Juno
Magnetometer

Juno Magnetometer (MAG) Standard Product Data Record and Archive Volume Software Interface Specification

Preliminary
March 6, 2018

Prepared by:

Jack Connerney and Patricia Lawton

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Approved:

________________________________ ____________
John E. P. Connerney — Date
MAG Principal Investigator

________________________________ ____________
Raymond J. Walker — Date
PDS PPI Node Manager

Concurrence:

________________________________ ____________
Patricia J. Lawton — Date
MAG Ground Data System Staff

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1 Introduction

This software interface specification (SIS) describes the format and content of the Juno 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

Name	Organization	Email
R. Beebe	New Mexico State University (UMSU)	rbeebe@nmsu.edu
J.E.P. Connerney	Space Research Corporation at National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC)	Jack.Connerney@nasa.gov
D. Gell	Southwest Research Institute	David.Gell@swri.edu
L. Huber	NMSU	lhuber@nmsu.edu
S. Joy	Planetary Data System (PDS)/Planetary Plasma Interactions (PPI)/University of California Los Angeles (UCLA)	sjoy@igpp.ucla.edu
P. Lawton	ADNET Systems Inc. at NASA GSFC	Patricia.J.Lawton@nasa.gov
W. Kurth	University of Iowa	wsk@space.physics.uiowa.edu
J. Mafi	PDS/PPI/UCLA	jmafi@igpp.ucla.edu
R. Walker	PDS/PPI/UCLA	rwalker@igpp.ucla.edu

1.2 Document change log

Table 2: Document change log

Change	Date	Affected portion
Initial MAG version (based upon MGS MAG)	05/03/2010	All
Draft	08/23/2010	All
Edits	06/20/2011	All
Edits	06/24/2012	Most
Edits	06/27/2014	Many
Edits	6/30/2014	Many
Connerney e-mail address corrected	8/11/2014	Appendix
RS/RTN changed to SCSE	11/14/2014	Table 12
RS/RTN changed to SCSE; add payload	11/24/2014	Many
Modify directory structure and add README.TXT file	12/10/2014	Section 5 – Figure 9 & Table 12
more RS to SE; SCSE to SE; rearranged directory structure	2/3/2015	Tables 1.4, 7a, 9, 12, and 13
directory structure; filename	2/9/2015	Section 5
	2/12/2015	
modifications for JSOC ; correct typo	3/5/2015	Tables 12 & 13; Table 7a
directory structure and filenames	4/3/2015	Section 5 Table 12
updates	12/23/2015	Sections 1.4, 1.6, 2.2, & 5; Tables 13 & 14; App B & C
update; rearrange; remove browse; update	1/8 & 12/2016	Section 2.7,Table 8a, Figure 9, Appendix B
affiliation; filenames	2/24/2016	Tables 1, 13, 14, & 19a
all payload will be resampled to 1 second (was cruise at 2 seconds); remove se_ql; add se resample at 1 hour	9/16/2016	Table 13; Figure 9
updates	10/26/2016	Section 1.6, Table 8a, and Figure 9
responses to PDS liens	11/04/2016	reversed Tables 6 & 7 (now 7 & 8); Sections 1.6, 1.9, 2.2, 2.7, 6.2.6; added Table 5; update Tables 12 & 13, Figure 3, Appendices A & B
update 1 hour filename	12/15/2016	Table 14
Space Science Review paper information	1/10/2017	1.7, 1.9, 2.7
SSR reference details added, additional columns for PJ files, correct typos	1/8/2018	1.7, 1.9, 2.3, 2.7, 3.1, Figure 9, Table 19
Inboard notes	3/5/2018	3.4.2 and Table 19

1.3 TBD items

Table 3 lists items that are not yet finalized.

Table 3: List of TBD items

Item	Section(s)	Page(s)
Technical University of Denmark (DTU) Advanced Stellar Compass (ASC) reference	1.9, 2.7	
impact of missing camera kernels (cks) on planetocentric (pc) & Sun-State (ss) files vs payload (pl) files		

1.4 Abbreviations

Table 4: Abbreviations and their meaning

Abbreviation	Meaning
A/D	Analog to Digital
ASC	Advanced Stellar Compass
ASCII	American Standard Code for Information Interchange
C&DH	Command and Data Handling
CCD	Charged Coupled Device
CCSDS	Consultative Committee for Space Data Systems
CD-ROM	Compact Disc – Read-Only Memory
CFDP	CCSDS File Delivery Protocol
CG	Center of Gravity
CHU	Camera Head Unit (optical head for Advanced Stellar Compass)
CK	C-matrix Kernel (NAIF orientation data)
CODMAC	Committee on Data Management, Archiving, and Computing
DMAS	Data Management and Storage
DOY	Day Of Year
DPU	Digital Processing Unit
DSN	Deep Space Network
dsid	data set identifiers
DTL	Decommutated Telemetry File (file extension)
DTU	Technical University of Denmark
EFB	Earth Fly By
EPO	Educational and Public Outreach
EDR	Experiment Data Record
FEI	File Exchange Interface
FGM	Fluxgate Magnetometer
FPGA	Field Programmable Gate Array
FTP	File Transfer Protocol
G	Gauss
GSFC	Goddard Space Flight Center
HGA	High Gain Antenna
HTML	Hypertext Markup Language
Hz	Hertz
IB	Inboard Magnetometer
ICD	Interface Control Document
IOT	Instrument Operations Team
ISO	International Standards Organization
JADE	Jovian Auroral Plasma Distributions Experiment
jan or JAN	Jupiter ANalysis Program (FORTRAN)
JEDI	Jupiter Energetic Particle Detector Instrument

