Mars Atmosphere and Volatile Evolution
(MAVEN) Mission
Magnetometer

MAG Standard Product
PDS Archive
Software Interface Specification

Preliminary
May 12, 2017

Prepared by:

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MAVEN
Magnetometer

MAG Standard Product
Data Record and Archive Volume
Software Interface Specification

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1 Introduction

This software interface specification (SIS) describes the format and content of the MAVEN Magnetometer (MAG) Planetary Data System (PDS) data archive. It includes descriptions of the Standard Data Products and associated metadata, and the volume archive format, content, and generation pipeline.

1.1 Distribution list

Table 1: Distribution list

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1.2 Document change log

Table 2: Document change log

Change	Date	Affected portion
Initial MAG version (based upon Juno MAG)	08/08/2010	All
Modifications based on comments	08/11/2014	Many
Added Figures 1 & 2; renumber figures	11/14/2014	2.1, 2.2, 4.1.1.1
RS changes to SE; note about v00	2/3/2015	5.2
filenames – remove ‘d’ and v numbers	4/3/2015	5.2
add down sampled filenames; additional fields; + and – Y mag designations	4/7/2015	5.2, 6.1.1, 1.4
updated data processing, label sample, and data sample	4/9/2015	4, A, B
modifications	4/10/2015	many
cleaned up figure labels; correction to data processing figure; added TBDs	4/13/2015	
instrument paper reference added; updated sample data	7/24/2015	1.7, 1.9, 2.7; Appendix C
updated sample label	7/30/2015	Appendix B
address comments from PDS review	8/30/2016	many
address comments from J. Mafi email	5/11-12/2017	1.9, 2.1, 4.1.1.3, 4.2.2.1, 5.2.1.2; Tables 4, 7, 9, 10 and 12; Figure 8; change from Draft to Preliminary

1.3 TBD items

Table 3 lists items that are not yet finalized.

Table 3: List of TBD items

Item	Section(s)	Page(s)

1.4 Abbreviations

Table 4: Abbreviations and their meaning

Abbreviation	Meaning
APP	Articulated Payload Platform
ASCII	American Standard Code for Information Interchange
C&DH	command and data handling
CCSDS	Consultative Committee for Space Data Systems
CD-ROM	Compact Disc – Read-Only Memory
CFDP	CCSDS File Delivery Protocol
CG	Center of Gravity
CK	C-matrix Kernel (NAIF orientation data)
CODMAC	Committee on Data Management, Archiving, and Computing
DMAS	Data Management and Storage
DOY	Day Of Year
DSN	Deep Space Network
DTL	Decommutated Telemetry File (file extension)
EDR	Experiment Data Record
ESA	European Space Agency
EUV	Extreme Ultraviolet
FPGA	field programmable gate array
FTP	File Transfer Protocol
G	Gauss
GSFC	Goddard Space Flight Center
HGA	High Gain Antenna
IAU	International Astronomical Union
IB	Inboard Magnetometer; MAG2; aka. –Y mag
IG	
IGPP	Institute of Geophysics and Planetary Physics
ISO	International Standards Organization
IT	Instrument Team
IUVS	Imaging Ultraviolet Spectrograph

jan	Juno Analysis
JPL	Jet Propulsion Laboratory
keV	kiloelectronvolt
kg	kilogram
KHz	Kilohertz
km	kilometer
krad	kilorad
LID	Logical Identifier
LM	Lockheed Martin
LPW	Langmuir Probe and Waves
MAG	Magnetic Field Investigation; magnetometer
MAVEN	Mars Atmosphere and Volatile Evolution
MeV	Megaelectronvolt
mgan	Mars Global Analysis Program (MGS FORTRAN)
MGS	Mars Global Surveyor
MHA	Mario H. Acuña
moan	Mars Observer ANalysis
MTF	Magnetic Test Facility
NAIF	Navigation and Ancillary Information Facility (JPL)
NASA	National Aeronautics and Space Administration
NGIMS	Neutral Gas and Ion Mass Spectrometer
NMSU	New Mexico State University
nT	nanotesla
OB	Outboard Magnetometer; MAG1; aka. +Y mag
ODL or odl	Object Description Language
OG	
pc or PC	Planetocentric coordinate system
PCK	Planetary Cartographic and Physical Constants Kernel (NAIF)
PDS	Planetary Data System
PF	Particle and Fields
PFDPU	Particle and Field Data Processor
PFP	Particles and Fields Package
PPI	Planetary Plasma Interactions Node (PDS)
ppm	Parts per million
RDM	radiation design margin
R_M	Mars radius
RMS	Root Mean Square
SA	Solar array
sc or s/c	Spacecraft
SCET	Spacecraft Event Time
SCLK	Spacecraft Clock
SDC	Science Data Center

SEP	Solar Energetic Particle
sftp	secure file transport protocol
SIS	Software Interface Specification
SOPS	Standard Operating Procedures
SPICE	Spacecraft, Planet, Instrument, C-matrix, and Events (NAIF data format)
SPK	SPICE (ephemeris) Kernel (NAIF)
ss or SS	Sun-State coordinate system
STATIC	Supra-Thermal and Thermal Ion Composition
STS	Standard Time Series File (file extension)
SWEA	Solar Wind Electron Analyzer
SWIA	Solar Wind Ion Analyzer
TBD	To Be Determined
TID	total ionizing dose
UCLA	University of California, Los Angeles
URN	Uniform Resource Name
UTC	Coordinated Universal Time
UV	Ultraviolet
XML	eXtensible Markup Language

1.5 Glossary

Archive – A place in which public records or historical documents are preserved; also the material preserved – often used in plural. The term may be capitalized when referring to all of PDS holdings – the PDS Archive.

Basic Product – The simplest product in PDS4; one or more data objects (and their description objects), which constitute (typically) a single observation, document, etc. The only PDS4 products that are *not* basic products are collection and bundle products.

Bundle Product – A list of related collections. For example, a bundle could list a collection of raw data obtained by an instrument during its mission lifetime, a collection of the calibration products associated with the instrument, and a collection of all documentation relevant to the first two collections.

Class – The set of attributes (including a name and identifier) which describes an item defined in the PDS Information Model. A class is generic – a template from which individual items may be constructed.

Collection Product – A list of closely related basic products of a single type (e.g. observational data, browse, documents, etc.). A collection is itself a product (because it is simply a list, with its label), but it is not a *basic* product.

Data Object – A generic term for an object that is described by a description object. Data objects include both digital and non-digital objects.

Description Object – An object that describes another object. As appropriate, it will have structural and descriptive components. In PDS4 a ‘description object’ is a digital object – a string of bits with a predefined structure.

Digital Object – An object which consists of real electronically stored (digital) data.

Identifier – A unique character string by which a product, object, or other entity may be identified and located. Identifiers can be global, in which case they are unique across all of PDS (and its federation partners). A local identifier must be unique within a label.

Label – The aggregation of one or more description objects such that the aggregation describes a single PDS product. In the PDS4 implementation, labels are constructed using XML.

Logical Identifier (**LID**) – An identifier which identifies the set of all versions of a product.

Versioned Logical Identifier (LIDVID) – The concatenation of a logical identifier with a version identifier, providing a unique identifier for each version of product.

Manifest - A list of contents.

Metadata – Data about data – for example, a 'description object' contains information (metadata) about an 'object.'

Non-Digital Object – An object which does not consist of digital data. Non-digital objects include both physical objects like instruments, spacecraft, and planets, and non-physical objects like missions, and institutions. Non-digital objects are labeled in PDS in order to define a unique identifier (LID) by which they may be referenced across the system.

Object – A single instance of a class defined in the PDS Information Model.
PDS Information Model – The set of rules governing the structure and content of PDS metadata. While the Information Model (IM) has been implemented in XML for PDS4, the model itself is implementation independent.

Product – One or more tagged objects (digital, non-digital, or both) grouped together and having a single PDS-unique identifier. In the PDS4 implementation, the descriptions are combined into a single XML label. Although it may be possible to locate individual objects within PDS (and to find specific bit strings within digital objects), PDS4 defines 'products' to be the smallest granular unit of addressable data within its complete holdings.

Tagged Object – An entity categorized by the PDS Information Model, and described by a PDS label.

Registry – A data base that provides services for sharing content and metadata.

Repository – A place, room, or container where something is deposited or stored (often for safety).

XML – eXtensible Markup Language.

XML schema – The definition of an XML document, specifying required and optional XML elements, their order, and parent-child relationships.

1.6 MAVEN Mission Overview

The Mars Atmosphere and Volatile Evolution (MAVEN) mission launched on an Atlas V on November 18, 2013. After a ten-month ballistic cruise phase, Mars orbit insertion will occur on or after September 22, 2014. Following a 5-week transition phase, the spacecraft will orbit Mars at a 75° inclination, with a 4.5 hour period and periapsis altitude of 140-170 km (density corridor of 0.05-0.15 kg/km^3). Over a one-Earth-year period, periapsis will precess over a wide range of latitude and local time, while MAVEN obtains detailed measurements of the upper atmosphere, ionosphere, planetary corona, solar wind, interplanetary/Mars magnetic fields, solar Extreme Ultraviolet (EUV) and solar energetic particles, thus defining the interactions between the Sun and Mars. MAVEN will explore down to the homopause during a series of five 5-day "deep dip" campaigns for which periapsis will be lowered to an atmospheric density of 2 kg/km^3 (~125 km altitude) in order to sample the transition from the collisional lower atmosphere to the collisionless upper atmosphere. These five campaigns will be interspersed though the mission to sample the subsolar region, the dawn and dusk terminators, the anti-solar region, and the north pole.

1.6.1 Mission Objectives

The primary science objectives of the MAVEN project will be to provide a comprehensive picture of the present state of the upper atmosphere and ionosphere of Mars and the processes controlling them and to determine how loss of volatiles to outer space in the present epoch varies with changing solar conditions. Knowing how these processes respond to the Sun's energy inputs will enable scientists, for the first time, to reliably project processes backward in time to study atmosphere and volatile evolution. MAVEN will deliver definitive answers to high-priority science questions about atmospheric loss (including water) to space that will greatly enhance our understanding of the climate history of Mars. Measurements made by MAVEN will allow us to determine the role that escape to space has played in the evolution of the Mars atmosphere, an essential component of the quest to "follow the water" on Mars. MAVEN will accomplish this by achieving science objectives that answer three key science questions:

- What is the current state of the upper atmosphere and what processes control it?
- What is the escape rate at the present epoch and how does it relate to the controlling processes?
- What has the total loss to space been through time?

MAVEN will achieve these objectives by measuring the structure, composition, and variability of the Martian upper atmosphere, and it will separate the roles of different loss mechanisms for both neutrals and ions. MAVEN will sample all relevant regions of the Martian atmosphere/ionosphere system—from the termination of the well-mixed portion of the atmosphere (the "homopause"), through the diffusive region and main ionosphere layer, up into the collisionless exosphere, and through the magnetosphere and into the solar wind and downstream tail of the planet where loss of neutrals and ionization occurs to space—at all relevant latitudes and local solar times. To allow a meaningful projection of escape back in time, measurements of escaping species will be made simultaneously with measurements of the energy drivers and the controlling magnetic field over a range of solar conditions. Together with measurements of the isotope ratios of major species, which constrain the net loss to space over time, this approach will allow thorough identification of the role that atmospheric escape plays today and to extrapolate to earlier epochs.

