 MAG Science EDR ASCII Table

1. **TIME_TAG**
   Bytes: 14 Data_Type: ASCII_REAL

A derived value for the timetag associated with the x, y, z sample in each record. The derived value is created by the following formula:

MET + 0.05 * delta_ts + (dt_sample)*(I-1).

MET is the mission elapsed time for the entire science packet.
delta_ts is the delta time in seconds between the MET and the first sample in the downloaded science packet.
dt_sample is the time between samples in seconds and given by dt_sample = 1/sample_rate where sample_rate is the reported sample rate in samples per second.
I is the incremental counter for each data sample in the science packet. I=1 is the first sample in the packet.

2. **ACTUAL_RANGE**
   Bytes:1 Data_Type: ASCII_INTEGER

Actual Range used by MAG.
=0 1530 nT, =1 51300

3. **SAMPLE_X**
   Bytes:6 Data_Type: ASCII_INTEGER

X axis field value in signed integer counts. If DN is greater than 32768 then this value is DN - 65536. DN is the telemetry value stored in the downloaded packet.

4. **SAMPLE_Y**
   Bytes:6 Data_Type: ASCII_INTEGER

Y axis field value in signed integer counts. If DN is greater than 32768 then this value is DN - 65536. DN is the telemetry value stored in the downloaded packet.

5. **SAMPLE_Z**
   Bytes:6 Data_Type: ASCII_INTEGER

Z axis field value in signed integer counts. If DN is greater than 32768 then this value is DN - 65536. DN is the telemetry value stored in the downloaded packet.

### 6.2.3 MAG Science Header ASCII Table

1. **TIME_TAG**
   Bytes: 14 Data_Type: ASCII_REAL

A derived value for the timetag associated with the x, y, z sample in each record. The derived value is created by the following formula:

MET + 0.05 * delta_ts + (dt_sample)*(I-1).

MET is the mission elapsed time for the entire science packet.

delta_ts is the delta time in seconds between the MET and the first sample in the downloaded science packet.
dt_sample is the time between samples in seconds and given by dt_sample = 1/sample_rate where sample_rate is the reported sample rate in samples per second.
I is the incremental counter for each data sample in the science packet. I=1 is the first sample in the packet.

2. **DELTA_TS**
   Bytes:2 Data_Type: ASCII_INTEGER

The delta time in 50 millisecond steps between the MET value for the packet and the first sample in the science packet, provides a 50 millisecond resolution to the time tag for the first data value.

3. **NUM_SAMPLES**
   Bytes:3 Data_Type: ASCII_INTEGER

The number of MAG samples (0-200) in the science packet.

4. **NUM_LOGAC**
   Bytes:3 Data_Type: ASCII_INTEGER

The number of logAC samples (0-200) in the science packet.

5. **ANALOG_CAL**
   Bytes:1 Data_Type: ASCII_INTEGER

Analog calibration flag. =0 off, =1 on.

6. **A_D_CAL**
   Bytes:1 Data_Type: ASCII_INTEGER

A/D calibration flag. =0 off, =1 on.

7. **COMPRESS_ON**
   Bytes:1 Data_Type: ASCII_INTEGER

Indicates whether science packet was compressed or uncompressed.
=0 uncompressed, =1 compressed.

8. **RANGE_MODE**
   Bytes:1 Data_Type: ASCII_INTEGER

Range control mode used. =0 manual, =1 automatic.

9. **FILTERS_ON**
   Bytes:1 Data_Type: ASCII_INTEGER

Indicates whether filters were on or off. =0 off, =1 on

10. **MANUAL_RANGE_CMD**
    Bytes:1 Data_Type: ASCII_INTEGER

Commanded manual range setting. =0 1530 nT, =1 51300 Nt

11. **ACTUAL_RANGE**
    Bytes:1 Data_Type: ASCII_INTEGER

Actual range used by MAG. =0 1530 nT, =1 51300 nT.

**12. AC_AXIS**
Bytes:1 Data_Type: ASCII_INTEGER

AC axis selected. =0 X, =1 Y, =2 Z

**13. SAMPLE_RATE**
Bytes:2 Data_Type: ASCII_INTEGER

MAG sample rate.
=0 0.01/s, =1 0.02/s, =2 0.05/s, =3 0.1/s, =4 0.2/s, =5 0.5/s, =6 1/s, =7 2/s, =8 5/s, =9 10/s, =10 20/s

**14. APP_ID**
Bytes:3 Data_Type: ASCII_INTEGER

The Application Process ID of the science packet from which data was extracted. Values for PROBE_TEMPERATURE are N/A when this value is 721, which is the AppID of the old packet format. An AppID of 725 identifies the new packet format which contains valid values for PROBE_TEMPERATURE.

**15. X_SAMPLES_COMPRESSION_BITS**
Bytes:2 Data_Type: ASCII_INTEGER

Number of bits needed to store each compressed X axis sample.

**16. Y_SAMPLES_COMPRESSION_BITS**
Bytes:2 Data_Type: ASCII_INTEGER

Number of bits needed to store each compressed Y axis sample.

**17. Z_SAMPLES_COMPRESSION_BITS**
Bytes:2 Data_Type: ASCII_INTEGER

Number of bits needed to store each compressed Z axis sample.

**18. PROBE_TEMPERATURE**
Bytes:5 Data_Type: ASCII_INTEGER

Raw telemetry counts of the High temperature resolution probe temperature. This is set to an N/A value of 65535 when APP_ID is 721.

### 6.2.4 MAG AC EDR ASCII Table

**1. TIME_TAG**
Bytes: 14 Data_Type: ASCII_REAL

A derived value for the timetag associated with the data values in each record.
The derived value is created by the following formula:

MET + 0.05 * delta_ts + 0.5 + (dt_sample)*(i-1)*(num_samples/num_AC).

MET is the mission elapsed time for the entire science packet.
delta_ts is the time in seconds between the MET and the first sample in the science packet.
dt_sample is the time between samples in seconds and is given by

dt_sample = 1/sample_rate where sample_rate is the reported sample rate in samples per second.
num_samples is number of magnetometer samples.
num_AC is the number of logAC values.
i is the incremental counter for each of the logAC values. i=1 is the first logAC value in the science packet.

2. **AC_AXIS**
   Bytes:1 Data_Type: ASCII_INTEGER

The AC axis selected.

3. **LOG_AC**
   Bytes:5 Data_Type: ASCII_INTEGER

An 8-bit log AC value generated from the 16-bit AC value. This is done by shifting the 16-bit mantissa left one bit at a time while it does not overflow. The log AC value consists of shift count which is 15 minus the number of shifts (0-15) combined with the four MSBs of the shifted mantissa; the shift count will be in the four MSBs of the log AC value; the mantissa bits are in the four LSBs.

4. **AC_COUNT**
   Bytes:5 Data_Type: ASCII_INTEGER

The calculated AC count value; derived from the LOG_AC value by the following formula:
AC_exp = LOG_AC/16 (exponent value)
AC_mant = LOG_AC - 16*AC_exp (mantissa value)
CNT_AC = (AC_mant + 0.5)* (2**(AC_exp-4))

5. **APP_ID**
   Bytes:3 Data_Type: ASCII_INTEGER

The Application Process ID of the science packet from which data was extracted. Values for PROBE_HEATER_STATE are N/A when this value is 721, which is an older version of the science packet.

6. **PROBE_HEATER_STATE**
   Bytes:1 Data_Type: ASCII_INTEGER

The MAG-EPU sensor survival heater request bit at the time of the LOG_AC value. =0 off, =1 on, =2 N/A.

### 6.2.5 MAG Low-Rate Housekeeping (LRHK) EDR ASCII Table

1. **TIME_TAG**
   Bytes: 14 Data_Type: ASCII_REAL

A derived value for the timetag associated with the data values in each record of the EDR table. The timetag is created by the following formula:
TIME_TAG = MET + 0.05 * (low_rate_offset_time).
The MET is the mission elapsed time recorded for a given LRHK packet.
The low_rate_offset_time is the difference in units of 50 milliseconds between the MET and the time when a sampled field value is taken. Each sampled field value has an associated low_rate_offset_time.

2. **ACTUAL_RANGE**

Bytes:1 Data_Type: ASCII_INTEGER

Actual range used by the MAG. =0 2048 nT, =1 65536 nT.

3. **CNT_AC**
   Bytes:5 Data_Type: ASCII_INTEGER

The calculated AC count value. This is derived from the LOG_AC value reported by the LRHK packet by the following formula:
AC_exp = LOG_AC/16
AC_mant = LOG_AC - 16*AC_exp
CNT_AC = (AC_mant + 0.5) * (2**(AC_exp-4))

4. **CNT_SENSOR_X**
   Bytes:6 Data_Type: ASCII_INTEGER

X axis field value in signed integer counts. If DN is greater than 32768 then this value is DN - 65536. DN is the telemetry value stored in the downloaded packet.

5. **CNT_SENSOR_Y**
   Bytes:6 Data_Type: ASCII_INTEGER

Y axis field value in signed integer counts. If DN is greater than 32768 then this value is DN - 65536. DN is the telemetry value stored in the downloaded packet.

6. **CNT_SENSOR_Z**
   Bytes:6 Data_Type: ASCII_INTEGER

Z axis field value in signed integer counts. If DN is greater than 32768 then this value is DN - 65536. DN is the telemetry value stored in the downloaded packet.

### 6.2.6 MAG LRHK Header EDR ASCII Table

1. **MET**
   Bytes: 12 Data_Type: ASCII_INTEGER

Mission elapsed time in seconds.

2. **LR_OFFSET_TIME0**
   Bytes:4 Data_Type: ASCII_INTEGER

The delta time offset from MET for the first low-rate data sample in the LRHK packet (in steps of 50 milliseconds). Provides 50 msec resolution.

3. **MIN_INTERVAL**
   Bytes:4 Data_Type: ASCII_INTEGER

The minimum derived sampling interval in seconds. Determined by taking the minimum time difference between successive timestamps in the LRHK packet.

4. **MAX_INTERVAL**
   Bytes:4 Data_Type: ASCII_INTEGER

The maximum derived sampling interval in seconds. Determined by taking the maximum time difference between successive timestamps in the LRHK packet.

5. **NUM_LR_SAMPLES**
Bytes:2 Data_Type: ASCII_INTEGER

Number of low-rate sample data in the LRHK packet.

6. **RNG_UP_TIME_DELAY**
Bytes:4 Data_Type: ASCII_INTEGER

Samples before increasing range.

7. **RNG_DN_TIME_DELAY**
Bytes:4 Data_Type: ASCII_INTEGER

Samples before decreasing range.

8. **MAG_DC_DC_CURR**
Bytes:8 Data_Type: ASCII_REAL

The derived MAG DC/DC current; used the following formula:
if the DN (telemetry value) is less than 128:
MAG_DC_DC_CURR = DN/64
else
MAG_DC_DC_CURR = (DN-256)/64
The resulting value is in units of amps.