JIRAM	Jupiter InfraRed Auroral Mapper
JPL	Jet Propulsion Laboratory
JSC	Johnson Spaceflight Center
JSOC	Juno Science Operations Center
KHz	Kilohertz
km	kilometer
LM	Lockheed Martin
MAG	Magnetic Field Investigation
mgan	Mars Global Analysis Program (MGS FORTRAN)
MGS	Mars Global Surveyor
MHA	Mario H. Acuña
moan	Mars Observer ANalysis
MOB	Magnetometer Optical Bench
MSA	Mission Support Area
MTF	Magnetic Test Facility
MWR	Microwave Radiometer Instrument
NAIF	Navigation and Ancillary Information Facility (JPL)
NASA	National Aeronautics and Space Administration
NMSU	New Mexico State University
NSSDC	National Space Science Data Center
nT	nanotesla
OB	Outboard Magnetometer
ODL or odl	Object Description Language
pc or PC	Planetocentric coordinate system
PCK	Planetary Cartographic and Physical Constants Kernel (NAIF)
PDS	Planetary Data System
pl or PL	Payload
PPI	Planetary Plasma Interactions Node (PDS)
ppm	parts per million
RDM	radiation design margin
R_J	Jupiter radius
RMS	Root Mean Square
RPM	Rotations per minute
SA	Solar Array
sc or s/c	Spacecraft
SCET	Spacecraft Event Time
SCLK	Spacecraft Clock
se or SE	Spacecraft – Solar equator coordinate system
SIS	Software Interface Specification
SPICE	Spacecraft, Planet, Instrument, C-matrix, and Events (NAIF data format)
SPK	SPICE (ephemeris) Kernel (NAIF)
SRU	Stellar Reference Unit

ss or SS	Sun-State coordinate system
STS	Standard Time Series File (file extension)
SwRI	Southwest Research Institute
TBD	To Be Determined
UTC	Coordinated Universal Time
UVS	Ultraviolet Spectrometer Instrument
V-EGA	Venus-Earth Gravity Assist

1.5 Glossary

Archive – An archive consists of one or more data sets along with all the documentation and ancillary information needed to understand and use the data. An archive is a logical construct independent of the medium on which it is stored.

Archive Volume – A volume is a logical organization of directories and files in which data products are stored An *archive volume* is a volume containing all or part of an archive; i.e. data products plus documentation and ancillary files.

Archive Volume Set – When an archive spans multiple volumes, they are called an *archive volume set*. Usually the documentation and some ancillary files are repeated on each volume of the set, so that a single volume can be used alone.

Catalog Information – High-level descriptive information about a data set (e.g. mission description, spacecraft description, instrument description), expressed in Object Description Language (ODL), which is suitable for loading into a PDS catalog.

Data Product – A labeled grouping of data resulting from a scientific observation, usually stored in one file. A product label identifies, describes, and defines the structure of the data. An example of a data product is a planetary image, a spectral table, or a time series table.

Data Set – A data set is an accumulation of data products together with supporting documentation and ancillary files.

Experiment Data Record – An accumulation of raw output data from a science instrument, in chronological order, with duplicate records removed, together with supporting documentation and ancillary files.

Pipeline Data Record – An accumulation of calibrated data from a science instrument, derived from experiment data records, together with supporting documentation, calibration data, and ancillary files.

Standard Data Product – A data product generated in a predefined way using well-understood procedures and processed in "pipeline" fashion. Data products that are generated in a non-standard way are sometimes called *special data products*.

1.6 Juno Mission Overview

The Juno spacecraft, atop an Atlas 551 launch vehicle, lifted off from Kennedy Space Center on August 5, 2011. The spacecraft uses an energy efficient ΔV-EGA trajectory in transit to Jupiter ("delta V, Earth gravity assist"). This trajectory used deep space maneuvers on 30 August 2012 and 14 September 2012 followed by an Earth gravity assist (close flyby) on 9 October 2013, during which it passed by the Earth at an altitude of approximately 500 km.

A brief description of the current mission plan follows; note, however, that the mission plan is under consideration at this time and is subject to change.

Jupiter arrival (orbit insertion) occurs on 5 July 2016. The capture orbit and orbit to follow will be 53.5-day orbits prior to commencing operations. Juno's prime mission consists of 32 or more high inclination, high eccentricity orbits of Jupiter. The orbit is polar (90º inclination) with a periapsis altitude of about 4500 km and a semimajor axis at ~100 R_j with the mission conducted using the existing 53 day orbit period. The primary science is acquired during approximately 6 hours centered on each periapsis. However, fields and particles data are acquired at lower rates for the remaining portion of each orbit. All orbits will include fields and particles measurements of the planet's auroral regions.