1.6.2 Payload

MAVEN will use the following science instruments to measure the Martian upper atmospheric and ionospheric properties, the magnetic field environment, the solar wind, and solar radiation and particle inputs:

- NGIMS Package:
  - Neutral Gas and Ion Mass Spectrometer (NGIMS) measures the composition, isotope ratios, and scale heights of thermal ions and neutrals.
- RS Package:
  - Imaging Ultraviolet Spectrograph (IUVS) remotely measures ultraviolet (UV) spectra in four modes: limb scans, planetary mapping, coronal mapping and stellar occultations. These measurements provide the global composition, isotope ratios, and structure of the upper atmosphere, ionosphere, and corona.
- Particles and Fields (PF) Package (PFP):
  - Supra-Thermal and Thermal Ion Composition (STATIC) instrument measures the velocity distributions and mass composition of thermal and suprathermal ions from below escape energy to pickup ion energies.
  - Solar Energetic Particle (SEP) instrument measures the energy spectrum and angular distribution of solar energetic electrons (30 keV – 1 MeV) and ions (30 keV – 12 MeV).
  - Solar Wind Ion Analyzer (SWIA) measures solar wind and magnetosheath ion density, temperature, and bulk flow velocity. These measurements are used to determine the charge exchange rate and the solar wind dynamic pressure.
  - Solar Wind Electron Analyzer (SWEA) measures energy and angular distributions of 5 eV to 5 keV solar wind, magnetosheath, and auroral electrons, as well as ionospheric photoelectrons. These measurements are used to constrain the plasma environment, magnetic field topology and electron impact ionization rate.
  - Langmuir Probe and Waves (LPW) instrument measures the electron density and temperature and electric field in the Mars environment. The instrument includes an EUV Monitor that measures the EUV input into Mars atmosphere in three broadband energy channels.
  - Magnetometer (MAG) measures the vector magnetic field in all regions traversed by MAVEN in its orbit.

1.7 SIS Content Overview

Section 2 provides a brief introduction to the MAG instrument, the primary reference for which is, however, the Space Science Reviews paper [Connerney, J. E. P., *et. al.*, 2015]. Section 3 describes the data sets, data flow, and validation. Sections 4 and 5 describe the structure of the archive volumes and contents of each file. Section 6 describes the file formats used in the archive volumes. Individuals responsible for generating the archive volumes are listed in Appendix A. PDS-compliant label files for all MAG standard data products are itemized and described in Appendix B, while the data products file headers and data record formats are itemized and described in Appendix C.

1.8 Scope of this document

The specifications in this SIS apply to all MAG Standard Data Record products submitted for archive to the PDS, for all phases of the MAVEN mission.

1.9 Applicable Documents

ISO 9660-1988, Information Processing—Volume and File Structure of CD-ROM for Information Exchange, 04/15/1988.

Planetary Data System Data Provider's Handbook, TBD.

Planetary Data System Standards Reference, Version 1.2.0, March 27, 2014.

PDS4 Data Dictionary: Abridged - Version 1.2.0.1, Planetary Data System, March 28, 2014.

Mars Atmosphere and Volatile Evolution (MAVEN) Science Data Management Plan, Rev. C, doc. no.MAVEN-SOPS-PLAN-0068

The MAVEN Magnetic Field Investigation,
Connerney, J. E. P., Espley, J., Lawton, P., Murphy, S., Odom, J., Oliversen, R., and Sheppard, D., 2015, *Space Science Reviews*, DOI: 10.1007/s11214-015-0169-4.

Additional calibration, comparison with SWEA, and spacecraft field mitigation details:

First results of the MAVEN magnetic field investigation,
Connerney, J.E.P., Espley, J.R., DiBraccio, G.A., Gruesbeck, J.R., Oliversen, R.J., Mitchell, D.L., Halekas, J., Mazelle, C., Brain, D.A., & Jakosky, B.M., 2015, *Geophys. Res. Lett., 42,* 8819–8827, doi:10.1002/2015GL065366.

Calibration methods and techniques outlined in greater detail:

The Juno Magnetic Field Investigation,
Connerney, J. E. P., Benn, M., Bjarno, J. B., Denver, T., Espley, J., Jorgensen, J. L., Jorgensen, P. S., Lawton, P., Malinnikova, A., Merayo, J. M., Murphy, S., Odom, J., Oliversen, R., Schnurr, R., Sheppard, D., and Smith, E. J., 2017, *Space Sci. Rev.,* doi: 10.1007/s11214-017-0334-z.

Absolute Calibration and Alignment of Vector Magnetometers in the Earth's Field,
Merayo, J. M. G., Brauer, P., Primdahl, F. & Petersen, J. R., 2001,
Ground and In-Flight Space Magnetometer Calibration Techniques, ESA SP-490,
Primdahl, F. & Balogh, A. (eds.).

Scalar Calibration of Vector Magnetometers,
Merayo, J. M. G., Brauer, P., Primdahl, F., Petersen, J. R. & Nielsen, O. V.,
2000, *Meas. Sci. Technol.*11, 2, p. 120-132.

1.10 Audience

This document is useful to those wishing to understand the format and content of the MAG PDS data product archive collection. Typically, these individuals would include planetary scientists, data analysts, or software engineers.

2 MAG Instrument Description

2.1 Science Objectives

The MAVEN Magnetometer (MAG) Investigation will sample the magnetic field from the Sun and the Mars crust. Mars is neither an unmagnetized body, such as Venus, nor a magnetized body, like Earth. Where the Mars crust is intensely magnetized it can establish order over scale lengths of hundreds of kilometers much in the way the Earth's field does. In the Earth's upper atmosphere and ionosphere, a complex system of currents flow in response to solar heating of the atmosphere, particularly where horizontal magnetic fields are encountered (equatorial fountain effect and electrojet), and in response to the imposition of electric potentials. By analogy to magnetized planets, field-aligned currents, called *Birkeland currents*, flow along the magnetic field and deposit energy into the electrically conducting ionosphere, particularly during solar storms, leading to auroral displays. Auroral emissions have been observed on Mars in association with the most intensely magnetized regions [refs.] of the southern highlands.

Figure 1 illustrates the complexity of the magnetic field observed in a meridian plane projection over the southern highlands, extending throughout the Mars upper atmosphere and ionosphere. The MAVEN spacecraft will sample the magnetic field and plasma environment throughout this region from about 120 km upwards, during "deep dip" campaigns and nominal orbital operations.

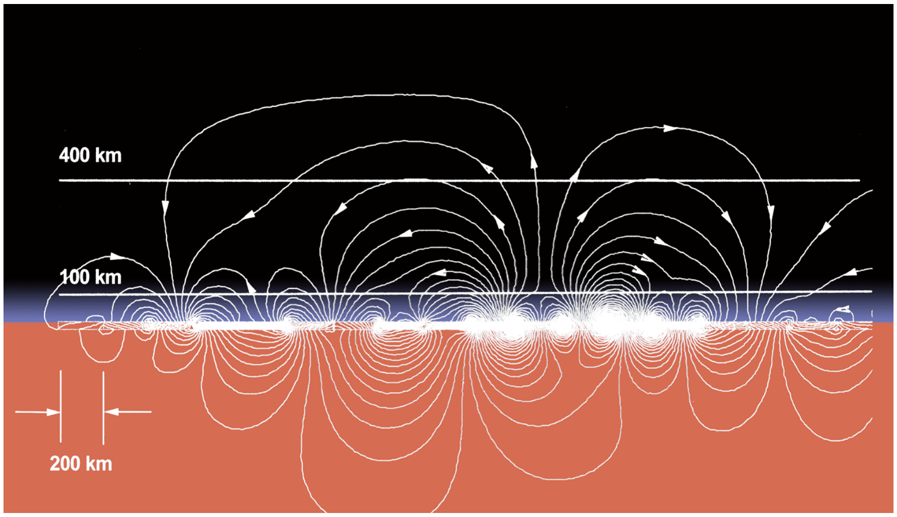

Figure 1*: Plane projection of southern highlands*
Plane projection of the magnetic field geometry above the intensely magnetized southern highlands based on the crustal magnetic field model of Connerney et al., [1999]. This figure illustrates the field geometry that would be encountered during periapsis passes along a line of constant longitude (near 150 degrees east) and centered at 50 degrees south latitude. Similar "mini-magnetospheres" may be encountered above much of the magnetized crust, depending on spacecraft altitude and solar wind conditions.

The crustal fields are strong enough to dramatically alter the nature of the interaction with the solar wind, as can be seen in the multi-fluid magnetohydrodynamic simulation [*Dong et al., 2014*]. Field magnitudes are appreciably larger in regions of strong crustal fields than they would otherwise be, creating "mini-magnetospheres" where charged particle motion is guided by persistent, and stable, magnetic geometries. The geometry imposed by strong crustal fields dictates where field lines threading the ionosphere link with the solar wind and distant plasma environments, giving rise to deposition of energy and aurorae. Numerical simulations have amply demonstrated that the strong magnetic fields associated with the southern highlands have a shielding effect that reduces the ion escape flux [*Ma et al, 2004; Dong et al., 2014*].

The MAVEN magnetic field investigation is more thoroughly documented in the Space Sciences Reviews paper [Connerney, J. E. P., *et. al*., 2015].

2.2 Detectors

The MAVEN particles and fields instrumentation form an ensemble of instruments ("Particles and Fields Package") controlled by a single hardware redundant data processing unit (PFDPU) interfacing to the spacecraft. The MAVEN magnetic field investigation (MAG) consists of two independent and identical fluxgate magnetometer systems that are interfaced to and controlled by the PFDPU. The particles and fields package is a stack of individual electronics boxes that service each of the instruments; two of the "slices" are occupied by identical magnetometer electronics boxes that service the two magnetometer sensors. Each electronics box is fully shielded and each draws power from the redundant power supplies within the PFP.

Individual and independent a/c heater electronics assemblies are also accommodated within the PFP. These are powered directly by the spacecraft, providing uninterruptable power for sensor thermal control regardless of the state (on or off) of the PFP. The a/c heaters are proportional controllers that maintain sensor temperature within comfortable operational limits. They are designed to insure that no dc currents can circulate in the resistive heater elements that are placed underneath the sensor base and within thermal blanketing. (Spacecraft heaters are direct current powered and are therefore not suitable for use in proximity with a magnetic sensor).

The magnetometer sensors are located at the very end of the solar array panels on modest extensions (.66 m in length) designated as MAG "boomlets", placing them approximately 5.6 m from the center of the spacecraft body. Magnetometer sensors are best accommodated remotely, as far from spacecraft subsystems as is practical, to minimize the relative contribution of spacecraft-generated magnetic fields. Care is taken to minimize the magnetic signature of spacecraft subsystems, of course, but one of the most effective ways to reduce spacecraft-generated magnetic fields is to separate spacecraft systems and sensor, taking maximum advantage of the $1/r^3$ diminution of a magnetic (dipole) source with distance from the source. Thus magnetometer sensors are often accommodated on a lengthy dedicated magnetometer boom that is deployed after launch. Alternatively, they may be accommodated at the outer extremity of the solar arrays, taking advantage of an essential appendage that also deploys post-launch. MAVEN took the latter approach, much as its predecessor Mars Global Surveyor did [Acuna et al., 2001].

***Figure 2**: The MAVEN MAG at the end of the MAG boomlet*
The MAVEN spacecraft in the clean room at Lockheed Martin during assembly. The (-Y) MAG sensor (left extremity) is mounted at the end of the MAG "boomlet". A cautionary piece of yellow tape hangs below the sensor. The sensor cover bears laminations of copper tape and Kapton tape providing electrostatic and electromagnetic shielding.

In typical implementations, a pair of magnetic sensors ("dual magnetometer technique") provides hardware redundancy as well as a capability to detect magnetic fields at two locations on the spacecraft. This capability offers the potential to monitor spacecraft generated magnetic fields in flight, by comparison of the field measured by each sensor.