9. **PROBE_TEMP**
Bytes:9 Data_Type: ASCII_REAL

The derived MAG probe temperature:
PROBE_TEMP = 0.0123*(DN**2) - 0.7316*DN - 144.85. The value is in units of degrees Celsius.

10. **MAG_ELEC_TEMP**
Bytes:9 Data_Type: ASCII_REAL

The derived MAG electronics temperature:
MAG_ELEC_TEMP = (155*DN/127) - 55
The value for this column is in units of degrees Celsius.

### 6.2.7 MAG Burst EDR ASCII Table

1. **TIME_TAG**
Bytes: 14 Data_Type: ASCII_REAL

A derived value for the timetag associated with the data values in each record. The length of the observation (8 minutes) and the sample rate results in a total of 9600 records. However, the burst packet can only contain up to 640 records. Fifteen burst packets are required to download all the records for one burst observation. The timetag for each record is created by:
MET + 0.05*delta_t - 0.05*(9600-640*(i-1)-j)
MET is mission elapsed time for the last burst record of the observation.
delta_t is the delta time for the last burst record of the observation, giving a 50ms resolution to the timestamp. i is the 'ith' record in a given burst packet.

2. **SAMPLE_X**
   Bytes:5 Data_Type: ASCII_INTEGER

X axis field value in signed integer counts. If DN is greater than 32768 then this value is DN - 65536. DN is the telemetry value stored in the downloaded burst packet.

3. **SAMPLE_Y**
   Bytes:5 Data_Type: ASCII_INTEGER

Y axis field value in signed integer counts. If DN is greater than 32768 then this value is DN - 65536. DN is the telemetry value stored in the downloaded burst packet.

4. **SAMPLE_Z**
   Bytes:5 Data_Type: ASCII_INTEGER

Z axis field value in signed integer counts. If DN is greater than 32768 then this value is DN - 65536. DN is the telemetry value stored in the downloaded burst packet.

### 6.2.8 MAG Burst Log EDR ASCII Table

1. **MET**
   Bytes: 12 Data_Type: ASCII_INTEGER

Mission elapsed time for the last burst record in the burst observation.

2. **DELTA_T**
   Bytes:4 Data_Type: ASCII_INTEGER

An offset time from the MET for the last burst record in the burst observation. Provides 50 msec resolution to the time stamp for the last burst record.

3. **NUM_BURST_PKTS**
   Bytes:2 Data_Type: ASCII_INTEGER

Number of burst packets downloaded for the burst observation. Nominally there should be 15 burst packets for one complete burst observation. A value of less than 15 indicates missing packets.

4. **ACTUAL_RANGE**
   Bytes:1 Data_Type: ASCII_INTEGER

Actual range used by MAG. =0 2048 nT, =1 65536 Nt

## *6.3 Label and Header Descriptions*

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

**`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. Note: In the PDS, when record_type is used in a detached label file it always describes its corresponding detached data file, not the label file itself. The use of record_type along with other file-related data elements is fully described in the PDS Standards Reference.

**RECORD_BYTES**

Indicates the number of bytes in a physical file record, including record terminators and separators. Note: In the PDS, the use of record_bytes, along with other file-related data elements is fully described in the Standards Reference.

**PRODUCT_ID**

Represents a permanent, unique identifier assigned to a data product by its producer. For the MAG EDRs it is the base file naming convention (section 6.4) without the file extensions.

**PRODUCT_VERSION_ID**

Defines the version of the EDR product. Version numbering starts at "V1" and will be incremented if the EDR product needs to be regenerated due to errors in the product or the software creating the product.

**PRODUCT_CREATION_TIME**

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

**PRODUCT_TYPE**

Identifies the type or category of a product within a data set.

**STANDARD_DATA_PRODUCT_ID**

Used to link a MAG EDR file to one of the eight types of MAG data products defined within the MAG EDR SIS.

**SOFTWARE_NAME**

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

**SOFTWARE_VERSION_ID**

Identifies the version of the data processing software used to generate the EDR products from the spacecraft telemetry.

**MD5_CHECKSUM**

Used to verify the successful electronic transfer of the EDR from the SOC to the PDS-PPI Node.

**INSTRUMENT_HOST_NAME**

Specifies the host on which the MAG instrument is based, the MESSENGER spacecraft.

**INSTRUMENT_NAME**

Provides the full name of the MAG instrument.

**INSTRUMENT_ID**

Provides an abbreviated name or acronym which identifies an instrument.

**DATA_SET_ID**
The data_set_id element is a unique alphanumeric identifier for a data set or a data product. There is only 1 data_set_id for the MAG EDRs.

**MISSION_PHASE_NAME**
Provides the commonly used identifier of a mission phase.

**TARGET_NAME**
The target_name element identifies a target. The target may be a planet, satellite, ring, region, feature, asteroid or comet.

**START_TIME**
Provides the date and time of the beginning of an event or observation in UTC system format.

**STOP_TIME**
Provides the date and time of the end of an observation or event in UTC system format.

**SPACECRAFT_CLOCK_START_COUNT**
Provides the value of the spacecraft clock at the beginning of a time period of interest.

**SPACECRAFT_CLOCK_STOP_COUNT**
Provides the value of the spacecraft clock at the end of a time period of interest.

**^TABLE**
This is a pointer to the external data file containing the ASCII table. The TABLE object is a uniform collection of rows containing binary 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. For all MAG EDR data files except the Burst Log the base form of the EDR filename (without the file extension) is: "MAGRRRYYDDDHHMM_V#".
The ASCII table files are defined by the file extension ".TAB" and the detached PDS label file with the file extension ".LBL". The file naming convention of the 7 EDR products (excluding Burst Log EDR) is explained as follows.

MAG : Instrument name
RRR : Record type. Identifies one of 7 possible EDR products:
STA – status
SCI – science
SHD – science header
LAC – Log AC (includes linear AC counts)

LHK – Low Rate Housekeeping
LHD – Low Rate Housekeeping header
BST – Burst data

YY : Is the last two digits of the year in which the data were acquired.

DDD : Is the three digit (zero padded) day of the year in which the data where acquired.

HHMM:

For STA, SCI, LAC, LHK,BST EDR files this is the UTC hour and minute corresponding to the TIME_TAG of the first sample in the ASCII table.

For the SCI_HDR and LHK_HDR files this is the UTC hour and minute corresponding to the MET time of the first record in the ASCII table.

V# : Version number. The initial version number is "V1". The version number increments to "V2", "V3", etc. for each successive version of the EDR product that is produced. A new version of the EDR product may be produced as a result of an error in the product or as a result of errors discovered in the product generation process.

There is only one Burst Log file for the entire MESSENGER mission and the base filename is MAG_BST_LOG. The ASCII table file is defined by the file extension ".TAB" and the detached PDS label file with the file extension ".LBL". Because this file represents the cumulative log of all burst observations for the mission it will be contained in the last volume delivered to the PDS archive.

### 6.5 Archive Volume and File Size

Two archive volumes are created to archive both the MAG EDR data and the documentation which will be needed to analyze the EDRs. The first volume is the MAG documentation volume. The MAG documentation volume will contain products related to both the MAG EDR and RDR data archives. The initial release of the documentation volume will contain only EDR level documentation. RDR documents (such as the RDR SIS and dataset catalog) will be added to the volume at the time of initial release of those datasets. Once all of the MAG data products are designed and released, the documentation volume will contain the following products:

1. All required PDS catalog files for the EDR and RDR archives (dataset, instrument, mission, etc.)
2. The EDR and RDR SIS documents
3. The SSR instrument paper once copyright permission is obtained. This may not be included in the initial release for copyright reasons.

4. The MAG calibration report
5. A MAG calibration procedures document. This will contain appropriate pseudo-code for calibrating the data, converting the time word (MET to UTC), and transforming the data into useful coordinate systems.
6. Calibration tables including: sensor offsets time series, gains for each gain state, and the matrices required to orthogonalize the field vector components and orient them in the spacecraft frame.
7. Other documents considered useful by the MESSENGER project or MAG team (i.e. “data processing guide”)

The second archive volume will contain the EDR data and required files for conforming to PDS volume archive standards. This includes the Index files, AAREADME.TXT, etc. This is designated as the MAG EDR data archive volume. The final MAG EDR data archive volume contains about 20,000 files and has a size of approximately 130 GB.

### *6.6 Directory Structure And Contents For MAG Documentation Volume*

The following illustration shows the directory structure overview for the MAG documentation volume. This volume will be periodically updated as knowledge of the instrument, its calibration, and its operation improve over time. A first release of this volume that includes parameters derived from the ground calibration tests will accompany the initial release of the EDR data archive. After the initial release, there will be updates whenever the MAG team determines that they have a sufficiently improved calibration to warrant a new release.

**<u>Documentation Volume Directory Structure</u>**

```
                                  <ROOT>
       _____________________________|_______________________
       |                          |                          |
<CALIBRATION>                 <CATALOG>                <DOCUMENT>
        ____________________________________________________|_____
        |             |             |             |              |
    <EDR_SIS>     <CDR_SIS>     <RDR_SIS>         |     <CALIBRATION_PROCEDURE>
                                                  |
                                  <MERCURY_MAGNETIC_FIELD_MODELS>
```

### 6.6.1 Directory Contents

**<ROOT> Directory**

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

**AAREADME.TXT** - General information file. Provides users with an overview of the contents and organization of the associated volume, general instructions for its use, and contact 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, and possibly previous volumes of a set. Any known errors for the associated volume will be documented in this file.

**<CALIBRATION> Directory**

This will contain the calibration tables needed to analyze the MAG EDR data. The calibration tables are in ASCII comma separated value format.

**CALINFO.TXT** – Brief description of the directory contents and naming conventions.

**<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 the function of each file in the catalog directory.

**DATASET.CAT**: Describes the general content of the data set and includes information about the duration of the mission and the person or group responsible for producing the data.

**INSTRUMENT.CAT**: Describes physical attributes of the MAG 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.

**<DOCUMENT> Directory**

This subdirectory contains the documentation that will be needed in order to understand and analyze the EDR and RDR data volumes. The documents will be separated into individual subdirectories according to the document type. The document types are not restricted to the four shown in the graphical depiction of the directory structure. There will be as many document types as needed to categorize each document. The following file is included in the subdirectory.

**DOCINFO.txt:** Identifies and describes the function of each file in the DOCUMENT directory.

**<EDR_SIS> Directory**

Contains the EDR SIS document in various formats.

**<CDR_SIS> Directory**

Contains the CDR SIS document in various formats.

**<RDR_SIS> Directory**

Contains the RDR SIS document in various formats.

**<CALIBRATION_PROCEDURE> Directory**

Contains the document that describes the calibration procedure.

**<MECURY_MAGNETIC_FIELD_MODELS> Directory**

Contains a document that provides a brief summary of the magnetic field models and associated references.

## *6.7 Directory Structure and Contents for MAG EDR Data Volume*

The following illustration shows the directory structure overview for the MAG data volume. This volume contains the MAG EDR products any additional files required for the volume to be compliant with PDS volume standards. The content of the volume is expected to remain fairly static except for periodic releases according to the schedule in the MESSENGER Data Management and Archiving Plan. Revised EDRs (if needed) will be also be delivered according to the same schedule. Revised EDRs will be identified with an updated version number in the filename according to the file naming convention in section 6.4.