The Juno spacecraft is spin stabilized with a rotation rate of (approximately) either 1 or 2 rotations per minute (RPM). For the radiometry orbits the spin axis is precisely perpendicular to the orbit plane so that the radiometer fields of view pass through the nadir. For all other (gravity) passes, the spin axis is aligned to the Earth direction, allowing for Doppler measurements throughout the periapsis portion of the orbit. The orbit plane is initially very close to perpendicular to the Sun-Jupiter line and evolves slowly over the 1-year mission. Data acquired during the periapsis passes are either telemetered in near real time or recorded and played back over the subsequent portion of the orbit. MAG data will be telemetered in real time whenever spacecraft attitude during periapsis permits, to mitigate risk of loss of a pass (and thus complete global mapping coverage) as a result of a spacecraft anomaly.

Juno's instrument complement includes Gravity Science using the X and Ka bands to determine the structure of Jupiter's interior; a magnetic field investigation (MAG) with dual vector fluxgate magnetometers (FGM) and four co-located star cameras (ASC, Advanced Stellar Compass) to study the magnetic dynamo and interior of Jupiter as well as the polar magnetosphere; and a microwave radiometer (MWR) experiment to perform deep atmospheric sounding and composition measurements. The instrument complement also includes a suite of fields and particle instruments to study the polar magnetosphere and Jupiter's aurora. This suite includes an energetic particle detector (JEDI), a Jovian auroral (plasma) distributions experiment (JADE), a radio and plasma wave instrument (Waves), an ultraviolet spectrometer (UVS), and a Jupiter infrared auroral mapping instrument (JIRAM). The JunoCam is a camera included for education and public outreach. While this is not a science instrument, the project plans to capture the data and archive them in the PDS along with the other mission data.

1.7 Software Interface Specification 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 et al., Space Science Reviews, 2017]. 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 Juno 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 Archive Preparation Guide, Version 1.1, JPL D-31224, 08/29/2006.

Planetary Data System Standards Reference, JPL D-7669, Part 2, Version 3.8, 02/27/2009.

Planetary Science Data Dictionary Document, Planetary Data System, JPL D-7116, Version 1r65, 02/2007.

Juno Mission Operations Concept Document, JPL D-35531, Version Preliminary, 04/30/2007.
Juno Science Data Management and Archive Plan, Version Final, JPL D-34032, 08/26/2009.

Juno Science Operations Center (JSOC) JSOC-IOT Interface Control Document, 12029.02-JSOC_IOT_ICD-01, Rev 4 Chg 0, December 2013

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McPherron, R.L., and R.C. Sare, (1978) A procedure for accurate calibration of the orientation of the three sensors in a vector magnetometer, *IEEE Trans. Geosci. Electron.*, GE-16(2), 134-137.

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 Magnetic Field Investigation Instrument Description

2.1 Science Objectives

The Juno Magnetometer (MAG) Investigation is a principal science investigation on the Juno New Frontier Mission to Jupiter. MAG will conduct the first global magnetic mapping of Jupiter and contribute to studies of Jupiter's polar magnetosphere. The Juno MAG investigation is designed to acquire highly accurate measurements of the magnetic field in Jupiter's environment, mapping the planetary magnetic field with extraordinary accuracy and spatial resolution (orders of magnitude better than current knowledge).

2.2 Detectors

The reader is referred to the Magnetometer Investigation Instrument paper in Space Science Reviews for a more complete description of the investigation, flight hardware, and operation.

The MAG Instrument Suite consists of two boom mounted observing platforms (MAG Optical Bench, or MOB) each supporting a vector Fluxgate Magnetometer (FGM) and two non-magnetic Advanced Stellar Compass (ASC) Camera Head Units (CHUs). The ASC determines the attitude of the MOB in inertial space and relative to the JUNO spacecraft's Stellar Reference Units (SRU). The FGM was built at the Goddard Space Flight Center (GSFC); the ASC was built at the Technical University of Denmark (DTU).

The Juno FGM is fully redundant, with two identical power converters providing power to one of two identical field programmable gate array (FPGA)-based digital systems. Only one set (power converter and digital system) is powered at a time; the other is a cold back-up. Either set receives commands from, and transmits data to, either side of the spacecraft command and data handling (C&DH) unit through redundant interfaces. Two identical sets of analog electronics, both continuously powered by either power converter, drive the outboard (OB) and inboard (IB) sensors, via separate cables connecting the remote FGM sensors and electronics box, and both are controlled by and communicate with either of the digital systems. No single point failure can result in loss of data from both OB and IB FGM sensors.

Each FGM sensor block uses two miniature ring-core fluxgate sensors to measure the magnetic field in three components of the vector field. Each of the two ring-core sensors measures the field in two orthogonal directions in the plane of the ring core. With two such sensors, oriented in planes intersecting at 90 degrees, all three components of the vector field are measured (one component measured, redundantly, by both). The sensor electronics uses negative feedback to null the magnetic field in each core, providing linearity over the full dynamic range of the instrument. The field in each ring core is both sensed and nulled by a pair of nested coils within which the ring core resides. Each coil nulls the field in one of the two perpendicular axes that define the plane of the ring core sensing element. All elements are maintained in precise alignment by a sensor block assembly constructed of a machinable glass ceramic with low thermal expansion (MACOR) and excellent mechanical stability. The FGM sensor block attaches to the optical bench via a three point kinematic mount to maintain accurate alignment over the range or environments experienced. The FGM sensor block is designed to operate at about 0° C, whereas the optical bench and CHUs are designed to operate at about -58° C to minimize noise and radiation effects. The FGM sensor block is thermally isolated from the optical bench via the three point kinematic mount and individual thermal blanketing. The FGM sensor itself is impervious to radiation effects.