The Goddard Space Flight Center (GSFC) fluxgate magnetometer meets and exceeds the vector measurement requirement with a simple and robust instrument with extensive flight heritage. The Maven magnetometer design draws from Mario Acuna's extensive flight experience, with over 50 space flight magnetometers developed for planetary research and built at GSFC. The MAVEN sensor design covers the modest dynamic range requirement with two instrument ranges that will be used in the Mars environment (512 nT and 2048 nT full scale). The instrument also has a high range (65,536 nT full scale) that is useful in integration and test, permitting operation in ambient field on Earth.

A more complete study of the magnetic field magnitudes that MAVEN may sample, between target altitudes of 125 and 400 km, was performed to optimize the choice of instrument dynamic ranges. Since MAVEN's mission plan does not target specific latitudes/longitudes, we need be prepared for the maximum field magnitude that might be experienced above the surface of the planet at altitudes in excess of ~100 km. This study demonstrated that it is very unlikely that a dynamic range of 512 nT might be exceeded throughout the entire mission, including the "deep dip" orbits. The magnetometer system provided as part of the Particles and Fields Package meets and exceeds the Project requirements with a pair of independent magnetic sensors

The following is from ftp://naif.jpl.nasa.gov/pub/naif/MAVEN/kernels/spk/maven_struct_v00.bsp

Figure 3: *Locations of the spacecraft's CG and IB and OB MAGs*

This diagram illustrates the locations of the spacecraft's Center of Gravity (CG) and Inboard (IB) and Outboard (OB) MAGs:

```
Spacecraft CG (post-TCM1 location, X and Y coordinates are 0)
---------------------------------------------------------------------------

   -X s/c side:
   ------------

       *.                            _                            .*
     MAG `o.                  HGA  .' `.                       .o' MAG
            `-.                  .'     `.                  .-'
               `-.               ---------               .-'
                  `-o_________..-----------..__________o-'
                               |           |
                               |     ^ +Zsc|
                 ---           |  CG @     |
                  ^            |     |     |
         0.901 m  |            |     |     |
                  v       +Ysc `-----|-----'
                 ---         <-------x -'`-.
                            .-'      |      `-.
                         .-'         @         `-.
                      .-'             SWEA        `-.
               LPW .-'                               `-. LPW

                                                  +Xsc is into the page.
```

The following is from ftp://naif.jpl.nasa.gov/pub/naif/MAVEN/kernels/spk/maven_struct_v00.bsp

***Figure 4:** Locations of the MAG sensors relative to the Articulated Payload Platform (APP)*

```
APP (location of IG and OG axes intersection)
-----------------------------------------------------------------------

   +Z s/c side:
   ------------

                         0.2034 m
                        ---------->|-|<-

                                ._____. APP
   ---                          \__@__|
    ^                              |
    |                              |
    | 2.5887 m                     |  +Xsc
    |                              | ^
    |     .__________.__________..-----|-----..__________.__________.
    |     |         |         ||  .--|--.  ||         |         |>
    v   .-|         |     +Ysc   /   |   \ ||         |         |-. MAG
   --- <  |         |        <-------o    |||         |         |  >
        `-|         |            \       / ||         |         |-'
    MAG  <|_________|_________|HGA'-----'  ||_________|_________|
                               `-----------'
                               .-'   |   `-.
                            .-'      |      `-.
                         .-'         @         `-.
                      .-'             SWEA        `-.
               LPW .-'                               `-. LPW

                                                +Zsc is out of the page.
```

The following is from ftp://naif.jpl.nasa.gov/pub/naif/MAVEN/kernels/spk/maven_struct_v00.bsp

Figure 5: *MAG frames*

This diagram illustrates the MAG frames:

```
MAG sensors (X coordinates are 0)
-----------------------------------------------------------------------

   -X s/c side:
   ------------

                  5.601 m                        5.601 m
       |<--------------------------->|<--------------------------->|

   --- @.MAG                         _                            .@
    ^    `o.                  HGA  .' `.                       .o' MAG
    |       `-.                  .'     `.                  .-'
    |          `-.               ---------               .-'
    |             `-o_________..-----------.._________o-'
    |                          |           |
    | 2.871 m                  | +Zsc      |
    |                          |     ^     |
    |                          |     |     |
    |                          |     |     |
    v                     +Ysc `-----|-----'
   ---                       <-------x -'`-.
                            .-'      |      `-.
                         .-'         @         `-.
                      .-'             SWEA        `-.
               LPW .-'                               `-. LPW

                                                  +Xsc is into the page.
```

The following is from ftp://naif.jpl.nasa.gov/pub/naif/MAVEN/kernels/fk/maven_v03.tf

Figure 6: *The Solar Array (SA) and MAG Frames*

This diagram illustrates the Solar Array and Magnetometer frames:

```
      -X s/c side:
      ------------

              ^ +Zmagpy                                   +Zmagmy ^
             /         +Zsapyob                   +Zsamyob         \
   +Ymagpy  /        ^                                     ^        \
+Ymagmy
     <-.   / MAGpy  /                                       \  MAGmy \   .->
       `-x<        /                    _                    \       >o-'
   +Ysapyob `-.   /              HGA  .' `.                   \   .-'
+Ysamyob
             / `-x                  .'     `.                  o-' \
     20 deg /     `-.               ---------               .-'     \ 20 deg
          ---        `-o_________..-----------..__________o-'        ---
                                  |           |
                                  | +Zsc      |
                                  |     ^     |
                                  |     |     |
                                  |     |     |
                             +Ysc `-----|-----'
                                <-------x -'`-.
                               .-'      |      `-.
                            .-'         @         `-.
                         .-'             SWEA        `-.
                  LPW .-'                               `-. LPW

                                                 +Xsc is into the page.
                                     +Xsapyob and +Xmagpy are into the page.
                                     +Xsamyob and +Xmagmy are out of the
page.

   As seen on the diagram the MAG sensor frames are nominally co-aligned
   with the corresponding outboard SA panel frames.


   The MAG sensor frames -- MAVEN_MAG_PY, ID -202310, and MAVEN_MAG_PY,
   ID -202410, -- are defined as fixed offset frames with respect to
   the corresponding outboard SA panel frames as follows:

      -  +Y axis is normal to the sensor mounting plate and points from
         the plate toward the top of the sensor,

      -  +Z axis is normal to the sensor side opposite to the cable
         connector

      -  +X axis completes the right handed frame

      -  the origin of the frame is at the geometric center of the
         sensor.
```

2.3 Electronics

The MAG electronics are mounted in the PFP stack. The electronics are designed to meet or exceed the mission radiation requirement (total ionizing dose of 50 krad with a radiation design margin of 2). The analog electronics drives each ring core into saturation at a frequency of ~15.4 KHz using a dedicated toroidal winding on each ring core. The ambient magnetic field in each sensor is sensed by synchronous detection of the second harmonic (~ 30.7 KHz) of the drive frequency, the presence of which reveals an imbalance in the response of the permeable ring core due to the presence of an external field (Acuña, Reviews of Scientific Instruments, 2002). As with any fluxgate, care must be taken to insure that the spacecraft does not generate interference at harmonics of the drive frequency which could confuse the signal attributed as an ambient magnetic field.

The appropriate instrument dynamic range is selected, automatically, by range control logic within the field programmable gate array (FPGA), resulting in autonomous operation through the entire dynamic range. All range and instrument control functions are implemented in hardware. The MAG powers up in operational mode autonomously, sending telemetry packets to the spacecraft Command and Data Handler (C&DH) immediately without need of further commands. A limited command set allows us to tailor the science and engineering telemetry to available resources (via averaging and decimation of samples or packets) and to uplink changes in the parameters that control various functions as desired.

Table 5: MAG Performance and ranges

Performance	
Sensor type	Dual tri-axial ring core fluxgates
Accuracy	0.05% absolute vector accuracy
Intrinsic noise level	0.015 nT (most sensitive range)
Attitude knowledge	Better than 0.05 degrees
Zero level stability	< 1 nT
Dynamic ranges (resolution)	512 nT (± 0.015 nT) 2048 nT (± 0.062 nT) 65536 nT (± 2.0 nT)
Intrinsic sample rate	32 vector samples/second
Radiation total ionizing dose (TID)	> 50 krad (at component level)

.

The OB and IB MAG sensors sample the field in all (three) axes simultaneously at an intrinsic sample rate of 32 vector samples per second, synchronized to the spacecraft clock. Depending on PFP table settings, these data are stored in packet format awaiting transmission, or averaged and decimated to reduce telemetry resource requirements prior to packetizing for transmission, along with a PFP time stamp and header/trailer fields. The PFP also supports a lossless data compression scheme (8-bit differencing) that takes advantage of the 1/f natural spectral dependence of magnetometer data, and packs twice as many observations into a MAG packet of fixed size. It works as follows: all 16 bits of each component of the first vector observation is stored in the data portion of the packet after timing and header information; subsequent data samples are differenced from the preceding sample and only the difference (8 bits including sign bit) is stored in the packet for transmission. This process results in a 2:1 compression if the difference mode is selected (as it has been throughout most of the mission thus far). It is made lossless by sending the original data without differencing if one or more of the differences exceed 8 bits (and would therefore be difficult if not impossible to unambiguously reconstruct the measurement). Such packets occur very infrequently (<1%) at 32 samples/sec so 2:1 compression is realized throughout. Difference mode works on raw 32 samples/sec data or on averaged and decimated data per PFP command.

The data format of the OB and IB MAG sensors is controlled independently from each other, although the PFP maintains strict time synchronization of MAG samples from the two sensors and in the data packets from the two systems. For any choice of MAG sample rates, and thus packet cadence, the packet time stamp (“packet time”) of the less frequently sampled sensor can be found among those of the more frequently sampled sensor. So, in merging the two time series, packets remain synchronized and the first time step in paired IB and OB packets share a common packet time. Each MAG delivers a packet of data containing engineering, 32 samples of vector magnetic field measurements, and header/trailer fields to the PFP each second. The PFP receives a MAG packet from each sensor once per second, and repackages that data for transmission to ground. For each MAG, the PFP packages the science data according to PFP table settings. Averages over 2^n samples (n = 0,1,2,3,4,5), followed by decimation by two’s, can be combined with differencing mode (off -> 0, on -> 1) for lossless data compression.

Table 6: MAG Telemetry

average n	0	1	2	3	4	5
MAG packets (seconds of MAG data) per PFP MAG packet (differencing off)	1	2	4	8	16	32
MAG packets (seconds of MAG data) per PFP MAG packet (differencing on)	2	4	8	16	32	64

At power on, MAG returns science data in format based on the PFP table settings.

2.4 Measured Parameters

The OB and IB MAG sensors sample the magnetic field in all (three) axes simultaneously at an intrinsic sample rate of 32 vector samples per second, synchronized to the PFP clock. The three axes are X, Y, and Z.

2.5 Operational Modes

The MAG powers up in operational mode and returns telemetry immediately every clock tic (1 second). The MAG may be operated in autoranging mode, or manual range commands may be sent to fix the instrument in any of its dynamic ranges. Likewise any telemetry mode may be selected, depending on telemetry resource allocation. In addition, packets of engineering telemetry (in addition to science telemetry packets) are telemetered at a variable rate, from one per 2 seconds to one per 512 seconds, per commanded state.

2.6 Operational Considerations

The MAG is designed to power up in an operating mode, acquiring magnetic field data and transferring that data to the PFP every second without need of commanding. The instrument will autonomously select the appropriate dynamic range.

The MAG also sends a broadcast magnetic field vector to the spacecraft C&DH for transmission to the other science instruments on the payload. This facility provides the other instruments with the most recent magnetic field vector (in spacecraft payload coordinates) for their use in organizing data and selection of operational modes.