## Data Volume Directory Structure

```
                                 <ROOT>
___________________________________|________
  |                      |                  |
<DATA>               <GEOMETRY>          <INDEX>
   |
  _|______________________________________________________________________
  |    |          |     |                |         |        |        |
  | <BURST_DATA>  | <HOUSEKEEPING_DATA>  |   <SCIENCE_DATA> | <STATUS_DATA>
  |               |                      |                  |
<BURST_LOG>     <HOUSEKEEPING_HEADER>  <LOG_AC_DATA>   <SCIENCE_HEADER>
                       |
                    ___|______________
                    |        |      |
                   <2004> <2005>  <2006>
                                    |________________
                                      |     |       |
                                   <JAN>  <FEB>    <MAR> …
```

### 6.7.1 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 an overview of the contents and organization of the associated volume, general instructions for its use, and contact 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, and possibly previous volumes of a set. Any known errors for the associated volume will be documented in this file. This includes revised EDRs meant to replace EDRs in a previous PDS delivery.

**<DATA> - Directory**

This top level directory contains the EDR data products. Directly underneath the <DATA> directory are subdirectories corresponding to the eight standard data products (section 5.2). The directories are further subdivided into YEAR and MONTH directories.

**<GEOMETRY> Directory**

This subdirectory contains information about the files (e.g. SPICE kernels, etc.) needed to determine the observation geometry for the data.

**GEOMETRY.TXT** – Identifies and describes the SPICE kernels that a user must have in order to determine observation geometry for the data. The SPICE kernel files are archived with the PDS NAIF node.

**<INDEX> Directory**

This subdirectory contains the indices for all data products on the volume. The following files are contained in the index subdirectory.

**INDXINFO.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 EDR index file is organized as a table: there is one entry for each of the data files included in the UVVS data set; the columns contain parameters that describe the observation as well as instrument and spacecraft parameters. These parameters include state information, such as integration time, spacecraft clock count, time of observation, and instrument modes.

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

# 7. Archive Release Schedule to PDS

The MESSENGER MAG EDR archives will be transferred from the SOC to the PDS PPI Node using the electronic transfer process detailed in section 5.3.3. The transfer will take place according to the schedule in the MESSENGER Data Management and Archiving Plan.

# 8. Appendices

## *Appendix - MAG Status EDR PDS Label*

```
PDS_VERSION_ID                = "PDS3"

/*** FILE FORMAT ***/
FILE_RECORDS                  = 748
RECORD_TYPE                   = FIXED_LENGTH
RECORD_BYTES                  = 122

/*** GENERAL DATA DESCRIPTION PARAMETERS ***/
PRODUCT_ID                    = "MAGSTA061940302"
PRODUCT_VERSION_ID            = "V2"
PRODUCT_CREATION_TIME         = 2007-03-14T19:42:36
PRODUCT_TYPE                  = "ENGINEERING_DATA"
STANDARD_DATA_PRODUCT_ID      = "MAGSTA"
SOFTWARE_NAME                 = "PIPE-MAG2EDR"
SOFTWARE_VERSION_ID           = "1.0"
MD5_CHECKSUM                  = "abc123abc123abc123abc123"
INSTRUMENT_HOST_NAME          = "MESSENGER"
INSTRUMENT_NAME               = "MAGNETOMETER"
INSTRUMENT_ID                 = "MAG"
DATA_SET_ID                   = "MESS-E/V/H/SW-MAG-2-EDR-RAWDATA-V1.0"

MISSION_PHASE_NAME            = "VENUS 1 CRUISE"
TARGET_NAME                   = "CALIBRATION"
START_TIME                    = 2006-07-13T03:02:37
STOP_TIME                     = 2006-07-13T23:59:17
SPACECRAFT_CLOCK_START_COUNT  = 61246901
SPACECRAFT_CLOCK_STOP_COUNT   = 61322301
^TABLE                        = "MAGSTA061940302_V2.TAB"

OBJECT                        = TABLE
COLUMNS                       = 18
INTERCHANGE_FORMAT            = ASCII
ROW_BYTES                     = 122
ROWS                          = 748
DESCRIPTION                  = "
  The table contains the timetags and 3-axis samples of the Low Voltage Power
  Supply (LVPS) as well as instrument parameters. The sample rate is
  commandable and can vary. The table contains data from MAG Status Packets
  generated on a given day. START_TIME and STOP_TIME correspond to the
  TIME_TAG values of the first row and last row (respectively) in the table.
"

  OBJECT           = COLUMN
    NAME           = TIME_TAG
    COLUMN_NUMBER  = 1
    BYTES          = 12
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 1
    UNIT           = SECONDS
    DESCRIPTION    = "The Mission Elapsed Time (MET) in seconds
        when the LVPS X,Y,Z axis samples were collected.
                     "
  END_OBJECT       = COLUMN

  OBJECT           = COLUMN
    NAME           = ACTUAL_RANGE
    COLUMN_NUMBER  = 2
    BYTES          = 1
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 15
    DESCRIPTION    = "Actual Range used by MAG. =0 1530 nT, =1 51300 nT"
  END_OBJECT       = COLUMN

  OBJECT           = COLUMN
    NAME           = STATUS_CNT_SENSOR_X
```

```
    COLUMN_NUMBER  = 3
    BYTES          = 5
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 18
    DESCRIPTION    = "The LVPS X-axis sample. X axis field value in signed
      integer counts. If DN value is greater than 8192 then this value is
      DN - 16384. DN is the telemetry value stored in the downloaded packet.
      "
  END_OBJECT       = COLUMN

  OBJECT           = COLUMN
    NAME           = STATUS_CNT_SENSOR_Y
    COLUMN_NUMBER  = 4
    BYTES          = 5
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 25
    DESCRIPTION    = "The LVPS Y-axis sample. Y axis field value in signed
      integer counts. If DN value is greater than 8192 then this value is
      DN - 16384. DN is the telemetry value stored in the downloaded packet.
      "
  END_OBJECT       = COLUMN

  OBJECT           = COLUMN
    NAME           = STATUS_CNT_SENSOR_Z
    COLUMN_NUMBER  = 5
    BYTES          = 5
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 32
    DESCRIPTION    = "The LVPS Z-axis sample. Z axis field value in signed
      integer counts. If DN value is greater than 8192 then this value is
      DN - 16384. DN is the telemetry value stored in the downloaded packet.
      "
  END_OBJECT       = COLUMN

  OBJECT           = COLUMN
    NAME           = MAG_DC_DC_CURR
    COLUMN_NUMBER  = 6
    BYTES          = 8
    DATA_TYPE      = ASCII_REAL
    START_BYTE     = 39
    FORMAT         = "F8.4"
    UNIT           = "AMP"
    DESCRIPTION    = "The derived MAG DC/DC current; used the following
                      formula:
                      If the DN value is less than 128,
                        MAG_DC_DC_CURR = DN/64
                      else
                        MAG_DC_DC_CURR = (DN-256)/64.
                      Where DN is the telemetry value."
  END_OBJECT       = COLUMN

  OBJECT           = COLUMN
    NAME           = MAG_ELEC_TEMP
    COLUMN_NUMBER  = 7
    BYTES          = 9
    DATA_TYPE      = ASCII_REAL
    START_BYTE     = 49
    FORMAT         = "F9.2"
    UNIT           = "CELSIUS"
    DESCRIPTION    = "The derived MAG electronics temperature; used the
      following formula:
      MAG_ELEC_TEMP = (155*DN/127) - 55
      Where DN is the telemetry value.
      "
  END_OBJECT       = COLUMN

  OBJECT           = COLUMN
    NAME           = MAG_PROBE_TEMP
    COLUMN_NUMBER  = 8
    BYTES          = 9
    DATA_TYPE      = ASCII_INTEGER
```

```
    START_BYTE      = 60
    DESCRIPTION     = "The raw telemetry counts for the MAG probe temperature."
  END_OBJECT        = COLUMN

  OBJECT            = COLUMN
    NAME            = FSW_VERSION
    COLUMN_NUMBER   = 9
    BYTES           = 3
    DATA_TYPE       = ASCII_INTEGER
    START_BYTE      = 71
    DESCRIPTION     = "The Flight Software (FSW) version number."
  END_OBJECT        = COLUMN

  OBJECT            = COLUMN
    NAME            = LVPS_PLUS5V
    COLUMN_NUMBER   = 10
    BYTES           = 3
    DATA_TYPE       = ASCII_INTEGER
    START_BYTE      = 76
    DESCRIPTION     = "The raw integer counts for LVPS +5 voltage counter.
      The values for this column are set to an N/A value of 999 when
      FSW_VERSION is less than 9; the measurement did not exist in prior
      flight software versions."
  END_OBJECT        = COLUMN

  OBJECT            = COLUMN
    NAME            = LVPS_MINUS5V
    COLUMN_NUMBER   = 11
    BYTES           = 3
    DATA_TYPE       = ASCII_INTEGER
    START_BYTE      = 81
    DESCRIPTION     = "The raw integer counts for LVPS -5 voltage counter.
      The values for this column are set to an N/A value of 999 when
      FSW_VERSION is less than 9; the measurement did not exist in prior
      flight software versions."
  END_OBJECT        = COLUMN

  OBJECT            = COLUMN
    NAME            = LVPS_PLUS12V
    COLUMN_NUMBER   = 12
    BYTES           = 3
    DATA_TYPE       = ASCII_INTEGER
    START_BYTE      = 86
    DESCRIPTION     = "The raw integer counts for LVPS +12 voltage counter.
      The values for this column are set to an N/A value of 999 when
      FSW_VERSION is less than 9; the measurement did not exist in prior
      flight software versions."
  END_OBJECT        = COLUMN

  OBJECT            = COLUMN
    NAME            = LVPS_MINUS12V
    COLUMN_NUMBER   = 13
    BYTES           = 3
    DATA_TYPE       = ASCII_INTEGER
    START_BYTE      = 91
    DESCRIPTION     = "The raw integer counts for LVPS -12 voltage counter.
      The values for this column are set to an N/A value of 999 when
      FSW_VERSION is less than 9; the measurement did not exist in prior
      flight software versions."
  END_OBJECT        = COLUMN

  OBJECT            = COLUMN
    NAME            = LVPS_PLUS5I
    COLUMN_NUMBER   = 14
    BYTES           = 3
    DATA_TYPE       = ASCII_INTEGER
    START_BYTE      = 96
    DESCRIPTION     = "The raw integer counts for LVPS +5 current counter.
      The values for this column are set to an N/A value of 999 when
      FSW_VERSION is less than 9; the measurement did not exist in prior
      flight software versions."
```

```
  END_OBJECT       = COLUMN

  OBJECT           = COLUMN
    NAME           = LVPS_MINUS5I
    COLUMN_NUMBER  = 15
    BYTES          = 3
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 101
    DESCRIPTION    = "The raw integer counts for LVPS -5 current counter.
      The values for this column are set to an N/A value of 999 when
      FSW_VERSION is less than 9; the measurement did not exist in prior
      flight software versions."
  END_OBJECT       = COLUMN

  OBJECT           = COLUMN
    NAME           = LVPS_PLUS12I
    COLUMN_NUMBER  = 16
    BYTES          = 3
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 106
    DESCRIPTION    = "The raw integer counts for LVPS +12 current counter.
      The values for this column are set to an N/A value of 999 when
      FSW_VERSION is less than 9; the measurement did not exist in prior
      flight software versions."
  END_OBJECT       = COLUMN

  OBJECT           = COLUMN
    NAME           = LVPS_MINUS12I
    COLUMN_NUMBER  = 17
    BYTES          = 3
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 111
    DESCRIPTION    = "The raw integer counts for LVPS -12 current counter.
      The values for this column are set to an N/A value of 999 when
      FSW_VERSION is less than 9; the measurement did not exist in prior
      flight software versions."
  END_OBJECT       = COLUMN

  OBJECT           = COLUMN
    NAME           = HEATER_DUTY_CYCLE
    COLUMN_NUMBER  = 18
    BYTES          = 5
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 116
    DESCRIPTION    = "The heater duty cycle.
      The values for this column are set to an N/A value of 65533 when
      FSW_VERSION is less than 9; the measurement did not exist in prior
      flight software versions."
  END_OBJECT       = COLUMN

  END_OBJECT       = TABLE
END
```