The two FGM sensors are separated by 2 meters on the MAG boom, one sensor (inboard, or "IB" sensor) is located 2 m radially outward from the end of the solar array and the other sensor (outboard, or "OB" sensor) is located at the outer end of the MAG boom. This arrangement ("dual magnetometer") provides the capability to monitor spacecraft-generated magnetic fields in flight. The MAG boom is located on the outermost end of one (+x panel) of three solar panels and is designed to mimic the outermost solar array panel (of the other two solar array structures) in mass and mechanical deployment. The OB and IB sensor packages are identical. The CHUs measure the attitude of the sensor assembly continuously in flight to 20 arcsec and are used to establish, and continuously monitor, the attitude of the sensor assembly with respect to the spacecraft SRUs through cruise, orbit insertion at Jupiter, and initial science orbits. In addition to the extraordinarily accurate attitude reference provided by the MAG investigation's multiple ASC CHUs, the spacecraft provides (reconstructed) knowledge of the FGM sensor assembly attitude to an accuracy of 200 arcsec throughout the mission, using sensors on the body of the spacecraft and knowledge of the attitude transfer between the ASC camera heads and spacecraft SRUs. This provides a redundant attitude determination capability that could be used if ASC attitude solutions are interrupted for any reason (e.g., blinding by a sunlit Jupiter obscuring the field of view for certain geometries, radiation effects). If this redundant capability is required at any time, the stability of the mechanical system (MAG boom, solar array hinges, structure, and articulation strut) linking the body of the spacecraft (SRU reference) to the FGM sensors (and CHUs) is an important element in satisfying the spacecraft requirement.

The Advanced Stellar Compass is a unique *non-magnetic* star camera designed and built by the Technical University of Denmark, a largely off-the-shelf product evolved from the Oersted, SAC-C, CHAMP, and SMART-1 star cameras. The ASC is an attitude sensor that determines the attitude of the MAG optical bench assembly with respect to an inertial reference frame by imaging the sky and comparing that image with its on-board database of objects. The ASC is capable of an estimated 2 arcsec performance (end-of-life), although operation on a spinning spacecraft (2 rpm) and in a challenging radiation environment will degrade performance. To mitigate the relatively rapid motion of stars across the field of view (14° x 20°) due to spacecraft spin, the CHUs are mounted with their optical axes offset from the spacecraft spin axis by about ±13° in the y-direction. To mitigate the harsh radiation environment, additional shielding mass is configured around the charge-coupled device (CCD).

The ASC consists of separate units: four Camera Head Units mounted on the two MOBs, with dual baffle systems to mitigate blinding, and a Data Processing Unit (DPU) capable of driving up to four CHUs simultaneously. The Juno ASC electronics box, in the shielded spacecraft vault, is configured with a dual DPU. Either side of the DPU can drive any or all camera heads (by cross-strapping of CHUs). Each DPU has its own power converter, redundant power, command, and telemetry interfaces with the spacecraft C&DH. The DPUs are operated one hot and one cold (cold back-up). The system design is such that no single point failure can result in loss of data from multiple CHUs. The CHUs are separate camera heads, two of which mount to each of the FGM MAG optical bench assemblies via three point kinematic mounts. The CHUs use light-sensitive CCDs operating at low temperatures (-58°C) to minimize noise and radiation effects. The design of the optical bench assembly and its remote location provide adequate passive cooling in the Jovian environment so active cooling is not necessary.

The CHUs image the sky with a ¼ second integration time (4 Hz), synchronized to the spacecraft clock timing reference. The CCD is read out and analog data is transmitted to the DPU in the vault where it is digitized and stored for analysis. Raw images can, by command, be stored and transmitted to ground as desired. The image is examined for stars, and, depending on the settings and region of the sky imaged, a number of stars (between 20 and a few 100) are detected (among a number of "false stars" and non-stellar objects). The initial attitude acquisition algorithm selects a group of stars, brighter than a set value, for analysis. They are scanned for nearest, and next nearest neighbors. The resulting sets of triplets are matched against a pre-flight compilation of the star catalog, the star database. This match gives a coarse attitude determination (good to approximately 1/50 degree) and this result may also be used to seed an algorithm to determine fine attitude. The quality of the fit is reported along with the attitude. In May 2015, the star catalog was updated in flight to be in sync with the time period Juno is in orbit at Jupiter.