2.7 Ground Calibration

The magnetometers were calibrated in the Planetary Magnetospheres Laboratory and the GSFC Mario H. Acuña (MHA) Magnetic Test Facility (MTF), a remote facility located near the GSFC campus. These facilities are sufficient to calibrate magnetometers to 100 parts per million (ppm) absolute vector accuracy. An independent measurement of the magnetic field strength in the 0.25 and 1 Gauss ranges is provided by Overhausen Proton Precession magnetometers placed in a reference position within the coil facility and near the magnetometer under test.

Two independent methods are used to calibrate the magnetometers. The vector fluxgates are calibrated in the 22' facility using a method ("MAGSAT method") developed by Mario Acuña and others. This technique uses precise 90 degree rotations of the sensing element and a sequence of applied fields to simultaneously determine the magnetometer instrument model response parameters (the "A matrix") as well as a similar set of parameters (the "B matrix") that describe the facility coil orthogonality [Connerney, J. E. P., *et. al.*, 2015]. The second calibration method (called the "thin shell" and "thick shell") uses a large set of rotations in a known field (magnitude) to obtain the same instrument parameters, subject to an arbitrary rotation [Merayo, J. M. G., 2000 & 2001]. In the "thin shell" method, the sensor is articulated through all orientations in a fixed, or known field magnitude. This can be done in a facility like the GSFC 22 foot coil system, wherein any fixed field up to about 1.2 Gauss may be utilized, or it may be done in the Earth's field using the ambient field in a gradient-free region and a system to compensate for variations in the ambient field (normally corrected via a secondary reference magnetometer coupled with a Proton Precession total field instrument). Application of this method in a coil facility (with closed loop control for ambient field variations) allows for the "thin shell" to be performed at many field magnitudes ("thick shell").

The MAGSAT calibration method provides the instrument calibration parameters referenced to the optical cube mounted on the sensor which defines the instrument coordinate system. These parameters include the instrument scale factors, 3 by 3 instrument response matrix (or "A" matrix), and zero offsets for each instrument dynamic range. The "thin shell" method provides the same parameters, but since the method conveys no attitude information, only the symmetric part of the instrument response matrix is determined via "thin shell". Nevertheless, it provides a useful independent verification of the MAGSAT calibration.

2.8 Inflight Calibration

In-flight calibration activities are designed to monitor instrument zero offsets and spacecraft-generated magnetic fields. These consist primarily of rolls about two spacecraft principal axes, originally planned to occur every other month or so during science operations. These will be augmented by additional in-flight spacecraft maneuvers, and magnetic compatibility tests, as necessary, if needed to diagnose spacecraft – generated magnetic fields. The MAVEN spacecraft magnetic field requirement was 2 nT static and 0.25 nT variable; analysis of in-flight maneuvers is ongoing at this time, but spacecraft generated magnetic fields are estimated to be of about this magnitude. One of the mag roll maneuvers performed in cruise, in a relatively quiet and constant magnetic field environment provided by the solar wind, is shown below:

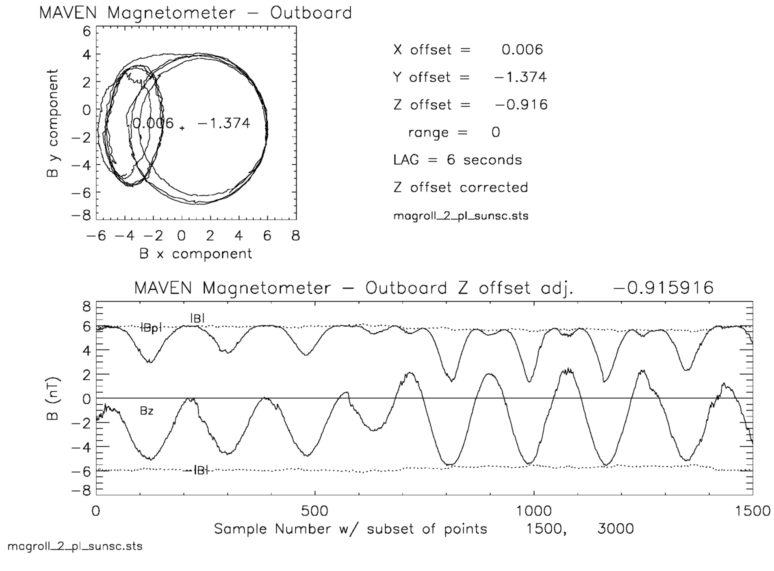

Figure 7: *Hodogram and spacecraft x-y (Bp) plots*

A hodogram appears on the upper left, and a time series is shown in the lower plot. The magnetic field in the spacecraft x-y plane (Bp) is plotted along with the field component along the sc z axis (solid lines). During the first half of this sequence, the spacecraft executed rolls about one axis (principal moment of inertia) and during the second half of the sequence, it rolled about an axis orthogonal to the first. The dotted line is the field magnitude (and the negated field magnitude) which – if the offsets are correctly estimated – ought to show no rotation modulation.

As of this writing, we have but one set of mag rolls performed after deployment of the APP and subsequent to Mars Orbit Insertion (MOI). Another set is scheduled for the end of April, 2015, when the spacecraft is passing behind Mars in eclipse and in the relatively distant and magnetically quiet magnetotail region. After these mag roll maneuvers are analyzed for spacecraft fields, we will better know how stable the "static" spacecraft field is. Since we can only perform mag roll maneuvers infrequently, we are very interested in the stability of the spacecraft field over time.

3 Data Overview

3.1 Bundle Products

The standard product types generated by the MAG Instrument Team (IT) are listed in Table **7**. See Section 10B of *Planetary Data System Standards Reference* for definition of the data processing levels.

Table 7: MAG Bundles

Bundle Logical Identifier	PDS4 Reduction Level	Description	Data Provider
maven.mag.calibrated	Calibrated	Payload (PL) (Orbital) Planetocentric (PC) (Orbital only) Sun-State (SS) (Orbital only)	ITF

Table 8: Standard Data Product Contents

ID	Physical Parameters	Processing Inputs	Product Format	Description
M1	Tabulated vector magnetic field vs. time	EDR, ancillary data, NAIF kernels, calibration	ASCII table	Calibrated Science data with position in specified coordinate system

Each MAG supplied product is an ASCII file containing a time series of magnetic field vectors in geophysical units (nanotesla, nT) that have been corrected for instrumental and spacecraft effects (calibrated). In addition, these data have been transformed into physically meaningful coordinate systems. MAG data products are generated for all mission phases.

3.2 Data Flow

Lockheed Martin (LM) will receive packets and Consultative Committee for Space Data Systems (CCSDS) File Delivery Protocol (CFDP) products from the Deep Space Network (DSN). The MAVEN Science Data Center (SDC) will query the data at Lockheed Martin and store the data on a computer at the University of Colorado Boulder. The MAG Instrument Team retrieves the data from the SDC via a secure file transfer protocol (sftp) script. Ancillary data is similarly obtained from the SDC. Kernel files are obtained from Navigation and Ancillary Information Facility (NAIF) and the SDC.

The MAG Science Investigation Team will develop higher level data products based on the Committee on Data Management, Archiving, and Computing (CODMAC) Level 3 data and ancillary data and deliver these to the SDC. The Science Investigation Team will be responsible for ensuring that the metadata and documentation included with these data sets are complete and accurate.

The SDC will deliver archive data to the PDS.

4 Archive Generation

4.1 Data Processing and Production Pipeline

4.1.1 Calibrated Data Production Pipeline

4.1.1.1 Decommutate

MAG packets are generated by the experiment on board the spacecraft. Those packets are transmitted to the PFP which packages according to the format settings and then transmits the PFP MAG packet to the spacecraft. MAG Level 0 packets are retrieved from the Science Data Center via periodic queries.

The de-commutation (maven_mag_pkts_read) processing element reconstructs the data placed in the packet according to the PFP MAG packet telemetry formats. This science data packet includes spacecraft time (1 second clock timestamp), instrument range identification, and magnetometer data time series.

The MAG science data is formatted in the PFP MAG packet in one of several ways, determined by the contents of two bytes in the PFP MAG science packet header. There are thus 10 possible selections per MAG sensor, although in practice few will be utilized, depending on the data requirements (e.g., success of the s/c magnetic control program is a factor in establishing the data requirements). The de-commutation will reconstruct the MAG data according to the mode selection (which is telemetered in every PFP MAG packet).

The output of the decom function is a readable ASCII file of the contents of the MAG telemetry packet in a "Keyword = Value" format that can be read by the MAVEN data processing program (mvn – pronounced 'mave'.). This is a format that is similar to the Navigation and Ancillary Information Facility (NAIF) ASCII text format kernel files. The advantage to this format, and the reason it was developed, is that it allows for addition of ancillary data from other sources – which need not be defined or anticipated early in software development – if it becomes necessary to augment the instrument-provided data. So, for example, if it should become obvious during the mission that additional data is required to mitigate spacecraft magnetic fields (such as measurements of currents in the s/c power subsystem, or orientation of an articulated system), that data may be inserted into the input stream rather easily.

The MAG engineering data is de-commutated via the same software, creates a similar readable ASCII file which can be processed by the same MAVEN data processing program (mvn). The engineering packet can be set to be produced once every 2^n seconds where n is an integer [0,1,2,...8].