## *Appendix - MAG Science EDR PDS Label*

```
PDS_VERSION_ID                 = "PDS3"

/*** FILE FORMAT ***/
FILE_RECORDS                   = 86400
RECORD_TYPE                    = FIXED_LENGTH
RECORD_BYTES                   = 42

/*** GENERAL DATA DESCRIPTION PARAMETERS ***/
PRODUCT_ID                     = "MAGSCI061960001"
PRODUCT_VERSION_ID             = "V1"
PRODUCT_CREATION_TIME          = 2006-07-19T15:02:36
PRODUCT_TYPE                   = "DATA"
STANDARD_DATA_PRODUCT_ID       = "MAGSCI"
SOFTWARE_NAME                  = "PIPE-MAG2EDR"
```

```
SOFTWARE_VERSION_ID           = "1.1"
MD5_CHECKSUM                  = "abc123abc123abc123abc123"
INSTRUMENT_HOST_NAME          = "MESSENGER"
INSTRUMENT_NAME               = "MAGNETOMETER"
INSTRUMENT_ID                 = "MAG"
DATA_SET_ID                   = "MESS-E/V/H/SW-MAG-2-EDR-RAWDATA-V1.0"

MISSION_PHASE_NAME            = "CRUISE"
TARGET_NAME                   = "CALIBRATION"
START_TIME                    = 2006-07-15T00:01:28
STOP_TIME                     = 2006-07-15T23:58:13
SPACECRAFT_CLOCK_START_COUNT  = 61408783
SPACECRAFT_CLOCK_STOP_COUNT   = 61494987
^TABLE                        = "MAGSCI061960001_V1.TAB"

OBJECT                        = TABLE
COLUMNS                       = 5
INTERCHANGE_FORMAT            = ASCII
ROW_BYTES                     = 42
ROWS                          = 86400
DESCRIPTION                  = "
The table contains the timetags and 3-axis samples of the magnetic field. The
sampling rate is commandable and can vary. The table contains data from MAG
science packets generated on a given day; data from each packet will be stored
as one row in the ASCII table. START_TIME and STOP_TIME correspond to the
TIME_TAG values of the first row and last row (respectively) in the table.
"

  OBJECT           = COLUMN
    NAME           = TIME_TAG
    COLUMN_NUMBER  = 1
    BYTES          = 14
    DATA_TYPE      = ASCII_REAL
    START_BYTE     = 1
    FORMAT         = "F14.2"
    DESCRIPTION    = "A derived value for the timetag associated with the
           x,y,z sample in each record. The derived value is created by the
           following formula:
           MET + 0.05 * delta_ts + (dt_sample)*(I-1).
           MET is the mission elapsed time for the entire science packet.
           delta_ts is the delta time in seconds between the MET and
           the first sample in the downloaded science packet.
           dt_sample is the time between samples in seconds and given by
           dt_sample = 1/sample_rate where sample_rate is the reported
           sample rate in samples per second.
           I is the incremental counter for each data sample in the
           science packet. I=1 is the first sample in the packet.
    "
  END_OBJECT       = COLUMN

  OBJECT           = COLUMN
    NAME           = ACTUAL_RANGE
    COLUMN_NUMBER  = 2
    BYTES          = 1
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 17
    DESCRIPTION    = "Actual range used by MAG. =0 1530 nT, =1 51300 nT."
  END_OBJECT       = COLUMN

  OBJECT           = COLUMN
    NAME           = SAMPLE_X
    COLUMN_NUMBER  = 3
    BYTES          = 6
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 20
    DESCRIPTION    = "X axis field value in signed integer counts. If DN is
      greater than 32768 then this value is DN - 65536. DN is the telemetry
      value stored in the downloaded packet."
  END_OBJECT       = COLUMN

  OBJECT           = COLUMN
```

```
    NAME           = SAMPLE_Y
    COLUMN_NUMBER  = 4
    BYTES          = 6
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 28
    DESCRIPTION    = "Y axis field value in signed integer counts. If DN is
      greater than 32768 then this value is DN - 65536. DN is the telemetry
      value stored in the downloaded packet."
  END_OBJECT       = COLUMN

  OBJECT           = COLUMN
    NAME           = SAMPLE_Z
    COLUMN_NUMBER  = 5
    BYTES          = 6
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 36
    DESCRIPTION    = "Z axis field value in signed integer counts. If DN is
      greater than 32768 then this value is DN - 65536. DN is the telemetry
      value stored in the downloaded packet."
  END_OBJECT       = COLUMN

  END_OBJECT       = TABLE
END
```

## *Appendix - MAG Science Header EDR PDS Label*

```
PDS_VERSION_ID                 = "PDS3"

/*** FILE FORMAT ***/
FILE_RECORDS                   = 71
RECORD_TYPE                    = FIXED_LENGTH
RECORD_BYTES                   = 82

/*** GENERAL DATA DESCRIPTION PARAMETERS ***/
PRODUCT_ID                     = "MAGSHD051782103"
PRODUCT_VERSION_ID             = "V2"
PRODUCT_CREATION_TIME          = 2007-03-16T14:45:34
PRODUCT_TYPE                   = "ENGINEERING_DATA"
STANDARD_DATA_PRODUCT_ID       = "MAGSHD"
SOFTWARE_NAME                  = "PIPE-MAG2EDR"
SOFTWARE_VERSION_ID            = "1.1"
MD5_CHECKSUM                   = "abc123abc123abc123abc123"
INSTRUMENT_HOST_NAME           = "MESSENGER"
INSTRUMENT_NAME                = "MAGNETOMETER"
INSTRUMENT_ID                  = "MAG"
DATA_SET_ID                    = "MESS-E/V/H/SW-MAG-2-EDR-RAWDATA-V1.0"

MISSION_PHASE_NAME             = "EARTH CRUISE"
TARGET_NAME                    = "CALIBRATION"
START_TIME                     = 2005-06-27T21:03:26
STOP_TIME                      = 2005-06-27T23:59:07
SPACECRAFT_CLOCK_START_COUNT   = 28393350
SPACECRAFT_CLOCK_STOP_COUNT    = 28403891
^TABLE                         = "MAGSHD051782103_V2.TAB"

OBJECT                         = TABLE
COLUMNS                        = 18
INTERCHANGE_FORMAT             = ASCII
ROW_BYTES                      = 82
ROWS                           = 71
DESCRIPTION                   = "
  The table contains information reflecting the instrument state
  (health and mode) as reported by the MAG science packet. Each record in the
  table corresponds to the instrument state for a given science packet as
  these parameters are only updated once per packet. The table contains data
  from Science packets generated on a given day; data from each packet will
  be stored as one row in the ASCII table. START_TIME and STOP_TIME correspond
  to the MET values of the first row and last row (respectively) in the table.
"
```

```
OBJECT           = COLUMN
  NAME           = TIME_TAG
  COLUMN_NUMBER  = 1
  BYTES          = 14
  DATA_TYPE      = ASCII_REAL
  START_BYTE     = 1
  FORMAT         = "F14.2"
  DESCRIPTION    = "A derived value for the timetag associated with the
         x,y,z sample in each record. The derived value is created by the
         following formula:
         MET + 0.05 * delta_ts + (dt_sample)*(I-1).
         MET is the mission elapsed time for the entire science packet.
         delta_ts is the delta time in seconds between the MET and
         the first sample in the downloaded science packet.
         dt_sample is the time between samples in seconds and given by
         dt_sample = 1/sample_rate where sample_rate is the reported
         sample rate in samples per second.
         I is the incremental counter for each data sample in the
         science packet. I=1 is the first sample in the packet.
  "
END_OBJECT       = COLUMN

OBJECT           = COLUMN
  NAME           = DELTA_TS
  COLUMN_NUMBER  = 2
  BYTES          = 2
  DATA_TYPE      = ASCII_INTEGER
  START_BYTE     = 17
  DESCRIPTION    = "The delta time in 50 millisecond steps between the MET
     value for the packet and the first sample in the science packet,
     provides a 50 millisecond resolution to the time tag for the first data
     value."
END_OBJECT       = COLUMN

OBJECT           = COLUMN
  NAME           = NUM_SAMPLES
  COLUMN_NUMBER  = 3
  BYTES          = 3
  DATA_TYPE      = ASCII_INTEGER
  START_BYTE     = 21
  DESCRIPTION    = "The number of MAG samples (0-200) in the science
                    packet."
END_OBJECT       = COLUMN

OBJECT           = COLUMN
  NAME           = NUM_LOGAC
  COLUMN_NUMBER  = 4
  BYTES          = 3
  DATA_TYPE      = ASCII_INTEGER
  START_BYTE     = 26
  DESCRIPTION    = "The number of logAC samples (0-200) in the
                    science packet."
END_OBJECT       = COLUMN

OBJECT           = COLUMN
  NAME           = ANALOG_CAL
  COLUMN_NUMBER  = 5
  BYTES          = 1
  DATA_TYPE      = ASCII_INTEGER
  START_BYTE     = 31
  DESCRIPTION    = "Analog calibration flag. =0 off, =1 on."
END_OBJECT       = COLUMN

OBJECT           = COLUMN
  NAME           = A_D_CAL
  COLUMN_NUMBER  = 6
  BYTES          = 1
  DATA_TYPE      = ASCII_INTEGER
  START_BYTE     = 34
  DESCRIPTION    = "A/D calibration flag. =0 off, =1 on."
```

```
END_OBJECT       = COLUMN

OBJECT           = COLUMN
  NAME           = COMPRESS_ON
  COLUMN_NUMBER  = 7
  BYTES          = 1
  DATA_TYPE      = ASCII_INTEGER
  START_BYTE     = 37
  DESCRIPTION    = "Indicates whether science packet was compressed or
                    uncompressed. =0 uncompressed, =1 compressed."
END_OBJECT       = COLUMN

OBJECT           = COLUMN
  NAME           = RANGE_MODE
  COLUMN_NUMBER  = 8
  BYTES          = 1
  DATA_TYPE      = ASCII_INTEGER
  START_BYTE     = 40
  DESCRIPTION    = "Range control mode used. =0 manual, =1 automatic"
END_OBJECT       = COLUMN

OBJECT           = COLUMN
  NAME           = FILTERS_ON
  COLUMN_NUMBER  = 9
  BYTES          = 1
  DATA_TYPE      = ASCII_INTEGER
  START_BYTE     = 43
  DESCRIPTION    = "Indicates whether filters were on or off.
                    =0 off, =1 on"
END_OBJECT       = COLUMN

OBJECT           = COLUMN
  NAME           = MANUAL_RANGE_CMD
  COLUMN_NUMBER  = 10
  BYTES          = 1
  DATA_TYPE      = ASCII_INTEGER
  START_BYTE     = 45
  DESCRIPTION    = "Commanded manual range setting.
                    =0 1530 nT, =1 51300 nT"
END_OBJECT       = COLUMN

OBJECT           = COLUMN
  NAME           = ACTUAL_RANGE
  COLUMN_NUMBER  = 11
  BYTES          = 1
  DATA_TYPE      = ASCII_INTEGER
  START_BYTE     = 49
  DESCRIPTION    = "Actual range used by MAG. =0 1530 nT, =1 51300 nT."
END_OBJECT       = COLUMN

OBJECT           = COLUMN
  NAME           = AC_AXIS
  COLUMN_NUMBER  = 12
  BYTES          = 1
  DATA_TYPE      = ASCII_INTEGER
  START_BYTE     = 52
  DESCRIPTION    = "AC axis selected.
                    =0 X, =1 Y, =2 Z"
END_OBJECT       = COLUMN

OBJECT           = COLUMN
  NAME           = SAMPLE_RATE
  COLUMN_NUMBER  = 13
  BYTES          = 2
  DATA_TYPE      = ASCII_INTEGER
  START_BYTE     = 55
  DESCRIPTION    = "MAG sample rate. =0 0.01/s, =1 0.02/s,
                    =2 0.05/s, =3 0.1/s, =4 0.2/s, =5 0.5/s,
                    =6 1/s, =7 2/s, =8 5/s, =9 10/s, =10 20/s"
END_OBJECT       = COLUMN
```

```
  OBJECT            = COLUMN
    NAME            = APP_ID
    COLUMN_NUMBER   = 14
    BYTES           = 3
    DATA_TYPE       = ASCII_INTEGER
    START_BYTE      = 59
    DESCRIPTION     = "The Application Process ID of the science packet from
    which data was extracted. Values for PROBE_TEMPERATURE are N/A when this
    value is 721, which is the AppID of the old packet format. An AppID of 725
    identifies the new packet format which contains valid values for
    PROBE_TEMPERATURE."
  END_OBJECT        = COLUMN

  OBJECT            = COLUMN
    NAME            = X_SAMPLES_COMPRESSION_BITS
    COLUMN_NUMBER   = 15
    BYTES           = 2
    DATA_TYPE       = ASCII_INTEGER
    START_BYTE      = 64
    DESCRIPTION     = "Number of bits needed to store each compressed X axis
    sample."
  END_OBJECT        = COLUMN

  OBJECT            = COLUMN
    NAME            = Y_SAMPLES_COMPRESSION_BITS
    COLUMN_NUMBER   = 16
    BYTES           = 2
    DATA_TYPE       = ASCII_INTEGER
    START_BYTE      = 68
    DESCRIPTION     = "Number of bits needed to store each compressed Y axis
    sample."
  END_OBJECT        = COLUMN

  OBJECT            = COLUMN
    NAME            = Z_SAMPLES_COMPRESSION_BITS
    COLUMN_NUMBER   = 17
    BYTES           = 2
    DATA_TYPE       = ASCII_INTEGER
    START_BYTE      = 72
    DESCRIPTION     = "Number of bits needed to store each compressed Z axis
    sample."
  END_OBJECT        = COLUMN

  OBJECT            = COLUMN
    NAME            = PROBE_TEMPERATURE
    COLUMN_NUMBER   = 18
    BYTES           = 5
    DATA_TYPE       = ASCII_INTEGER
    START_BYTE      = 76
    DESCRIPTION     = "Raw telemetry counts of the High temperature resolution
    probe temperature. This is set to an N/A value of 65535 when APP_ID is 721."
  END_OBJECT        = COLUMN

  END_OBJECT        = TABLE
END
```