The ASC time-stamps all attitudes and data with an accuracy of better than 0.1 ms. If the ASC has received a valid spacecraft time, that value appears in the time field; otherwise time is referenced to the internal time kept by the ASC initialized at turn-on. The ASC provides attitude quaternions to the spacecraft C&DH for each of the four ASC Camera Head Units (CHUs) at sample rates ranging from one each ¼ second to one per n seconds, selectable via ground command, according to needs and available telemetry. These are processed by Lockheed Martin (LM) and JPL's Navigation and Ancillary Information Facility (NAIF) to generate a suite of attitude kernels which may be called upon via NAIF software to determine the attitude of (1) each individual ASC CHU or (2) each of the MOBs. The ASC CHU NAIF kernels are managed in a stack such that attitude solutions may be obtained from a pair of CHUs on each MOB when available, or from an individual CHU on either MOB, or from CHUs on the other MOB with a fixed transformation between the two MOBs, or from the spacecraft SRUs and fixed transformations between SRUs and MOBs. The most accurate solutions are obtained using both CHUs on the respective MOB in a combined solution, since either CHU on its own is relatively less accurate in determination of the angle of rotation about the CHU boresight.

The Juno MAG sensors are remotely mounted (at approximately 10 m and 12 m) along a dedicated MAG boom that extends along the spacecraft +x axis, attached to the outer end of one of the spacecraft's three solar array structures. This design provides the maximum practical separation between MAG sensors and spacecraft to mitigate spacecraft-generated magnetic fields which would otherwise contaminate the measurements. A comprehensive magnetic control program is in place to ensure that the spacecraft magnetic field at the MAG sensors does not exceed 2 nT static or 0.5 nT variable. The separated, dual FGM sensors provide capability to monitor spacecraft-generated magnetic fields in flight.

The alignment of the outboard FGM is along the spacecraft's +x, +y, and +z axes. The inboard FGM is rotated approximately 180 degrees about the z axis, more or less aligning it with the spacecraft's –x, -y, and +z axes.

Table 5: Approximate Fluxgate Magnetometer alignment relative to spacecraft coordinates

spacecraft	outboard FGM	inboard FGM
+x	+x	-x
+y	+y	-y
+z	+z	+z

The NAIF kernels, ftp://naif.jpl.nasa.gov/pub/naif/JUNO/kernels/, should be reference for detail alignment information.

The following is from ftp://naif.jpl.nasa.gov/pub/naif/JUNO/kernels/spk/juno_struct_v02.bsp.lbl.

Figure 1: *Locations of the spacecraft's Center of Gravity and Inboard and Outboard Fluxgate Magnetometers*

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

```
 Spacecraft -Y side view:
 ------------------------
                          o
                         / HGA
---              .--------@--------, HGA
 ^                \               /
 |3.5m(est)        `.           .'
 |                    `-------'         Solar Array 1       Magnetometer
 |                    |       |                                 Boom
 |                    |       |
 | ---    =======o==o==o==o-----------o======o======@======o=====@====@*
 |  ^           |           |           |            SA1       FGM/IB FGM/OB
 |  | 2m(est) |           | s/c CG    |
 |  | ---     |           @           |
 |  |  ^      |                       |
 |  |  |1.5m  |      +Zsc ^           |
 |  |  |(est) |           |           |
 |  |  |      |           |           |
 V  V  V      |           |           |
---------     `----- +Ysc x------>   -'
                       /_____\  +Xsc

                          |     6 m (estimated)
                          |<----------------------->|
                          |                         |

                          |          10 m (estimated)            |
                          |<------------------------------------>|
                          |                                      |

                          |               12 m (estimated)            |
                          |<----------------------------------------->|
                          |                                           |
```

The following diagrams and text are from ftp://naif.jpl.nasa.gov/pub/naif/JUNO/kernels/fk /juno_v09.tf.

Figure 2: *Dimensions required for determination of locations of the Magnetic Field Investigation sensors relative to the spacecraft center*

The following diagram shows dimensions required for determination of locations of the MAG sensors relative to the s/c center:

```
Spacecraft -Y side view:
------------------------
                         o
                        / \
                .-----------------, HGA
                 \               /
                  `.           .'
                     `-------'
                     |       |                        Magnetometer
                     |       |                            Boom
================o==o==o==o-------o======o======o======o===========*
    Solar    |           |           |   Solar Array 1
   Array 2   |           |           |
             |                       |
             |                       |
             |      +Zsc ^           |
             |           |           |
             |           |           |
             |           |           |            +Ysc is into
             `----- +Ysc x------>   -'              the page.
                      /_____\  +Xsc
```

Figure 3: *Fluxgate Magnetometer frames*

This diagram illustrates the FGM frames:

```
      Spacecraft -Z side view:
      ------------------------

                         Magnetometer Boom

              /```---...
              |         ```---.. +Yfgm_ib
              |                        ^  .
              |                        |  ```---...
              |                        |   CHUD   CHUB...
 +Zsc    +Xsc |                      .-|--@.         .@----.| +Xfgm_ob
   x------>   |                 <------x @ |         | @ x------>
   |          |          +Xfgm_ib    `----@'         `@--|-'|
   |          |                            CHUC   CHUA'''|
   |          |                           ...---'''      |
   v          |                        /'''              V
    +Ysc      |         ...---'''\    /                +Yfgm_ob
              \...---'''          ---


                                        +Zsc, +Zfgm_ib, +Zfgm_ob,
                                            are into the page.
```