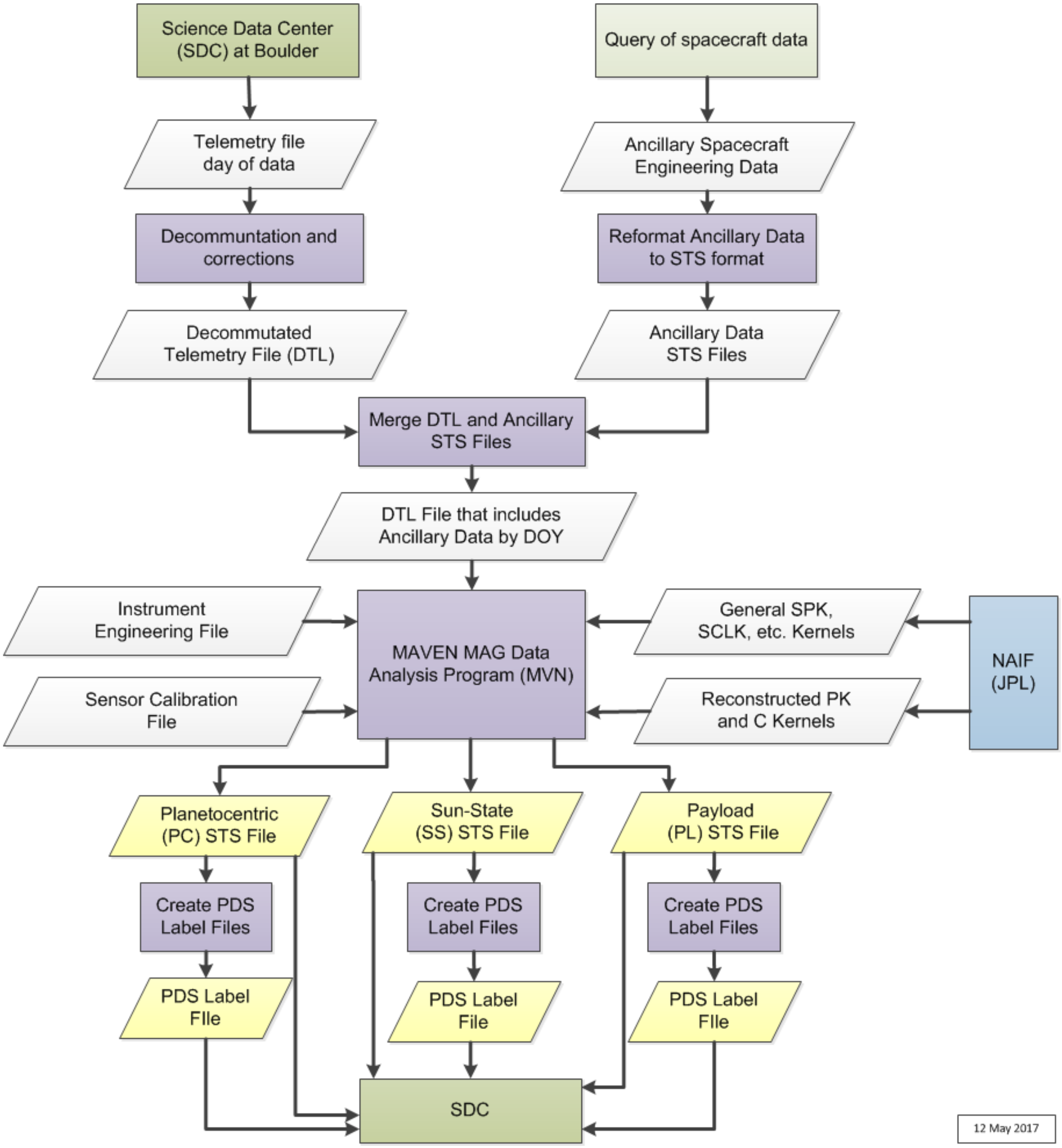

Figure 8: *MAG Archive Processing*
Flow diagram of MAG final data processing. Final processing is done subsequent to receipt of reconstructed spacecraft ephemeris and attitude kernels using the same program elements. Data files containing time-ordered records of fully-calibrated magnetic field vectors, rendered in several useful coordinate systems, are the archive data products. Each record contains spacecraft position rendered in the appropriate coordinate system along with supplementary engineering data, where useful.

4.1.1.2 Merge Ancillary

It is our intent that all information necessary to process MAG data arrives in the MAG science data packet; so, for example, sufficient time information, instrument range, mode and status words are included in each science data packet so that each may be processed independently. Our instrument and data processing is designed with this in mind. However, we have built into the data processing system a facility for augmenting the data in our data stream with other engineering and/or ancillary information should this be required. For example, if it is determined that specialized spacecraft engineering or ancillary data is needed to properly calculate and remove the flight system's magnetic field contribution, then the appropriate data will be merged into the MAG data for use in the MAG data processing (specialized routines, as needed, that correct the measured field for spacecraft-generated magnetic fields). The data input functionality of mvn is constructed to accept any input conforming to the requirements (NAIF-like "Keyword = Value" data stream), so both or either the de-commutated telemetry files and merged telemetry files can be read and interpreted by the same analysis program.

At the present time, we have determined that the outermost solar array circuits (when illuminated and selected by the SASM) contribute a small magnetic field (1/2 to 1 nT) largely in the payload y and z components to MAG measurements. After performing in-flight tests with the spacecraft power subsystem, we have characterized the source and implemented a mitigation strategy that requires measurements of the solar array currents and SASM switch states (for the outermost 6 circuits on the solar array panel). Thus we routinely access the project engineering data base to retrieve these measurements and switch status indicators. These have become available to the MAG investigation subsequent to January 9, 2015. Subsequent to this date, when available, these engineering quantities are merged with the MAG data for use in computing the magnetic field generated by the solar arrays (for removal from the measured field).

4.1.1.3 MAG Data Processing

The MAG data processing software (mvn) is based on heritage MAG data processing software. It was used regularly for the Mars Global Surveyor (MGS) Mission, in the form of a Fortran program mgan (Mars Global ANalysis) and is used for Juno in the form of a FORTRAN program jan. It was originally developed for the Mars Observer project and previously called moan (Mars Observer ANalysis), but that spacecraft suffered an early retirement. The software is designed to be flexible via the use of input files that control many spacecraft and mission specific aspects.

There are several different types of inputs to the MAG data processing software. There are command line options and input files. The command line options specify type of data (if applicable), resulting coordinate system, target body, and other options available within the software. The file inputs include a variety of kernel files supplied by NAIF, kernel like files created by GSFC personnel, and files of de-commutated MAG data packets (with ancillary engineering information as necessary). Archive files will all include a machine-readable attached header which precedes the tabular data. This attached header consists of elements that describe the data columns to follow and it provides an audit trail for the data processing that one ought not dismiss. Therefore we strongly encourage users to retain this attached header. It is easily skipped in reading in the desired data but once removed from a file it is gone forever. So retain it. As an attached header, it ought to never go missing.

The command line options specify the output coordinate system and data fields to be included, such as time format and magnetic field vectors. It is useful to understand the command line (found in the attached header) because inspection of the command line will reveal choice of coordinate system, for example, and target body. For example, the MAVEN mission will primarily use Mars as the default target body, but if we find it useful to provide data in another coordinate system – for example, planetocentric coordinates referenced to the satellite Phobos – this would be specified by inclusion of the option "-phobos" among the options on the command line. The option "-odl" instructs the program to output the attached header. The base coordinate system for rendering magnetic field and spacecraft position is the J2000 coordinate system. From J2000 we transform into other coordinate systems specified by command line option (-pc, -ss, -payload); where no option is specified output variables such as the magnetic field vector ("ob_b") and spacecraft position ("posn") or state vector ("state") are rendered in J2000. For example, the command line:

```
-odl   -Mars      time   dday   ob_b   posn
```

results in a magnetic field vector from the outboard magnetometer and spacecraft position rendered in J2000 coordinates relative to Mars;

```
 -odl   -pc   time   dday   ob_b   posn
```

will result in a magnetic field vector from the outboard magnetometer and spacecraft position rendered in (Mars) planetocentric coordinates; and

```
-odl   -ss   time   dday   ob_b   posn
```

will result in a magnetic field vector from the outboard magnetometer and spacecraft position rendered in Sun-State coordinates (described below).

```
-odl     time   dday   ob_bpl   posn   ob_bdpl
```

results in a magnetic field vector from the outboard magnetometer rendered in spacecraft payload coordinates and spacecraft position rendered in J2000 coordinates. In this last example, we've added the dynamic spacecraft field correction vector ("ob_bdpl") in spacecraft payload coordinates. This vector is computed using a proxy measurement of the current in the outer circuits of the solar array and it approximates the dynamic field produced by these circuits when illuminated and switched "on" by the spacecraft solar array switching module ("SASM"). It is provided so that users are aware of the correction that has been applied to the observed magnetic field vector to mitigate spacecraft interference.

There are four principal coordinate systems used to represent the data in this archive. We designate our coordinate systems with a terminology that can be applied uniformly to various bodies and that is easily understood if you remember the rule. The coordinate system is specified with definition of the reference vectors: the first is the primary reference vector, and the second is the secondary reference vector. So for example, the "sun-state" coordinate system ("ss") uses the vector from the designated body (in this case Mars) to the sun; the secondary reference vector is the planet's state vector (orbital motion). Thus the x axis points toward the sun, the y axis is orthogonal to the x axis and lies in the plane defined by the two vectors, and the z axis completes the system.

Mars orbital data will be rendered in both the sun-state (ss) and planetocentric (pc) coordinate systems for user convenience. Data will also be provided in the spacecraft playload (pl) coordinate system. It is recommended that spectral studies be performed in spacecraft payload coordinates since it is often the case that spacecraft magnetic interference appears organized in the natural coordinate system of the spacecraft. Cartesian representations are used for all three coordinate systems. These coordinate systems are specified relative to a "target body" which may be any solar system object (but for this orbital operations will Mars). In what follows we will reference Mars as the target body, but, for example, if observations near a satellite (such as Phobos) are desired in Phobos-centric coordinates, the satellite Phobos may be specified as the target body.

The ss coordinate system is defined using the instantaneous Mars-Sun vector as the primary reference vector (x direction). The X-axis lies along this vector and is taken to be positive toward the Sun. The Mars orbital velocity vector is the second vector used to define the coordinate system; the y axis lies in the plane determined by the Mars-Sun vector and the velocity vector and is orthogonal to the x axis (very nearly the negative of the velocity vector). The vector cross product of x and y yields a vector z parallel to the northward (upward) normal of the orbit plane of Mars. This system is sometimes called a sun-state (ss) coordinate system since its principal vectors are the Sun vector and the Mars state vector. It is identical to the MSO system.

The planetocentric (pc) coordinate system is body-fixed and rotates with the body as it spins on its axis. The body rotation axis is the primary vector used to define this coordinate system. Z is taken to lie along the rotation axis and be positive in the direction of positive angular momentum. The X-axis is defined to lie in the equatorial plane of the body, perpendicular to Z, and in the direction of the prime meridian as defined by the International Astronomical Union (IAU). The Y axis completes the right-handed set.

The spacecraft payload coordinate system is defined with respect to the body of the spacecraft, illustrated below:

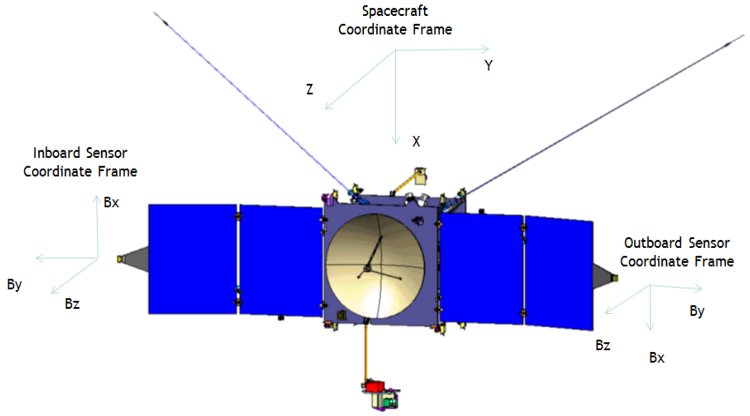

Figure 9: *Spacecraft payload coordinate system*

The sc body upper panel face (upon which the high gain antenna (HGA) sits) lies in the x – y plane, with the x axis parallel to the solar array hinge line, pointing down towards the deployed auxiliary pointed platform (APP). The y axis is parallel to the other face and is defined such that the sc z axis (x cross y) is aligned with the HGA boresight (approximately).

Data in the vicinity of the moons of Mars (Phobos, Deimos) may be provided in separate files in moon centered coordinate systems, if it turns out that the mission plan affords an opportunity to acquire data in the immediate vicinity of any of these bodies The planetocentric and SS data follows the definitions above with the reference body being the moon or target specified via option in the command line All of the archived data files are simple and readable ASCII files with attached documentation in a header that precedes the columns of data. Files using a coordinate system centered on a target body other than Mars are identified via the target body listed on the command line which appears in the header along with an audit trail of supplementary engineering (kernel) files.

"NOCANDO" is a flag that appears in the output records in place of a variable that was requested but cannot be delivered by the program; either it is not a variable that the program knows how to compute, or it is a variable that is missing from the input stream, or it is a variable for which the necessary supplementary and engineering data does not exist in the files specified in the loadlist (e.g., insufficient C-kernel data, missing ephemeris, etc.). In routine data processing we are aware of the omission ("NOCANDO") but data processing can proceed anyway. "NOCANDO" lines are removed before the data is delivered to the archive.

The output from the processing program is in Standard Time Series (STS) format. The Object Description Language (odl) header is included in the STS file. All other browse data products are made from the STS files, but as yet it is not determined how browse products may be transferred to the PDS; this issue is pending resolution. It is our intent to provide browse plots.

4.2 Data Validation

Products submitted to the SDC and to PDS will be validated via automatic software checks and routine use.