## *Appendix - MAG AC EDR PDS Label*

```
PDS_VERSION_ID                  = "PDS3"

/*** FILE FORMAT ***/
FILE_RECORDS                    = 10739
RECORD_TYPE                     = FIXED_LENGTH
RECORD_BYTES                    = 41

/*** GENERAL DATA DESCRIPTION PARAMETERS ***/
PRODUCT_ID                      = "MAGLAC051782103"
PRODUCT_VERSION_ID              = "V2"
PRODUCT_CREATION_TIME           = 2007-03-16T15:54:07
```

```
PRODUCT_TYPE                  = "DATA"
STANDARD_DATA_PRODUCT_ID      = "MAGLAC"
SOFTWARE_NAME                 = "PIPE-MAG2EDR"
SOFTWARE_VERSION_ID           = "1.1"
MD5_CHECKSUM                  = "abc123abc123abc123abc123"
INSTRUMENT_HOST_NAME          = "MESSENGER"
INSTRUMENT_NAME               = "MAGNETOMETER"
INSTRUMENT_ID                 = "MAG"
DATA_SET_ID                   = "MESS-E/V/H/SW-MAG-2-EDR-RAWDATA-V1.0"

MISSION_PHASE_NAME            = "EARTH CRUISE"
TARGET_NAME                   = "CALIBRATION"
START_TIME                    = 2005-06-27T21:03:26
STOP_TIME                     = 2005-06-27T23:59:07
SPACECRAFT_CLOCK_START_COUNT  = 28393350
SPACECRAFT_CLOCK_STOP_COUNT   = 28403891
^TABLE                        = ("MAGLAC051782103_V2.TAB")

OBJECT                        = TABLE
COLUMNS                       = 6
INTERCHANGE_FORMAT            = ASCII
ROW_BYTES                     = 41
ROWS                          = 10739
DESCRIPTION                  = "
The table contains the timetags and 3-axis samples of the magnetic field.
The sampling rate is commandable and can vary. The data from each packet
will be stored as one row in the ASCII table. START_TIME and STOP_TIME
correspond to the TIME_TAG values of the first row and last row (respectively)
in the table.
"

  OBJECT             = COLUMN
    NAME             = TIME_TAG
    COLUMN_NUMBER    = 1
    BYTES            = 14
    DATA_TYPE        = ASCII_REAL
    START_BYTE       = 1
    FORMAT           = "F14.2"
    DESCRIPTION      = "A derived value for the timetag associated with the
      data values in each record.
      The derived value is created by the following formula:
      MET + 0.05 * delta_ts + 0.5 + (dt_sample)*(i-1)*(num_samples/num_AC).
      MET is the mission elapsed time for the entire science packet.
      delta_ts is the time in seconds between the MET and the first sample
      in the science packet.
      dt_sample is the time between samples in seconds and is given by
      dt_sample = 1/sample_rate where sample_rate is the reported sample
      rate in samples per second.
      num_samples is number of magnetometer samples.
      num_AC is the number of logAC values.
      i is the incremental counter for each of the logAC values. i=1 is the
      first logAC value in the science packet.
    "
  END_OBJECT         = COLUMN

  OBJECT             = COLUMN
    NAME             = AC_AXIS
    COLUMN_NUMBER    = 2
    BYTES            = 1
    DATA_TYPE        = ASCII_INTEGER
    START_BYTE       = 17
    DESCRIPTION      = "The AC axis selected."
  END_OBJECT         = COLUMN

  OBJECT             = COLUMN
    NAME             = LOG_AC
    COLUMN_NUMBER    = 3
    BYTES            = 5
    DATA_TYPE        = ASCII_INTEGER
    START_BYTE       = 20
    DESCRIPTION      = "An 8-bit log AC value generated from the 16-bit AC
```

```
      value. This is done by shifting the 16-bit mantissa left one bit at a
      time while it does not overflow. The log AC value consists of shift
      count which is 15 minus the number of shifts (0-15) combined with the
      four MSBs of the shifted mantissa;  the shift count will be in the
      four MSBs of the log AC value; the mantissa bits are in the four LSBs.
      "
  END_OBJECT       = COLUMN

  OBJECT           = COLUMN
    NAME           = AC_COUNT
    COLUMN_NUMBER  = 4
    BYTES          = 5
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 27
    DESCRIPTION    = "The calculated AC count value; derived from the LOG_AC
      value by the following formula:
      AC_exp = trunc(LOG_AC/16) (exponent value)
      AC_mant = LOG_AC - 16*AC_exp (mantissa value)
      CNT_AC = (AC_mant + 0.5)* (2**(AC_exp-4))"
  END_OBJECT       = COLUMN

  OBJECT           = COLUMN
    NAME           = APP_ID
    COLUMN_NUMBER  = 5
    BYTES          = 3
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 34
    DESCRIPTION    = "The Application Process ID of the science packet from
    which data was extracted. Values for PROBE_HEATER_STATE are N/A when this
    value is 721, which is an older version of the science packet."
  END_OBJECT       = COLUMN

  OBJECT           = COLUMN
    NAME           = PROBE_HEATER_STATE
    COLUMN_NUMBER  = 6
    BYTES          = 1
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 39
    DESCRIPTION    = "The MAG-EPU sensor survival heater request bit at the
    time of the LOG_AC value. = 0 off, =1 on, =2 N/A."
  END_OBJECT       = COLUMN

  END_OBJECT       = TABLE
END
```