Figure 4: *Advanced Stellar Compass Camera Head Units (CHU) frames*

This diagram illustrate the ASC CHU frames:

```
    Spacecraft -Z side view:
    ------------------------


                      Magnetometer Boom
               /```---...           ___
               |         ```---.../    \    ^ +YchuD
               |                        \...|
               |                            ^ +YchuC
               |                      CHUD |        ```- CHUB
  +Zsc    +Xsc |                      .--- o----> <----o----..
    x------>   |                FGM_IB| @ @|| +X   +X ||@ @ ||FGM_OB
    |          |                      `--- o----> <----o----''
    |          |                      CHUC          ...| CHUA
    |          |                           ...- +YchuB V
    v          |                       /'''            |
     +Ysc      |         ...---'''\   /         +YchuA V
               \...---'''          ---

                                             +Zsc is into the page.
```

```
                                        +Zchu1, +Zchu2, +Zchu3, and +Zchu4
                                         are out of the page, inclined at
                                                   ~13 degrees.
```

Figure 5: *Magnetometer Optical Bench frames*

This diagram illustrates the MOB frames:

```
      Spacecraft -Z side view:
      ------------------------


                         Magnetometer Boom

                 /```---...          ___
                 |         ```---.../   \  +Ymob_ib
                 |                       \..^
                 |                          |```---...
                 |                          | CHUD   CHUB...
    +Zsc    +Xsc |                      .---|@.  +X     .@----..
      x------>   |               FGM_IB | @ o-----> <-----o @ ||FGM_OB
      |          |                      `----@'     +X  `@|---''
      |          |                            CHUC   CHUA'|'
      |          |                           ...---'''    |
      v          |                       /'''             V
       +Ysc      |         ...---'''\   /               +Ymob_ob
                 \...---'''          ---

                                           +Zsc is into the page.

                                           +Zmob_ib, and +Zmob_ob
                                            are out of the page.
```

Figure 6: *All Magnetometer Frames*

This diagram illustrates all magnetometer frames together:

```
Spacecraft +X side view:
------------------------


      Outboard Bench                          Inboard Bench
      --------------                          -------------

              +Z            +Z                   +Z
               ^             ^                    ^
               |             |                    |
               | FGM_OB      | S/C         FGM_IB |
+X     +Y      |             |                    |     +Y     +X
 x------>      o------>      o------>     <------x      <------o
              +X      +Y      +X      +Y     +Y      +X             |
 | MOB_OB                                                 MOB_IB |
 |                                                              |
 v                                                              v
+Z                                                           +Z
                     .> +Y               +Y <.
              +X  .-'                          `-. +X
      +X x      x'  CHUA                         `o      o +X
        / `-.    \                               /    .-' \
       /     `>   \                       CHUD  /   <'     \
      / CHUB  +Y   \                           /  +Y  CHUC  \
     v              v                         v              v
   +Z              +Z                       +Z              +Z

   /<--------|-------->\                    /<--------|-------->\
      13 deg | 13 deg                          13 deg | 13 deg


 +Xs of s/c, FGM_OB, MOB_IB, CHUC, and CHUD are out of the page.
 +Xs of      FGM_IB, MOB_OB, CHUA, and CHUB are into   the page.
```

'JUNO_SPACECRAFT' frame is defined by the spacecraft (s/c) design as follows:

- +Z axis is along the nominal spin axis and points in the direction of the nominal High Gain Antenna (HGA) boresight
- +X axis is along the solar array 1 symmetry axis and points towards the magnetometer boom
- +Y axis completes the right-handed frame
- the origin of the frame is centered on the launch vehicle separation plane.

'JUNO_MOB_IB' and 'JUNO_MOB_OB' -- are defined as follows:

- +Z axis is normal to the optical bench plane on the FGM side
- +X axis is in the optical bench plane and points from the midpoint between ASCs towards FGM
- +Y axis completes the right-handed frame
- the origin of the frame is in the center of the outer mounting hole on the ASC side bracket
- +Z axis is along the vector that is the sum of the CHU boresight directions (CHUA + CHUB for OB, CHUD + CHUC for IB

- +Y axis is along the vector that is the difference of the boresight directions (CHUA - CHUB for OB, CHUD - CHUC for IB)
- +X axis completes the right-handed frame
- the origin of the frame is between the focal points of the two CHUs whose boresights define the frame.
- The OB MOB frame is nominally rotated from the s/c frame by 180 degrees about X, then by 180 degrees about Z.
- The IB MOB nominally rotated from the s/c frame by 180 degrees about X.

'JUNO_FGM_IB' and 'JUNO_FGM_OB' frames are the frames with respect to which the FGM sensors were calibrated. These frames are defined by the orthogonal faces of the alignment cubes mounted on the optical benches as follows:

- +Z axis is the normal to the top side of the alignment cube (the side parallel to the optical bench plane) and pointing away from the bench; nominally points in the same direction as the s/c +Z axis.
- +X axis is the normal to the side of the cube facing the FGM sensor mounted on the bench; for OB FGM nominally points in the same direction as the s/c +X axis, for IB FGM nominally points in the same direction as the s/c -X axis
- +Y axis completes the right-handed frame
- the origin of the frame is in the geometric center of the FGM enclosures
- The OB FGM frame is nominally co-aligned with the spacecraft frame.