4.2.1 Instrument Team Validation

Each MAG instrument packet and PFP MAG packet includes a checksum. The decommutation process verifies the checksum. Also, words or bytes in the PFP MAG packet are checked for compliance with the established rules for that word or byte. The established rules for a particular word or byte location in the PFP MAG packet are predetermined, may include minimum or maximum allowed values, difference from the previous value, etc. Anomalous behavior of selected engineering data indicative of instrument health will trigger notification output with diagnostic information.

4.2.2 Science Team Validation

MAG investigators will use the same files for their science analyses as are archived with the PDS. Further, other MAVEN scientists will access and use the same file from SDC prior to archiving for their analyses. "Use what you archive and archive what you use."

4.2.2.1 MAVEN MAG L2 Data Products Caveats

MAG data products are provided in several useful coordinate systems and at the highest time resolution available. The MAG observations contain some known artifacts that you may encounter in your use of the data that you should be aware of. These are related to several different sources on the spacecraft that have been, and continue to be, under investigation. **This message is dated April 10, 2015, and it represents our current (and evolving) understanding of the status of the spacecraft and its influence on MAG data.** These include:

(1) rapid magnetic field variations of ~6 nT in magnitude (in spacecraft payload coordinate axes y and z) associated with infrequent thruster firings (every few days) that are employed in trajectory correction maneuvers (TCM). These are relatively easy to identify.

(2) variations (in spacecraft payload coordinate axes y and z) of ~1 nT in magnitude associated with solar array currents in circuits at the outer edge of the solar arrays, near the magnetometer sensor. MAG processing mitigates these signatures where spacecraft engineering telemetry is available at high time resolution. The necessary spacecraft engineering data was made available after Jan 9, 2015, following in-flight spacecraft testing to isolate the problem. Prior to this time, we use a coarse indication of solar array currents to correct the data, and this correction will be out of time step with the actual needed correction part of the time. Corrections applied are listed on each record along with the corrected data. These variations may appear as step functions, e.g., when the spacecraft enters eclipse, or slow variations as the spacecraft attitude with respect to the sun varies. They were identified in the quiet, weak field environment of cruise and when illumination on the solar arrays was more intense than experienced in cruise.

(3) multiple sinewave variations usually of ~0.1 nT in magnitude, that track the frequency of operation of the four Reaction Wheel Assemblies (RWAs). The magnitude of these variations has been observed to increase substantially when the RWAs are operated at very low frequencies; at such times they may appear prominently in spectra of MAG observations.

(4) the "static" or slowly-varying spacecraft field has been estimated using spacecraft roll maneuvers that are scheduled to occur approximately every 2 months. The MAVEN static sc field specification was NTE 2 nT. The MAG data processed for December 2014 use an estimate of the spacecraft field obtained from the day 353 2014 magroll maneuvers, the only set performed subsequent to deployment of the APP after insertion into Mars orbit. We have yet to verify if this sc field estimate remains relatively constant or if it varies over the interval between magroll maneuvers. Investigation of the time variability of this part of the sc field is expected shortly.

(5) be aware of revisions to the level 2 MAG data products and substitute most recent versions as they are made available.

When the spacecraft position (spk) and/or orientation (ck) kernels are incomplete, transformation of the MAG data to the planetocentric (pc), and “sun-state” (ss) coordinates systems cannot be calculated. When MAG data is available, but kernels are missing, payload data may be available, but other coordinate system data will not be available.

4.3 Data Production and Transfer Methods

The instrument team (IT) produces the individual data files and the associated PDS labels for each of the standard data products defined in the data product SISs. Data products will be transferred via secure File Transport Protocol (sftp) to the SDC. SDC subsequently transfers data products to the PDS discipline node.

5 Archive organization and naming

This section describes the basic organization of a MAG bundle, and the naming conventions used for the product logical identifiers, and bundle, collection, and basic product filenames.

5.1 Logical Identifiers

Every product in PDS is assigned an identifier which allows it to be uniquely identified across the system. This identifier is referred to as a Logical Identifier or LID.

5.1.1 LID Formation

LIDs take the form of a Uniform Resource Name (URN). LIDs are restricted to ASCII lower case letters, digits, dash, underscore, and period. Colons are also used, but only to separate prescribed components of the LID. Within one of these prescribed components dash, underscore, or period are used as separators. LIDs are limited in length to 255 characters.

MAVEN [INST] LIDs are formed according to the following conventions:

- Bundle LIDs are formed by appending a bundle specific ID to the MAVEN [INST] base ID:

  urn:nasa:pds:maven.[inst].<bundle ID>

  Since all PDS bundle LIDs are constructed this way, the combination of maven.[inst].bundle must be unique across all products archived with the PDS.
- Collection LIDs are formed by appending a collection specific ID to the collection's parent bundle LID:

  urn:nasa:pds:maven.[inst].<bundle ID>:<collection ID>

  Since the collection LID is based on the bundle LID, which is unique across PDS, the only additional condition is that the collection ID must be unique across the bundle. Collection IDs correspond to the collection type (e.g. "browse", "data", "document", etc.). Additional descriptive information may be appended to the collection type (e.g. "data-raw", "data-calibrated", etc.) to insure that multiple collections of the same type within a single bundle have unique LIDs.
- Basic product LIDs are formed by appending a product specific ID to the product's parent collection LID:

  urn:nasa:pds:maven.[inst].<bundle ID>:<collection ID>:<product ID>

Since the product LID is based on the collection LID, which is unique across PDS, the only additional condition is that the product ID must be unique across the collection.

For a MAVEN MAG Sun-State product, the LID would be

urn:nasa:pds:maven.mag.calibrated:data.ss:<filename stem>

A list of MAG bundle LIDs is provided in Table 7.

5.2 MAG Archive Contents

The MAG archive includes the bundles listed in Table 7. The following sections describe the contents of each of these bundles in greater detail.

5.2.1 maven.mag.calibrated

Each MAG supplied product is an ASCII file containing a time series of magnetic field vectors in geophysical units (nanotesla, nT) that have been corrected for instrumental and spacecraft effects (calibrated). In addition, these data have been transformed into physically meaningful coordinate systems. MAG data products are generated for all mission phases.

Table 9: MAG collections

Collection LID	Description
urn:nasa:pds:maven.mag.calibrated:data.pl	Tabulated calibrated science vector magnetic field data with position in payload coordinate system vs. time
urn:nasa:pds:maven.mag.calibrated:data.pc	Tabulated calibrated science vector magnetic field data with position in pc coordinate system vs. time
urn:nasa:pds:maven.mag.calibrated:data.ss	Tabulated calibrated science vector magnetic field data with position in ss coordinate system vs. time
urn:nasa:pds:maven.mag.calibrated:browse	Root-Mean-Squared (RMS) plots

5.2.1.1 maven.mag.calibrated:data.[pl | pc | ss]

Table 10: Data Directory Contents

File Name	File Contents	Provided By
mvn_mag_l2_*<yyyy><ddd>*pl_*<yyyymmdd>*_v<zz>_r*<xx>*.sts mvn_mag_l2_*<yyyy><ddd>*pc_*<yyyymmdd>*_v<zz>_r*<xx>*sts mvn_mag_l2_*<yyyy><ddd>*ss_*<yyyymmdd>*_v<zz>_r*<xx>*.sts mvn_mag_l2_*<yyyy><ddd>*pl<*n*>s_*<yyyymmdd>*_v<zz>_r*<xx>*.sts mvn_mag_l2_*<yyyy><ddd>*pc<*n*>s_*<yyyymmdd>*_v<zz>_r*<xx>*sts mvn_mag_l2_*<yyyy><ddd>*ss<*n*>s_*<yyyymmdd>*_v<zz>_r*<xx>*.sts	Science data file. (pl, pc and ss during orbital operations)	Instrument Team
mvn_mag_l2_*<yyyy><ddd>*pl_*<yyyymmdd>*_v<zz>_r*<xx>*.xml mvn_mag_l2_*<yyyy><ddd>*pc_*<yyyymmdd>*_v<zz>_r*<xx>*.xml mvn_mag_l2_*<yyyy><ddd>*ss_*<yyyymmdd>*_v<zz>_r*<xx>*.xml mvn_mag_l2_*<yyyy><ddd>*pl<*n*>s_*<yyyymmdd>*_v<zz>_r*<xx>*.xml mvn_mag_l2_*<yyyy><ddd>*pc<*n*>s_*<yyyymmdd>*_v<zz>_r*<xx>*.xml mvn_mag_l2_*<yyyy><ddd>*ss<*n*>s_*<yyyymmdd>*_v<zz>_r*<xx>*.xml	PDS label for data files of same base name.	Instrument Team

Table 11: Filename Convention Elements

Token	Description
mvn	MAVEN
mag	Magnetometer three character instrument abbreviation
l2	MAVEN Processing Level 2 (equivalent to CODMAC Level 3)
yyyy	The year, such as 2014
ddd	The day of year, 001-366
pl|pc|ss	Coordinate system of data. PL (payload) or PC (Planetocentric) or SS (Sun-State)
*n*s	number of seconds data down sampled
yyyymmdd	Year, month, day of month
v*zz*	Version number; Version numbers of 00 are not for archive
r*xx*	revision number
sts	Standard Time Series (ASCII) file
xml	Label file

5.2.1.2 maven.mag.calibrated Document Collection

The maven.mag.calibrated document collection contains documents which are useful for understanding and using the MAVEN MAG data. Table contains a list of the documents included in this collection, along with the LID, and responsible group. Following this a brief description of each document is also provided.

Table 12: MAG Calibrated Science Data Documents

Document Name	LID	Responsiblility
MAVEN Science Data Management Plan	urn:nasa:pds:maven:document:sdmp	MAVEN Project
MAVEN MAG Archive SIS	urn:nasa:pds:maven.mag.calibrated:document:sis	MAG Team
MAVEN Mission Description	urn:nasa:pds:maven:document:mission.description	MAVEN Project
MAVEN Spacecraft Description	urn:nasa:pds:maven:document:spacecraft.description	MAVEN Project

MAVEN Science Data Management Plan – describes the data requirements for the MAVEN mission and the plan by which the MAVEN data system will meet those requirements

MAVEN MAG Archive SIS – describes the format and content of the MAG PDS data archive, including descriptions of the data products and associated metadata, and the archive format, content, and generation pipeline (this document)
MAVEN Mission Description – describes the MAVEN mission.
MAVEN Spacecraft Description – describes the MAVEN spacecraft.

While responsibility for the individual documents varies, the document collection itself is managed by the PDS/ Planetary Plasma Interactions (PPI) node.

6 Archive product formats

Data that comprise the MAG standard product archives will be formatted in accordance with PDS specifications [see *Planetary Science Data Dictionary*, *PDS Archiving Guide*, and *PDS Standards Reference* in §1.9].

6.1 Data File Formats

This section describes the format and record structure of each of the data file types.

6.1.1 Calibrated data file structure

A MAG product is organized as a table of ASCII data for a single day. Preceding the tabular data is a text header that describes the file contents and processing parameters. Each data record contains two (2) Coordinated Universal Time (UTC) time stamps using different date/time representations, a magnetic field vector, the instrument gain (range), and the spacecraft position vector at the sample time, followed by further columns relevant to the instrument calibration. The magnetic field (measured or correction) is treated as a 4 dimensional vector with the instrument range as the 4th component.