## *Appendix - MAG LRHK EDR PDS Label*

```
PDS_VERSION_ID                = "PDS3"

/*** FILE FORMAT ***/
FILE_RECORDS                  = 1720
RECORD_TYPE                   = FIXED_LENGTH
RECORD_BYTES                  = 50

/*** GENERAL DATA DESCRIPTION PARAMETERS ***/
PRODUCT_ID                    = "MAGLHK061960006"
PRODUCT_VERSION_ID            = "V1"
PRODUCT_CREATION_TIME         = 2006-07-19T00:21:16
PRODUCT_TYPE                  = "ENGINEERING_DATA"
STANDARD_DATA_PRODUCT_ID      = "MAGLHK"
SOFTWARE_NAME                 = "PIPE-MAG2EDR"
SOFTWARE_VERSION_ID           = "1.0"
MD5_CHECKSUM                  = "abc123abc123abc123abc123"
INSTRUMENT_HOST_NAME          = "MESSENGER"
INSTRUMENT_NAME               = "MAGNETOMETER"
INSTRUMENT_ID                 = "MAG"
```

```
DATA_SET_ID                    = "MESS-E/V/H/SW-MAG-2-EDR-RAWDATA-V1.0"

MISSION_PHASE_NAME             = "CRUISE"
TARGET_NAME                    = "CALIBRATION"
START_TIME                     = 2006-07-15T00:06:55
STOP_TIME                      = 2006-07-15T23:51:55
SPACECRAFT_CLOCK_START_COUNT   = 61409110
SPACECRAFT_CLOCK_STOP_COUNT    = 61494609
^TABLE                         = "MAGLHK061960006_V1.TAB"

OBJECT                         = TABLE
COLUMNS                        = 6
INTERCHANGE_FORMAT             = ASCII
ROW_BYTES                      = 50
ROWS                           = 1720
DESCRIPTION                   = "
The table contains the timetags and instrument state as reported by the
MAG Low-Rate Housekeeping (LRHK) packet. Each record in the table corresponds
to up to 10 sampled field values recorded by the MAG instrument.
The table contains data from LRHK packets generated on a given day.
START_TIME and STOP_TIME correspond to the MET values of the first row and
last row (respectively) in the table.
"

OBJECT         = COLUMN
   NAME           = TIME_TAG
   COLUMN_NUMBER  = 1
   BYTES          = 14
   DATA_TYPE      = ASCII_REAL
   START_BYTE     = 1
   FORMAT         = "F14.2"
   DESCRIPTION    = "A derived value for the timetag associated with the data
   values in each record of the EDR table. The timetag is created by the
   following formula:
     TIME_TAG = MET + 0.05 * (low_rate_offset_time).
     The MET is the mission elapsed time recorded for a given LRHK packet.
     The low_rate_offset_time is the difference in units of 50 milliseconds
     between the MET and the time when a sampled field value is taken.
     Each sampled field value has an associated low_rate_offset_time.
     "
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = ACTUAL_RANGE
   COLUMN_NUMBER  = 2
   BYTES          = 1
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 17
   DESCRIPTION    = "Actual range used by the MAG. =0 2048 nT, =1 65536 nT."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = CNT_AC
   COLUMN_NUMBER  = 3
   BYTES          = 5
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 20
   DESCRIPTION    = "The calculated AC count value. This is derived from the
   LOG_AC value reported by the LRHK packet by the following formula:
   AC_exp = LOG_AC/16
   AC_mant = LOG_AC - 16*AC_exp
   CNT_AC = (AC_mant + 0.5) * (2**(AC_exp-4))
   "
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = CNT_SENSOR_X
   COLUMN_NUMBER  = 4
   BYTES          = 6
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 27
```

```
   DESCRIPTION    = "X axis field value in signed integer counts. If DN is
     greater than 32768 then this value is DN - 65536. DN is the telemetry
     value stored in the downloaded packet."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CNT_SENSOR_Y
   COLUMN_NUMBER  = 5
   BYTES          = 6
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 35
   DESCRIPTION    = "Y axis field value in signed integer counts. If DN is
     greater than 32768 then this value is DN - 65536. DN is the telemetry
     value stored in the downloaded packet."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CNT_SENSOR_Z
   COLUMN_NUMBER  = 6
   BYTES          = 6
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 43
   DESCRIPTION    = "Z axis field value in signed integer counts. If DN is
     greater than 32768 then this value is DN - 65536. DN is the telemetry
     value stored in the downloaded packet."
END_OBJECT    = COLUMN

END_OBJECT       = TABLE

END
```

## Appendix - MAG LRHK Header EDR PDS Label

```
PDS_VERSION_ID                   = "PDS3"

/*** FILE FORMAT ***/
FILE_RECORDS                     = 172
RECORD_TYPE                      = FIXED_LENGTH
RECORD_BYTES                     = 80

/*** GENERAL DATA DESCRIPTION PARAMETERS ***/
PRODUCT_ID                       = "MAGLHD061960006"
PRODUCT_VERSION_ID               = "V1"
PRODUCT_CREATION_TIME            = 2006-07-19T18:09:30
PRODUCT_TYPE                     = "ENGINEERING_DATA"
STANDARD_DATA_PRODUCT_ID         = "MAGLHD"
SOFTWARE_NAME                    = "PIPE-MAG2EDR"
SOFTWARE_VERSION_ID              = "1.0"
MD5_CHECKSUM                     = "abc123abc123abc123abc123"
INSTRUMENT_HOST_NAME             = "MESSENGER"
INSTRUMENT_NAME                  = "MAGNETOMETER"
INSTRUMENT_ID                    = "MAG"
DATA_SET_ID                      = "MESS-E/V/H/SW-MAG-2-EDR-RAWDATA-V1.0"

MISSION_PHASE_NAME               = "CRUISE"
TARGET_NAME                      = "CALIBRATION"
START_TIME                       = 2006-07-15T00:06:55
STOP_TIME                        = 2006-07-15T23:51:55
SPACECRAFT_CLOCK_START_COUNT     = 61409110
SPACECRAFT_CLOCK_STOP_COUNT      = 61494609
^TABLE                           = ("MAGLHD061960006_V1.TAB")

OBJECT                           = TABLE
COLUMNS                          = 10
INTERCHANGE_FORMAT               = ASCII
ROW_BYTES                        = 80
ROWS                             = 172
DESCRIPTION                     = "
The table contains the instrument state (mode and health) as reported by the
MAG Low-Rate Housekeeping (LRHK) packet. Each record in the table corresponds
to the instrument state for a given LRHK packet. The table contains data from
```

```
LRHK packets generated on a given day; data from each packet is stored as one
row in the ASCII table. START_TIME and STOP_TIME correspond to the MET values
of the first row and last row (respectively) in the table.
"

OBJECT         = COLUMN
   NAME           = MET
   COLUMN_NUMBER  = 1
   BYTES          = 12
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 1
   UNIT           = SECONDS
   DESCRIPTION    = "Mission elapsed time in seconds."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = LR_OFFSET_TIME0
   COLUMN_NUMBER  = 2
   BYTES          = 4
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 15
   DESCRIPTION    = "The delta time offset from MET for the first low-rate
   data sample in the LRHK packet (in steps of 50 milliseconds). Provides 50
   msec resolution."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = MIN_INTERVAL
   COLUMN_NUMBER  = 3
   BYTES          = 4
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 21
   DESCRIPTION    = "The minimum derived sampling interval in seconds.
   Determined by taking the minimum time difference between successive
   timestamps in the LRHK packet.
   "
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = MAX_INTERVAL
   COLUMN_NUMBER  = 4
   BYTES          = 4
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 27
   DESCRIPTION    = "The maximum derived sampling interval in seconds.
   Determined by taking the maximum time difference between successive
   timestamps in the LRHK packet.
   "
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = NUM_LR_SAMPLES
   COLUMN_NUMBER  = 5
   BYTES          = 2
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 33
   DESCRIPTION    = "Number of low-rate sample data in the LRHK packet."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = RNG_UP_TIME_DELAY
   COLUMN_NUMBER  = 6
   BYTES          = 4
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 37
   DESCRIPTION    = "Samples before increasing range."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = RNG_DN_TIME_DELAY
   COLUMN_NUMBER  = 7
```

```
   BYTES          = 4
   DATA_TYPE      = ASCII_INTEGER
   START_BYTE     = 43
   DESCRIPTION    = "Samples before decreasing range."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = MAG_DC_DC_CURR
   COLUMN_NUMBER  = 8
   BYTES          = 8
   DATA_TYPE      = ASCII_REAL
   FORMAT         = "F8.4"
   START_BYTE     = 49
   DESCRIPTION    = "The derived MAG DC/DC current; used following formula:
   if the DN (telemetry value) is less than 128:
      MAG_DC_DC_CURR = DN/64
   else
      MAG_DC_DC_CURR = (DN-256)/64
   The resulting value is in units of amperes.
   "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = PROBE_TEMP
   COLUMN_NUMBER  = 9
   BYTES          = 9
   DATA_TYPE      = ASCII_REAL
   FORMAT         = "F9.2"
   START_BYTE     = 59
   DESCRIPTION    = "The derived MAG probe temperature:
     PROBE_TEMP = 0.0123*(DN**2) - 0.7316*DN - 144.85. Value is in units of
     degrees Celsius.
   "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = MAG_ELEC_TEMP
   COLUMN_NUMBER  = 10
   BYTES          = 9
   DATA_TYPE      = ASCII_REAL
   FORMAT         = "F9.2"
   START_BYTE     = 70
   DESCRIPTION    = "The derived MAG electronics temperature:
     MAG_ELEC_TEMP = (155*DN/127) - 55
    The value for this column is in units of degrees Celsius.
   "
END_OBJECT    = COLUMN

END_OBJECT       = TABLE
END
```

## *Appendix - MAG BURST EDR PDS Label*

```
PDS_VERSION_ID                   = "PDS3"

/*** FILE FORMAT ***/
FILE_RECORDS                     = 9600
RECORD_TYPE                      = FIXED_LENGTH
RECORD_BYTES                     = 36

/*** GENERAL DATA DESCRIPTION PARAMETERS ***/
PRODUCT_ID                       = "MAGBST052150015"
PRODUCT_VERSION_ID               = "V1"
PRODUCT_CREATION_TIME            = 2006-07-19T18:13:17
PRODUCT_TYPE                     = "DATA"
STANDARD_DATA_PRODUCT_ID         = "MAGBST"
SOFTWARE_NAME                    = "PIPE-MAG2EDR"
SOFTWARE_VERSION_ID              = "1.0"
MD5_CHECKSUM                     = "abc123abc123abc123abc123"
```

```
INSTRUMENT_HOST_NAME           = "MESSENGER"
INSTRUMENT_NAME                = "MAGNETOMETER"
INSTRUMENT_ID                  = "MAG"
DATA_SET_ID                    = "MESS-E/V/H/SW-MAG-2-EDR-RAWDATA-V1.0"
MISSION_PHASE_NAME             = "EARTH_ENCOUNTER"
TARGET_NAME                    = "EARTH"

START_TIME                     = 2005-08-03T00:07:50
STOP_TIME                      = 2005-08-03T00:15:49
SPACECRAFT_CLOCK_START_COUNT   = 31514814
SPACECRAFT_CLOCK_STOP_COUNT    = 31515293
^TABLE                         = "MAGBST052150015_V1.TAB"

OBJECT                         = TABLE
COLUMNS                        = 4
INTERCHANGE_FORMAT             = ASCII
ROW_BYTES                      = 36
ROWS                           = 9600
DESCRIPTION   = "The table contains the log of burst observations obtained
during the entire MESSENGER mission. It is intended to give an overview of
times when burst observations were conducted, a measure of their completeness
(whether packets are missing), and the actual range used when conducting the
burst observation.
"

  OBJECT            = COLUMN
    NAME            = TIME_TAG
    COLUMN_NUMBER   = 1
    BYTES           = 14
    DATA_TYPE       = ASCII_REAL
    START_BYTE      = 1
    FORMAT          = "F14.2"
    DESCRIPTION     = "A derived value for the timetag associated with the data
    values in each record. The length of the observation (8 minutes) and the
    sample rate results in a total of 9600 records. However, the burst packet
    can only contain up to 640 records. Fifteen burst packets are required to
    download all the records for one burst observation. The timetag for each
    record is created by:
       MET + 0.05*delta_t - 0.05*(9600-640*(i-1)-j)
    MET is mission elapsed time for the last burst record of the observation.
    delta_t is the delta time for the last burst record of the observation,
    giving a 50ms resolution to the timestamp.
    i is the 'ith' record in a given burst packet."
  END_OBJECT        = COLUMN

  OBJECT            = COLUMN
    NAME            = SAMPLE_X
    COLUMN_NUMBER   = 2
    BYTES           = 5
    DATA_TYPE       = ASCII_INTEGER
    START_BYTE      = 17
    DESCRIPTION     = "X axis field value in signed integer counts. If DN
    is greater than 32768 then this value is DN - 65536. DN is the
    telemetry value stored in the downloaded burst packet."
  END_OBJECT        = COLUMN

  OBJECT            = COLUMN
    NAME            = SAMPLE_Y
    COLUMN_NUMBER   = 3
    BYTES           = 5
    DATA_TYPE       = ASCII_INTEGER
    START_BYTE      = 24
    DESCRIPTION     = "Y axis field value in signed integer counts. If DN
    is greater than 32768 then this value is DN - 65536. DN is the
    telemetry value stored in the downloaded burst packet."
  END_OBJECT        = COLUMN

  OBJECT            = COLUMN
    NAME            = SAMPLE_Z
    COLUMN_NUMBER   = 4
    BYTES           = 5
```

```
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 31
    DESCRIPTION    = "Z axis field value in signed integer counts. If DN
    is greater than 32768 then this value is DN - 65536. DN is the
    telemetry value stored in the downloaded burst packet."
  END_OBJECT       = COLUMN

  END_OBJECT       = TABLE

END
```