The ASC CHU frames -- JUNO_ASC_CHUA, JUNO_ASC_CHUB, JUNO_ASC_CHUC, and JUNO_ASC_CHUD -- are defined as follows:

- +Z axis is along the boresight
- +X axis is along the sensor side roughly aligned with the cable direction, pointing away from the cable side.
- +Y axis completes the right-handed frame
- the origin of the frame is at the CHU's focal point

2.3 Electronics

The JUNO sensor design covers the wide dynamic range with six instrument ranges (see **Table 5**) increasing by factors of four the dynamic range in successive steps. The analog signals are digitized with a 16 bit analog to digital (A/D) converter, which yields a resolution of +/- 32768 steps for each dynamic range. In the table below, resolution, equal to ½ the quantization step size for each range, is listed in parentheses.

Table 6: Juno Fluxgate Magnetometer ranges

FGM Characteristics	**Dual Tri-Axial Ring Core Fluxgate**
Dynamic range (resolution) (1 G = 100,000 nT)	16.3840 G (±25.0 nT) 4.0960 G (±6.25 nT) 1.0240 G (±1.56 nT) 0.2560 G (±0.391 nT) 6400 nT (±0.10 nT) 1600 nT (±0.02 nT)
Measurement accuracy:	0.01% absolute vector accuracy
Intrinsic noise level	<<1 nT (range dependent)
Zero level stability	<1 nT (calibrated)
Intrinsic sample rate	64 vector samples/s

The FGM electronics are mounted in the spacecraft vault and partially shielded from radiation (total dose to 50 krad with a radiation design margin (RDM) of 2). The analog electronics drives each ring core into saturation at a frequency of 16 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 (32 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). The instrument is susceptible to spacecraft interference at harmonics of the drive frequency so care must be taken to insure that the spacecraft is quiet at these frequencies. The appropriate instrument dynamic range is selected, automatically, by range control logic, resulting in autonomous operation throughout the entire dynamic range. All range and instrument control functions are implemented in hardware (radiation-hard Field Programmable Gate Array FPGA). The FGM powers up in a fully operational mode autonomously without need of command and/or uplink. Upon power up, the instrument will transmit a data packet to the s/c C&DH every 2 seconds, i.e., in response to every clock pulse received from the C&DH. In the event that a clock pulse is not received, the instrument will transmit data based on an internal clock and re-synchronize with the spacecraft clock when it becomes available. A limited command set allows uplink of parameters and mode selection as desired.

The OB and IB FGM sensors sample the field in all (four) axes simultaneously at an intrinsic sample rate of 64 vector samples per second, synchronized to the spacecraft clock. Depending on instrument mode and telemetry allocation, these data are stored in packet format awaiting transmission, or first filtered (low pass filtered, or averaged) and resampled (decimated) prior to packetizing for transmission, along with a spacecraft time stamp, selected housekeeping and engineering telemetry, and header/trailer fields.

The data format of the OB and IB FGM sensors is controlled independently from the other. The science packet delivered from the instrument to the spacecraft every 2 seconds consists of a 24 byte header, the IB FGM sensor data, and the OB sensor data. The data from each sensor can be in one of eight data formats. The instrument intrinsic sample rate of 64 samples/second is supported in data formats 0 and 1; averages over 2^n samples (n = 1,2,3,4,5,6) are supported in telemetry modes 2 through 7. In telemetry mode 0 and 7, a redundant (Y) axis is returned with each sample (three components x, y, z, and a redundant y); all other modes return the three components of the field.

Table 7: Fluxgate Magnetometer data formats and rates per sensor

Telemetry format	Samples/ second	Vectors/ sample	Samples/ packet	Bytes/packet (excludes header)	Bits/second (excludes header)	Bits/second (includes IDP header)
0	64	4	128	1024	4096	4144
1	64	3	128	768	3072	3120
2	32	3	64	384	1536	1584
3	16	3	32	192	768	816
4	8	3	16	96	384	432
5	4	3	8	48	192	240
6	2	3	4	24	96	144
7	1	4	2	16	64	112

At power on, FGM returns science data in format IB 0 and OB 0 (64 samples per second) and engineering packets every 2 seconds. The spacecraft's various power on sequences for FGM quickly reduces these rates

Table 8: Fluxgate Magnetometer power on sequences data rates

IB format	OB format	IB rate (samples/second)	OB rate (samples/second)	Engineering rate (seconds between samples)
1	1	64	64	2
1	1	64	64	32
3	3	16	16	512
4	4	8	8	512
7	7	1	1	512

The FGM electronics also include a redundant pair of sensor thermal controllers to provide AC power to individual *non-magnetic* electrical heaters at the base of each FGM sensor block. These are independently powered by either side of the spacecraft via separate power interfaces (essential bus); they do not draw from instrument power so that they may be powered indefinitely, regardless of the state (on/off) of the FGM, to maintain the thermal state of the FGM sensors within acceptable limits. This function is performed by the FGM, and not the spacecraft, because the spacecraft heaters are DC heaters which, in close proximity to the magnetometer sensors, increase risk of magnetic interference.

2.4 Measured Parameters

The OB and IB FGM sensors sample the magnetic field in all (four) axes simultaneously at an intrinsic sample rate of 64 vector samples per second, synchronized to the spacecraft clock. The four axes are X, Y, Z, and redundant Y.