Table 13: Calibrated data file

Byte	Length (bytes)	Name	Fmt*	Units	Description
3	4	Year	I4		Year
8	3	DOY	I3		Day of year
12	2	Hour	I2	Hours	Hours
15	2	Min	I2	Minutes	Minutes
18	2	Sec	I2	Seconds	Seconds
21	3	Msec	I3	Milliseconds	Milliseconds
25	13	DDAY	F13.9	Day	Decimal Day
39	9	OB_B_X	F9.2	Nanotesla (nT)	Outboard magnetic field J2000 X
50	9	OB_B_Y	F9.2	nT	Outboard magnetic field J2000 Y
60	9	OB_B_Z	F9.2	nT	Outboard magnetic field J2000 Z
70	3	OB_B_range	F3.0	N/A	Outboard magnetic field J2000 range
74	14	POSN_X	F14.3	Kilometers (km)	Spacecraft position X
90	14	POSN_Y	F14.3	Km	Spacecraft position Y
105	14	POSN_Z	F14.3	Km	Spacecraft position Z
120	7	OB_BDPL_X	F7.3	nT	Outboard dynamic correction X in payload coordinates
129	7	OB_BDPL_Y	F7.3	nT	Outboard dynamic correction Y in payload coordinates
137	7	OB_BDPL_Z	F7.3	nT	Outboard dynamic correction Z in payload coordinates

Byte	Length (bytes)	Name	Fmt*	Units	Description
145	4	OB_BDPL_range	F4.0	N/A	Outboard dynamic correction range

6.2 Document Product File formats

All ASCII document files contain 80-byte fixed-length records; records are terminated with a carriage return (ASCII 13) and line feed character (ASCII 10) in the 79th and 80th byte, respectively. This format allows the files to be read by many operating systems, *e.g.*, UNIX, MacOSX, Windows, etc.

In general, documents are provided in ASCII text format. However, some documents in the DOCUMENT collection contain formatting and figures that cannot be rendered as ASCII text. Hence these documents are also given in additional formats such as hypertext, Microsoft Word, and Adobe Acrobat (PDF).

6.3 PDS labels

PDS labels are ASCII text files written, in the eXtensible Markup Language (XML). All product labels are detached from the digital files (if any) containing the data objects they describe (except Product_Bundle). There is one label for every product. Each product, however, may contain one or more data objects. The data objects of a given product may all reside in a single file, or they may be stored in multiple separate files. PDS4 label files must end with the file extension “.xml”. The structure of PDS label files is governed by the XML documents described in Section 3 of the Standards Reference document.

You may choose to use these detached label files or you may choose to work directly with the MAG STS files that have attached headers that describe the data content.

6.3.1 XML Documents

For the MAVEN mission PDS labels will conform to the PDS master schema based upon the 1.2.0.1 version of the PDS Information Model for structure, and the 1.2.0.1 version of the PDS schematron for content. By use of an XML editor these documents may be used to validate the structure and content of the product labels.

The PDS master schema and schematron documents are produced, managed, and supplied to MAVEN by the PDS. In addition to these documents, the MAVEN mission has produced additional XML documents which govern the products in this archive. These documents contain attribute and parameter definitions specific to the MAVEN mission.

An example of PDS labels required for the MAG archive is shown in the Appendices.

Appendix A Support staff and cognizant persons

Table 14: Instrument Archive collection support staff

MAG Team			
Name	**Address**	**Phone**	**Email**
Dr. John E.P. Connerney MAG PI	NASA/Goddard Space Flight Center Code 695 Greenbelt, MD 20771	301-286-5884	Jack.Connerney@nasa.gov
Ms. Patricia Lawton MAG Ground Data System Staff	NASA/Goddard Space Flight Center Code 695 Greenbelt, MD 20771	301-286-1788	Pat.Lawton@nasa.gov

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Table 15: PDS Archive collection support staff

UCLA			
Name	**Address**	**Phone**	**Email**
Dr. Steven Joy PPI Operations Manager	IGPP, University of California 405 Hilgard Avenue Los Angeles, CA 90095-1567 USA	+001 310 825 3506	sjoy@igpp.ucla.edu
Mr. Joseph Mafi PPI Data Engineer	IGPP, University of California 405 Hilgard Avenue Los Angeles, CA 90095-1567 USA	+001 310 206 6073	jmafi@igpp.ucla.edu

Appendix B Sample PDS label file

All MAG instrument data files are accompanied by PDS label files, possessing the same names are the files they describe, but with the extension xml. This sample is mvn_mag_l2_2014353pl_20141219_v01_r01.xml.

```
<?xml version="1.0" encoding="UTF-8"?>
<?xml-model href="http://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1400.sch"
    schematypens="http://purl.oclc.org/dsdl/schematron"?>
<?xml-model href="http://pds.nasa.gov/pds4/mvn/v1/PDS4_MVN_1011.sch"
   schematypens="http://purl.oclc.org/dsdl/schematron"?>
<Product_Observational xmlns="http://pds.nasa.gov/pds4/pds/v1"
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xmlns:mvn="http://pds.nasa.gov/pds4/mission/mvn/v1"
   xsi:schemaLocation="
      http://pds.nasa.gov/pds4/pds/v1
      http://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1400.xsd

      http://pds.nasa.gov/pds4/mission/mvn/v1
      http://pds.nasa.gov/pds4/mvn/v1/PDS4_MVN_1011.xsd
   ">
    <Identification_Area>

<logical_identifier>urn:nasa:pds:maven.mag.calibrated:data.pl:mvn_mag_l2_2014353pl_20141219</logi
cal_identifier>
        <version_id>1.0</version_id>
        <title>Tabulated vector magnetic field vs. time in Payload coordinates.</title>
        <information_model_version>1.4.0.0</information_model_version>
        <product_class>Product_Observational</product_class>
       <Citation_Information>
        <author_list>Connerney, J. E. P.</author_list>
        <publication_year>2015</publication_year>
        <description>
         Calibrated science magnetic field vector data with position in
        Payload coordinate system for 2014-12-19 (2014-353).
        </description>
       </Citation_Information>
       <Modification_History>
          <Modification_Detail>
             <modification_date>2015-04-09</modification_date>
             <version_id>1.0</version_id>
             <description>Initial version</description>
          </Modification_Detail>
       </Modification_History>
    </Identification_Area>
    <Observation_Area>
        <Time_Coordinates>
            <start_date_time>2014-12-19T00:00:01.030Z</start_date_time>
            <stop_date_time>2014-12-20T00:00:00.636Z</stop_date_time>
        </Time_Coordinates>
        <Primary_Result_Summary>
            <purpose>Science</purpose>
            <processing_level>Calibrated</processing_level>
            <Science_Facets>
                <discipline_name>Fields</discipline_name>
                <facet1>Magnetic</facet1>
                <facet2>Background</facet2>
            </Science_Facets>
        </Primary_Result_Summary>
        <Investigation_Area>
            <name>MAVEN</name>
            <type>Mission</type>
            <Internal_Reference>
                <lid_reference>urn:nasa:pds:context:investigation:mission.maven</lid_reference>
                <reference_type>data_to_investigation</reference_type>
            </Internal_Reference>
        </Investigation_Area>
        <Observing_System>
            <Observing_System_Component>
```

```
                <name>MAVEN</name>
                <type>Spacecraft</type>
                <Internal_Reference>

<lid_reference>urn:nasa:pds:context:instrument_host:spacecraft.maven</lid_reference>
                    <reference_type>is_instrument_host</reference_type>
                </Internal_Reference>
            </Observing_System_Component>
            <Observing_System_Component>
                <name>MAG</name>
                <type>Instrument</type>
                <Internal_Reference>
                    <lid_reference>urn:nasa:pds:context:instrument:mag.maven</lid_reference>
                    <reference_type>is_instrument</reference_type>
                </Internal_Reference>
            </Observing_System_Component>
        </Observing_System>
        <Target_Identification>
            <name>Mars</name>
            <type>Planet</type>
            <Internal_Reference>
                <lid_reference>urn:nasa:pds:context:target:planet.mars</lid_reference>
                <reference_type>data_to_target</reference_type>
            </Internal_Reference>
        </Target_Identification>
        <Mission_Area>
            <MAVEN xmlns="http://pds.nasa.gov/pds4/mvn/v1">
               <mission_phase_name>Prime Mission</mission_phase_name>
           </MAVEN>
        </Mission_Area>
    </Observation_Area>
    <File_Area_Observational>
        <File>
            <file_name>mvn_mag_l2_2014353pl_20141219_v01_r01.sts</file_name>
            <md5_checksum>80d2e9ddc90ddf17029c57819f85e125</md5_checksum>
            <comment>This file contains vector magnetic field data acquired by the
Fluxgate Magnetometer instrument aboard the MAVEN spacecraft.
The data are calibrated and provided in physical units (nT).
The time resolution depends on the telemetry rate available
when the data were taken.  The data are expressed in
Payload coordinates.</comment>
        </File>
        <Header>
            <offset unit="byte">0</offset>
            <object_length unit="byte">11126</object_length>
            <parsing_standard_id>7-Bit ASCII Text</parsing_standard_id>
        </Header>
        <Table_Character>
            <offset unit="byte">11126</offset>
            <records>2764800</records>
            <description>The magnetic field data are stored in a fixed field ASCII table
structure that immediately follows the attached header.  This table
contains time-tagged rows of magnetic field values and instrument
ranges.</description>
            <record_delimiter>Carriage-Return Line-Feed</record_delimiter>
            <Record_Character>
                <fields>13</fields>
                <groups>0</groups>
                <record_length unit="byte">150</record_length>
                <Field_Character>
                    <name>SAMPLE UTC</name>
                    <field_location unit="byte">3</field_location>
                    <data_type>ASCII_String</data_type>
                    <field_length unit="byte">21</field_length>
                    <description>Universal time of the sample at the spacecraft.  The time
appears as 6
integer columns (year, day of year, hour, minute, seconds, millisecond).
Individual elements of the time column are separated by a single ASCII
space character and have leading zeros omitted.  The individual elements
can be read by using the following FORTRAN format:
'(2X,I4,1X,I3,3(1X,I2),1X,I3)' IYR IDOY IHR IMIN ISEC IMSEC</description>
                </Field_Character>
                <Field_Character>
```

```
                    <name>DECIMAL DAY</name>
                    <field_location unit="byte">25</field_location>
                    <data_type>ASCII_Real</data_type>
                    <field_length unit="byte">13</field_length>
                    <description>Decimal day of year.  This column provides a second
representation of
the sample time.</description>
                </Field_Character>
                <Field_Character>
                    <name>BX PAYLOAD</name>
                    <field_location unit="byte">40</field_location>
                    <data_type>ASCII_Real</data_type>
                    <field_length unit="byte">9</field_length>
                    <description>B-field X-component in Payload coordinate system.</description>
                </Field_Character>
                <Field_Character>
                    <name>BY PAYLOAD</name>
                    <field_location unit="byte">50</field_location>
                    <data_type>ASCII_Real</data_type>
                    <field_length unit="byte">9</field_length>
                    <description>B-field Y-component in Payload coordinate system.</description>
                </Field_Character>
                <Field_Character>
                    <name>BZ PAYLOAD</name>
                    <field_location unit="byte">60</field_location>
                    <data_type>ASCII_Real</data_type>
                    <field_length unit="byte">9</field_length>
                    <description>B-field z-component in Payload coordinate system.</description>
                </Field_Character>
                <Field_Character>
                    <name>INSTRUMENT RANGE</name>
                    <field_location unit="byte">70</field_location>
                    <data_type>ASCII_Real</data_type>
                    <field_length unit="byte">3</field_length>
                    <description>Instrument range at time of the sample.  Pertains to B
components.</description>
                </Field_Character>
                <Field_Character>
                    <name>X</name>
                    <field_location unit="byte">75</field_location>
                    <data_type>ASCII_Real</data_type>
                    <field_length unit="byte">14</field_length>
                    <description>Spacecraft position X-component in Payload coordinate
system.</description>
                </Field_Character>
                <Field_Character>
                    <name>Y</name>
                    <field_location unit="byte">90</field_location>
                    <data_type>ASCII_Real</data_type>
                    <field_length unit="byte">14</field_length>
                    <description>Spacecraft position Y-component in Payload coordinate
system.</description>
                </Field_Character>
                <Field_Character>
                    <name>Z</name>
                    <field_location unit="byte">105</field_location>
                    <data_type>ASCII_Real</data_type>
                    <field_length unit="byte">14</field_length>
                    <description>Spacecraft position Z-component in Payload coordinate
system.</description>
                </Field_Character>
                <Field_Character>
                    <name>BDX PAYLOAD</name>
                    <field_location unit="byte">121</field_location>
                    <data_type>ASCII_Real</data_type>
                    <field_length unit="byte">7</field_length>
                    <description>B-field X-component dynamic correction in
Payload coordinate system.</description>
                </Field_Character>
                <Field_Character>
                    <name>BDY PAYLOAD</name>
                    <field_location unit="byte">129</field_location>
                    <data_type>ASCII_Real</data_type>
```

```
                    <field_length unit="byte">7</field_length>
                    <description>B-field Y-component dynamic correction in 
Payload coordinate system.</description>
                </Field_Character>
                <Field_Character>
                    <name>BDZ PAYLOAD</name>
                    <field_location unit="byte">137</field_location>
                    <data_type>ASCII_Real</data_type>
                    <field_length unit="byte">7</field_length>
                    <description>B-field Z-component dynamic correction in 
Payload coordinate system.</description>
                </Field_Character>
                <Field_Character>
                    <name>INSTRUMENT RANGE</name>
                    <field_location unit="byte">145</field_location>
                    <data_type>ASCII_Real</data_type>
                    <field_length unit="byte">4</field_length>
                    <description>Instrument range at time of the sample.  Pertains to B 
components.</description>
                </Field_Character>
            </Record_Character>
        </Table_Character>
    </File_Area_Observational>
</Product_Observational>
```