## Appendix - MAG BURST LOG EDR PDS Label

```
PDS_VERSION_ID                 = "PDS3"

/*** FILE FORMAT ***/
FILE_RECORDS                   = 26
RECORD_TYPE                    = FIXED_LENGTH
RECORD_BYTES                   = 28

/*** GENERAL DATA DESCRIPTION PARAMETERS ***/
PRODUCT_ID                     = "MAG_BURST_LOG"
PRODUCT_VERSION_ID             = "V1"
PRODUCT_CREATION_TIME          = 2006-07-19T15:48:42
PRODUCT_TYPE                   = "DATA"
STANDARD_DATA_PRODUCT_ID       = "MAGBSTLOG"
SOFTWARE_NAME                  = "PIPE-MAG2EDR"
SOFTWARE_VERSION_ID            = "1.0"
INSTRUMENT_HOST_NAME           = "MESSENGER"
INSTRUMENT_NAME                = "MAGNETOMETER"
INSTRUMENT_ID                  = "MAG"
DATA_SET_ID                    = "MESS-E/V/H/SW-MAG-2-EDR-RAWDATA-V1.0"

START_TIME                     = 2005-06-27T23:40:47
STOP_TIME                      = 2006-04-19T02:51:18
SPACECRAFT_CLOCK_START_COUNT   = 28402791
SPACECRAFT_CLOCK_STOP_COUNT    = 53902272
^TABLE                         = "MAG_BST_LOG_V1.TAB"

OBJECT                         = TABLE
COLUMNS                        = 4
INTERCHANGE_FORMAT             = ASCII
ROW_BYTES                      = 28
ROWS                           = 26
DESCRIPTION   = "The table contains the log of burst observations obtained
during the entire MESSENGER mission. It is intended to give an overview of
times when burst observations were conducted, a measure of their completeness
(whether packets are missing), and the actual range used when conducting the
burst observation."

  OBJECT           = COLUMN
    NAME           = MET
    COLUMN_NUMBER  = 1
    BYTES          = 12
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 1
    DESCRIPTION    = "Mission elapsed time for the last burst record in the
        burst observation."
  END_OBJECT       = COLUMN

  OBJECT           = COLUMN
    NAME           = DELTA_T
    COLUMN_NUMBER  = 2
    BYTES          = 4
    DATA_TYPE      = ASCII_INTEGER
    START_BYTE     = 15
    DESCRIPTION    = "An offset time from the MET for the last burst record
       in the burst observation. Provides 50 msec resolution to the time
       stamp for the last burst record."
  END_OBJECT       = COLUMN
```

```
  OBJECT            = COLUMN
    NAME            = NUM_BURST_PKTS
    COLUMN_NUMBER   = 3
    BYTES           = 2
    DATA_TYPE       = ASCII_INTEGER
    START_BYTE      = 21
    DESCRIPTION     = "Number of burst packets downloaded for the burst
       observation. Nominally there should be 15 burst packets for one
       complete burst observation. A value of less than 15 indicates missing
       packets."
  END_OBJECT        = COLUMN

  OBJECT            = COLUMN
    NAME            = ACTUAL_RANGE
    COLUMN_NUMBER   = 4
    BYTES           = 1
    DATA_TYPE       = ASCII_INTEGER
    START_BYTE      = 25
    DESCRIPTION     = "Actual range used by MAG. =0 2048 nT, =1 65536 nT"
  END_OBJECT        = COLUMN

  END_OBJECT        = TABLE
END
```

## *Appendix - SPICE Kernel files used in MESSENGER Data Products*

The following SPICE kernel files will be used to compute the UTC time and any geometric quantities found in the PDS labels. Kernel files will be generated throughout the mission with a filenaming 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 communication antennae frame definitions.

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

***.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.

***.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.

## *Appendix - MAG Instrument Overview*

### MAG Software Functionality

The MAG software receives vector magnetic field samples, 20 bits per X, Y, and Z axes, from the MAG electronics at 20 Hz. After bias removal, it filters and sub samples this data to generate output data samples at the commanded rate: 0.01, 0.02, 0.05, 0.1, 0.2, 0.5, 1, 2, 5, 10 or 20 samples/second. The MAG software consistently builds science records with compressed (if commanded) MAG data obtained from the above processing for transmission to the DPU via CCSDS telemetry packets.

Furthermore, the MAG software detects magnetic bursts during a commandable time period during orbit. The detection is done by passing the field samples of a selected axis from the bias removal logic through a 1 to 10 Hz pass band filter and determining a log AC value from this data. If this value indicates that the magnetic field is fluctuating above a trigger level, burst data over eight consecutive minutes is collected, compressed and sent to the DPU via CCSDS telemetry packets.

The MAG software also controls the MAG electronics via memory mapped I/O. The commands sent to the MAG instrument control the range of the MAG probe and set two calibration modes in the MAG electronics.

Finally, the MAG software collects housekeeping data indicating the state of the MAG instrument and software for packaging into low rate housekeeping (LRH) telemetry packets.

### MAG Electronics

The MAG is a miniature three-axis ring-core fluxgate magnetometer with low-noise electronics. It is mounted on a 3.6 meter boom in the anti-sunward direction. The MAG has +/-2048 and +/-65536 nT ranges with 20-bit internal resolution, 17-bit output resolution. (See Figure 2, Figure 3, and Figure 4).
The MAG probe samples X, Y, and Z axes magnetic field values at a rate of 20 samples/second. The data passes through an A/D converter where it is also filtered by the hardware.
The MAG software interfaces with the MAG electronics via memory mapped I/O for data collection, range control, and electronics calibration.

### Software External Interfaces and High-level Functionality

A summary of MAG instrument application software high-level functionality is listed below.

1) DPU Interface
   - receive S/C time and commands from DPU
   - provide instrument state, telemetry, and turn-off requests to DPU
2) Magnetometer Instrument Interface
   - range control, calibration, science data collection
3) MAG Field Sample Processing
   - bias removal, anti-alias filtering, output subsampling
4) Burst Detection and Burst Data Collection.
5) Science Data and Burst Data Compression
6) Command Handling
   - command / macro execution
7) Telemetry Handling
   - generation, buffering, and delivery to DPU
8) Fault Detection and Recovery