Appendix C Data sample

This section is a sample of a Standard Time Series file from mvn_mag_l2_2014353pl_20141219_v01_r01.sts.

```
OBJECT      =  FILE
OBJECT   =  HEADER
  PROGRAM   =  /home/magdata/software/fortran/mvn_20150406/mvn
  CMD_LINE  =  -odl -mars -dz -sc time dday ob_bpl posn ob_bdpl
  DATE      =  Thu Apr  9 18:03:37 2015
  HOST      =  gauss.gsfc.nasa.gov
  COMMENT   =  This version mvn compiled with gnu fortran and spicelib
               (GENERIC_TOOLKIT V.N0065)   on APR 1, 2015 by J. CONNERNEY
               (NASA/GSFC).mitigates SOLAR ARRAY dynamic SPACECRAFT FIELD.
  TITLE     =  MAVEN MAG
OBJECT      =  KERNEL_LIST
  META        3325  Thu Feb 19 11:42:12 2015  maven_rec_20141201_20141231_20150219a.tm
  TEXT        4146  Tue Mar  4 16:19:23 2014  mission_maven.ker
  TEXT        9497  Mon Apr  6 18:04:51 2015  sc_mod.ker
  TEXT       10586  Tue May 27 17:37:33 2014  mv_mags.ker
  TEXT        5086  Tue Jan 13 05:22:01 2015  naif0011.tls
  TEXT      114011  Mon Nov  3 17:02:21 2014  pck00009.tpc
  TEXT        6710  Tue Jan 20 05:21:04 2015  MVN_SCLKSCET.00015.tsc
  TEXT       88692  Mon Nov  3 17:16:21 2014  maven_v03.tf
  SPK      4364288  Tue Dec 10 05:21:08 2013  de430s.bsp
  SPK     93998080  Tue Dec 10 05:21:38 2013  mar097s.bsp
  SPK        17408  Wed Dec 11 05:21:05 2013  maven_struct_v00.bsp
  SPK      7020544  Thu Dec  4 13:20:09 2014  trj_orb_00259-00340_rec_v1.bsp
  SPK      1692672  Fri Dec 12 05:21:07 2014  trj_orb_00339-00360_rec_v1.bsp
  SPK      3348480  Wed Dec 17 05:21:08 2014  trj_orb_00360-00380_rec_v1.bsp
  SPK      5221376  Fri Dec 19 05:21:08 2014  trj_orb_00379-00415_rec_v1.bsp
  SPK      2391040  Wed Dec 24 05:21:07 2014  trj_orb_00414-00446_rec_v1.bsp
  SPK      2731008  Thu Jan  1 05:21:07 2015  trj_orb_00445-00483_rec_v1.bsp
  SPK      3047424  Thu Jan  8 05:21:08 2015  trj_orb_00482-00523_rec_v1.bsp
  CK      24253440  Tue Dec 30 05:22:33 2014  mvn_app_rel_141201_141207_v01.bc
  CK      30590976  Thu Dec 18 05:21:48 2014  mvn_sc_rel_141201_141207_v01.bc
  CK      24189952  Tue Dec 30 05:22:39 2014  mvn_app_rel_141208_141214_v01.bc
  CK      30477312  Sun Dec 21 05:21:31 2014  mvn_sc_rel_141208_141214_v01.bc
  CK      26402816  Tue Dec 30 05:22:46 2014  mvn_app_rel_141215_141221_v01.bc
  CK      29942784  Sun Dec 28 05:21:27 2014  mvn_sc_rel_141215_141221_v01.bc
  CK      26836992  Tue Jan  6 05:21:45 2015  mvn_app_rel_141222_141228_v01.bc
  CK      28035072  Sun Jan  4 05:21:27 2015  mvn_sc_rel_141222_141228_v01.bc
  CK      27935744  Sun Jan 11 05:21:21 2015  mvn_app_rel_141229_150104_v01.bc
  CK      29088768  Sun Jan 11 05:21:31 2015  mvn_sc_rel_141229_150104_v01.bc
END_OBJECT
END_OBJECT
OBJECT      =  RECORD
OBJECT   =  VECTOR
  NAME   =  TIME
  ALIAS  =  TIME
  TYPE   =  INTEGER
  OBJECT   =  SCALAR
    NAME   =  YEAR
    FORMAT =  1X,I4
  END_OBJECT
  OBJECT   =  SCALAR
    NAME   =  DOY
    FORMAT =  1X,I3
  END_OBJECT
  OBJECT   =  SCALAR
    NAME   =  HOUR
    FORMAT =  1X,I2
  END_OBJECT
  OBJECT   =  SCALAR
    NAME   =  MIN
    FORMAT =  1X,I2
  END_OBJECT
  OBJECT   =  SCALAR
    NAME   =  SEC
    FORMAT =  1X,I2
```

```
    END_OBJECT
    OBJECT   =  SCALAR
      NAME   =  MSEC
      FORMAT =  1X,I3
    END_OBJECT
  END_OBJECT
  OBJECT   =  SCALAR
    NAME   =  DDAY
    ALIAS  =  DECIMAL_DAY
    TYPE   =  REAL
    FORMAT =  F13.9
  END_OBJECT
  OBJECT   =  VECTOR
    NAME   =  OB_BPL
    ALIAS  =  OUTBOARD_B_PAYLOAD
    TYPE   =  REAL
    OBJECT   =  SCALAR
      NAME   =  X
      FORMAT =  1X,F9.2
      UNITS  =  NT
    END_OBJECT
    OBJECT   =  SCALAR
      NAME   =  Y
      FORMAT =  1X,F9.2
      UNITS  =  NT
    END_OBJECT
    OBJECT   =  SCALAR
      NAME   =  Z
      FORMAT =  1X,F9.2
      UNITS  =  NT
    END_OBJECT
    OBJECT   =  SCALAR
      NAME   =  RANGE
      FORMAT =  1X,F3.0
    END_OBJECT
  END_OBJECT
  OBJECT   =  VECTOR
    NAME   =  POSN
    ALIAS  =  SC_POSITION
    TYPE   =  REAL
    OBJECT   =  SCALAR
      NAME   =  X
      FORMAT =  1X,F14.3
      UNITS  =  KILOMETERS
    END_OBJECT
    OBJECT   =  SCALAR
      NAME   =  Y
      FORMAT =  1X,F14.3
      UNITS  =  KILOMETERS
    END_OBJECT
    OBJECT   =  SCALAR
      NAME   =  Z
      FORMAT =  1X,F14.3
      UNITS  =  KILOMETERS
    END_OBJECT
  END_OBJECT
  OBJECT   =  VECTOR
    NAME   =  OB_BDPL
    ALIAS  =  OUTBOARD_BD_PAYLOAD
    TYPE   =  REAL
    OBJECT   =  SCALAR
      NAME   =  X
      FORMAT =  1X,F7.3
      UNITS  =  NT
    END_OBJECT
    OBJECT   =  SCALAR
      NAME   =  Y
      FORMAT =  1X,F7.3
      UNITS  =  NT
    END_OBJECT
    OBJECT   =  SCALAR
      NAME   =  Z
      FORMAT =  1X,F7.3
```

```
    UNITS  =  NT
  END_OBJECT
  OBJECT   =  SCALAR
    NAME   =  RANGE
    FORMAT =  1X,F4.0
  END_OBJECT
END_OBJECT
END_OBJECT
END_OBJECT
  2014 353  0  0  1  30 353.000011921       1.77    -12.98       9.51  0.       -4459.368
3068.275       2367.830    0.000  -0.131   0.361   0.
  2014 353  0  0  1  61 353.000012280       2.19    -13.45       9.39  0.       -4459.433
3068.301       2367.775    0.000  -0.131   0.361   0.
  2014 353  0  0  1  92 353.000012639       1.19    -13.72       9.77  0.       -4459.498
3068.327       2367.721    0.000  -0.131   0.361   0.
  2014 353  0  0  1 124 353.000013009       0.99    -13.37       9.57  0.       -4459.563
3068.353       2367.666    0.000  -0.131   0.361   0.
  2014 353  0  0  1 155 353.000013368       0.69    -13.18       9.37  0.       -4459.628
3068.379       2367.612    0.000  -0.131   0.361   0.
  2014 353  0  0  1 186 353.000013727       0.27    -12.76       8.70  0.       -4459.693
3068.405       2367.557    0.000  -0.131   0.361   0.
  2014 353  0  0  1 217 353.000014086      -0.40    -11.72       7.88  0.       -4459.759
3068.431       2367.503    0.000  -0.131   0.361   0.
  2014 353  0  0  1 249 353.000014456      -0.66    -11.22       6.56  0.       -4459.824
3068.457       2367.448    0.000  -0.131   0.361   0.
  2014 353  0  0  1 280 353.000014815      -0.77    -11.49       5.87  0.       -4459.889
3068.483       2367.394    0.000  -0.131   0.361   0.
  2014 353  0  0  1 311 353.000015174       0.59    -11.58       4.18  0.       -4459.954
3068.509       2367.339    0.000  -0.131   0.361   0.
  2014 353  0  0  1 342 353.000015532       2.06    -10.40       3.18  0.       -4460.019
3068.534       2367.285    0.000  -0.131   0.361   0.
  2014 353  0  0  1 374 353.000015903       3.23     -9.72       2.88  0.       -4460.084
3068.560       2367.230    0.000  -0.131   0.361   0.
  2014 353  0  0  1 405 353.000016262       5.00     -9.58       2.64  0.       -4460.149
3068.586       2367.176    0.000  -0.131   0.361   0.
  2014 353  0  0  1 436 353.000016620       6.73     -9.23       3.60  0.       -4460.214
3068.612       2367.121    0.000  -0.131   0.361   0.
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