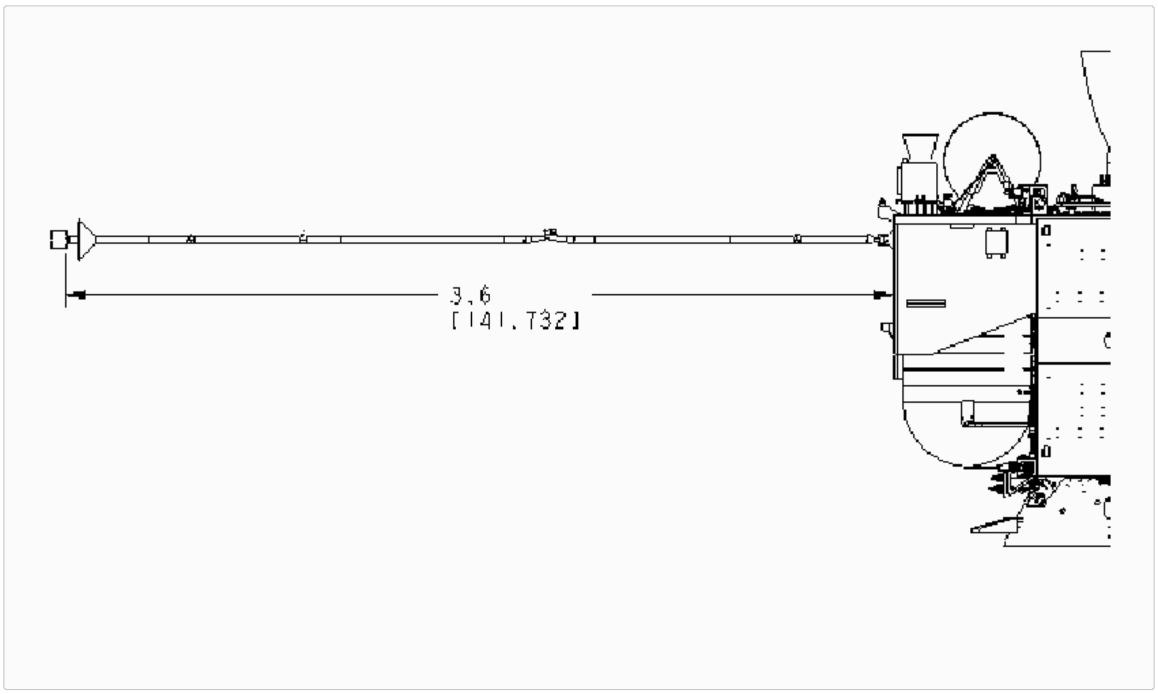



**Figure 2 Magnetometer Deployment.**

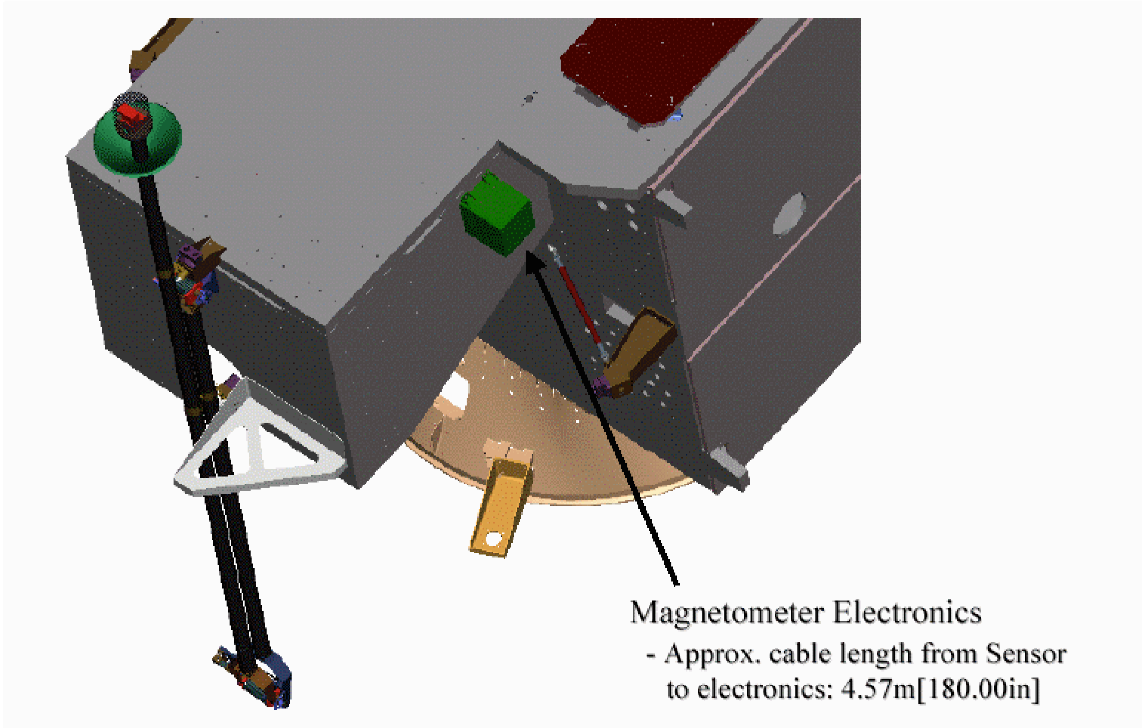



**Figure 3 Location of the Magnetometer Electronics.**

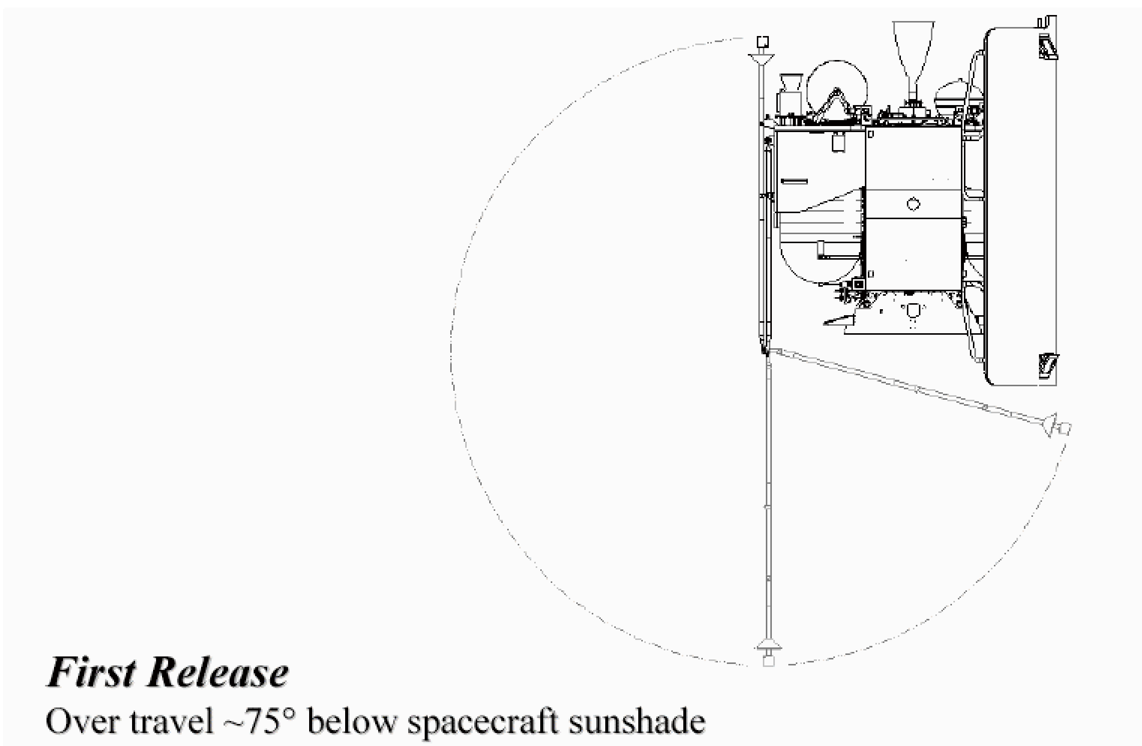



**Figure 4 Magnetometer Deployment.**

## *Appendix - Magnetometer Timing Latencies*

The high rate data (20/s sampling) is delayed relative to the actual magnetic field at the sensor due to anti-aliasing filtering, time delay in A/D sampling, and instrument feedback response time. The anti-alias filtering (15.9 ms time constant) is a combination of a single pole anti-alias filter (-3dB at 10 Hz, -6 dB/octave), the filter in the A/D (-3dB at 17Hz, -6dB/octave) and the instrument feedback response (time constant of 3.2 ms) in series account for 16.3 ms. The A/D conversion time is 49.5 ms corresponding to a latency of 24.8 ms. The expected instrument latency is the sum of 16.3 ms and 24.8 ms or 41 ms. This theoretical instrument latency is in excellent agreement with the measured value of 42 ms.

In addition to this time lag, the digital filtering introduces additional latency relative to the 20/s data. The digital filters are Butterworth IIR filters and with their 3 dB points set at the Nyquist of the sampling rate (e.g. 0.5 Hz for 1/s sampling or rate #6) as shown in Table 1. Rates 0 through 6 are subsampled from the 0.5/Hz filtered time series and all have the same time lag. Rates 7, 8 and 9 have different digital IIR filters and correspondingly different lag times. Rate 10 is not digitally filtered and is lagged by 42 ms. The physical sample times are obtained by subtracting the net lag from the time tags reported in the EDRs.

| Rate | Samples/sec | IIR 3dB (Hz) | IIR Lag (sec) | Net Lag (sec) |
|---|---|---|---|---|
| 0 | 0.01 | 0.5 | 2.316 | 2.358 |
| 1 | 0.02 | 0.5 | 2.316 | 2.358 |
| 2 | 0.05 | 0.5 | 2.316 | 2.358 |
| 3 | 0.10 | 0.5 | 2.316 | 2.358 |
| 4 | 0.20 | 0.5 | 2.316 | 2.358 |
| 5 | 0.50 | 0.5 | 2.316 | 2.358 |
| 6 | 1.00 | 0.5 | 2.316 | 2.358 |
| 7 | 2.0 | 1.0 | 1.144 | 1.186 |
| 8 | 5.0 | 2.5 | 0.435 | 0.477 |
| 9 | 10.0 | 5.0 | 0.181 | 0.223 |
| 10 | 20.0 | N/A | 0.0 | 0.042 |

Table 1. MESSENGER Magnetometer sample rates, digital IIR filter 3 dB points, IIR time lags and net time lags.

The MESSENGER spacecraft clock measures time in units of “ticks since spacecraft clock start”. In the case of MESSENGER, the smallest increment of time measured by a tick is one microsecond. However, by design, the time tag that is assigned to a given data packet, referred to by the MESSENGER Project as MET, has a resolution of one second with a precision of less than 10 microseconds. Higher resolution is available if desired by a given instrument and is provided in terms of a delta-time that is added to the MET. This is the case for the MAG Science EDR, where the original packet contained a delta-time in units of 50 milliseconds. This delta-time is added to the MET time to arrive at a 50 millisecond resolution of the time when the first data sample was taken.

A unit of ticks since spacecraft clock start is not useful when trying to analyze data. A more useful time standard would be Universal Time Coordinated (UTC). This is done easily by the use of SPICE kernels and the CHRONOS utility. The MESSENGER SPICE kernels are archived at the PDS NAIF node. CHRONOS is a utility included with the SPICE package that is distributed by the PDS NAIF node. The SPICE kernels are files that contain the information needed to perform the conversion. Two SPICE kernels are required. One is the Leapseconds Kernel (LSK) and the other is the MESSENGER Spacecraft Clock Kernel (SCLK). The SCLK file is used internally in CHRONOS to convert between spacecraft clock time to ephemeris time, which the LSK file can then convert to UTC time. The CHRONOS utility is self-documenting, and the SPICE package itself contains full documentation on each of the utilities and how they are used. As such, it is recommended that most current SPICE package be downloaded from the PDS NAIF node in order to ensure the correct usage of the CHRONOS utility.

## *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. |
| **Reduced data records** | Science data that have been processed from raw data to NASA Level 1 or higher. See Table for definitions of processing levels. |
| **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. |

## *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 Experiment Data Records (EDRs). Corresponds to NASA Level 0 data. |
| **3** | Calibrated Data | Edited data that are still in units produced by instrument, but have 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.<br>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 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.

## *Appendix - Acronyms*

| | |
|---|---|
| **ACT** | Applied Coherent Technology Corporation |
| **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** | Camera Kernel (SPICE) |
| **CoDMAC** | Committee on Data Management and Computation |
| **Co-I** | Co-Investigator |
| **DN** | Digital number, the raw telemetry count |
| **DPU** | Data Processing Unit |
| **DSN** | Deep Space Network |
| **EDR** | Experiment Data Records |
| **EPPS** | Energetic Particle and Plasma Spectrometer |
| **ET** | Ephemeris Time |
| **FIPS** | Fast Imaging Plasma Spectrometer |
| **FOV** | Field-of-View |
| **FTP** | File Transfer protocol |
| **GC** | Geochemistry Group |
| **GP** | Geophysics Group |
| **GRNS** | Gamma-ray and Neutron Spectrometer |
| **GSFC** | Goddard Space Flight Center |
| **I&T** | Integration and Test |
| **I2C** | Inter-Integrated Circuit |
| **IEM** | Integrated Electronic Module |
| **LSK** | Leapseconds 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** | National Aeronautics and Space Administration |
| **PCK** | Planetary Constant Kernel (SPICE) |
| **PDS** | Planetary Data System |
| **RDR** | Reduced Data Record |
| **SCLK** | Spacecraft Clock Kernel (SPICE) |
| **SOC** | Science Operations Center |
| **SPICE** | Spacecraft, Planet, Instrument, C-matrix Events, refers to the kernel files and NAIF Software used to generate viewing geometry |
| **SPK** | Spacecraft and Planets Kernel (SPICE) |
| **UTC** | Coordinated Universal Time |
| **XRS** | X-Ray Spectrometer |