2.5 Operational Modes

The FGM powers up in operational mode and returns telemetry immediately every clock tic (2 seconds). The FGM 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 FGM is designed to power up in an operating mode, acquiring magnetic field data and transferring that data to the spacecraft every 2 seconds without need of commanding. The instrument will autonomously select the appropriate dynamic range. The intent is to have the FGM operate continuously throughout the mission subject to practical considerations, forming data packets with averaged samples as necessary, to accommodate the telemetry allocation.

The FGM 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 FGMs 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 the FGMs to 100 parts per million (ppm) absolute vector accuracy. An independent measurement of the magnetic field strength in the 0.25, 1, and 4 Gauss ranges was provided by Overhausen Proton Precession magnetometers placed near the FGM. Scale factor calibration is extended to 16 Gauss using a specialized high field coil and measurement techniques (see JUNO Magnetic Field Investigation instrument paper). A nuclear magnetic resonance magnetometer (Virginia Scientific Instruments) provided the absolute field strength measurements in the 16 Gauss range.

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 et al., Space Science Reviews, 2017]. 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 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 (or MOB) 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

Inflight calibration activities are designed to monitor instrument parameters, primarily zero offsets, and to monitor the relative alignment of the magnetic field sensor platforms (the MOBs) and the spacecraft attitude reference (Stellar Reference Units, or SRUs). Spacecraft generated magnetic fields will be monitored using the dual magnetometer technique and a series of magnetic compatibility tests designed to identify the source of any magnetic signals (if any) associated with spacecraft payloads. Since Juno is a spinning spacecraft, spinning at 1 or 2 rpm nominally, any field fixed in the frame of reference of the spacecraft (e.g., fixed spacecraft-generated magnetic fields, sensor offsets, etc.) is easily identified. In practice we apply an algorithm developed independently by several groups (Acuña, Reviews of Scientific Instruments, 2002) to estimate bias offsets using differences in the measured field. This method handily corrects for biases in the spacecraft x and y axes, but since the spacecraft spins about the z axis, biases in z must be estimated using different methods. One technique utilizes the Alfvenic nature of fluctuations in the solar wind, that is, the magnitude preserving nature of variations in the field. Of course, not all fluctuations are Alfvenic (preserving magnitude) so some care is taken in application of this method to select appropriate events.

3 Data Set Overview

3.1 Data Sets

The standard product types generated by the MAG FGM Instrument Operation Team (IOT) are listed in Table **9a**.

The calibrated (CAL) data is from the Juno (JNO) Fluxgate Magnetometer (FGM). The data is for the Solar System (SS) or Jupiter (J) target. The data level is based on the Committee on Data Management, Archiving, and Computing (CODMAC) definition. See Section 6.3.2 of *Planetary Data System Standards Reference* for definition of the data processing levels.

Table 9a: Data Sets and Standard Data Products

Data Set ID	CODMAC Level	Standard Data Product ID	ID
JNO-SS-3-FGM-CAL-V1.0	3	SC-Solar Equatorial coordinate system (se) (cruise)	M1
JNO-SS-3-FGM-CAL-V1.0	3	Payload Coordinate system (pl) (cruise and Earth Fly By)	M1
JNO-SS-3-FGM-CAL-V1.0	3	Planetocentric (pc) (Earth Fly By [2013-282] and 2016 DOYs 177-181)	M1
JNO-SS-3-FGM-CAL-V1.0	3	Sun-State (ss) (Earth Fly By [2013-282] and 2016 DOYs 177-181)	M1
JNO-J-3-FGM-CAL-V1.0	3	Planetocentric (pc) (Orbital)	M1
JNO-J-3-FGM-CAL-V1.0	3	Sun-State (ss) (Orbital)	M1
JNO-J-3-FGM-CAL-V1.0	3	Payload Coordinate system (pl) (Orbital)	M1
JNO-J-2-FGM-N-V1.0	2	Time stutter file (at end of mission)	

Table 9b: 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. The MAG Maps (M3, M4) products are high-level data products that can only be produced after global coverage of the planet is available and thus will be provided at the end of the Mapping phase of the mission. A single map product will be delivered to the PDS and included on a high-level data product volume following the end of the prime mission.

NAIF created ASC CHU and MOB kernel files will be archived by NAIF.

3.2 Data Flow

The Juno Data Management and Storage (DMAS) will receive packets and Consultative Committee for Space Data Systems (CCSDS) File Delivery Protocol (CFDP) products from the Deep Space Network (DSN) and place these on the Project data repository system. The MAG Instrument Operations Team (IOT) will retrieve the data from the DMAS using File Exchange Interface (FEI) services and ancillary data from the JPL Mission Support Area (MSA), Juno Science Operations Center (JSOC), or NAIF.

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 JSOC. Higher level data set archives will be coordinated through the JSOC. The Science Investigation Team will be responsible for ensuring that the metadata and documentation included with these data sets are complete and accurate.

3.3 Data Processing and Production Pipeline

3.3.1 RDR (NASA Level 1B/CODMAC Level 3) Data Production Pipeline

Figure 7: *FGM Preliminary Processing*

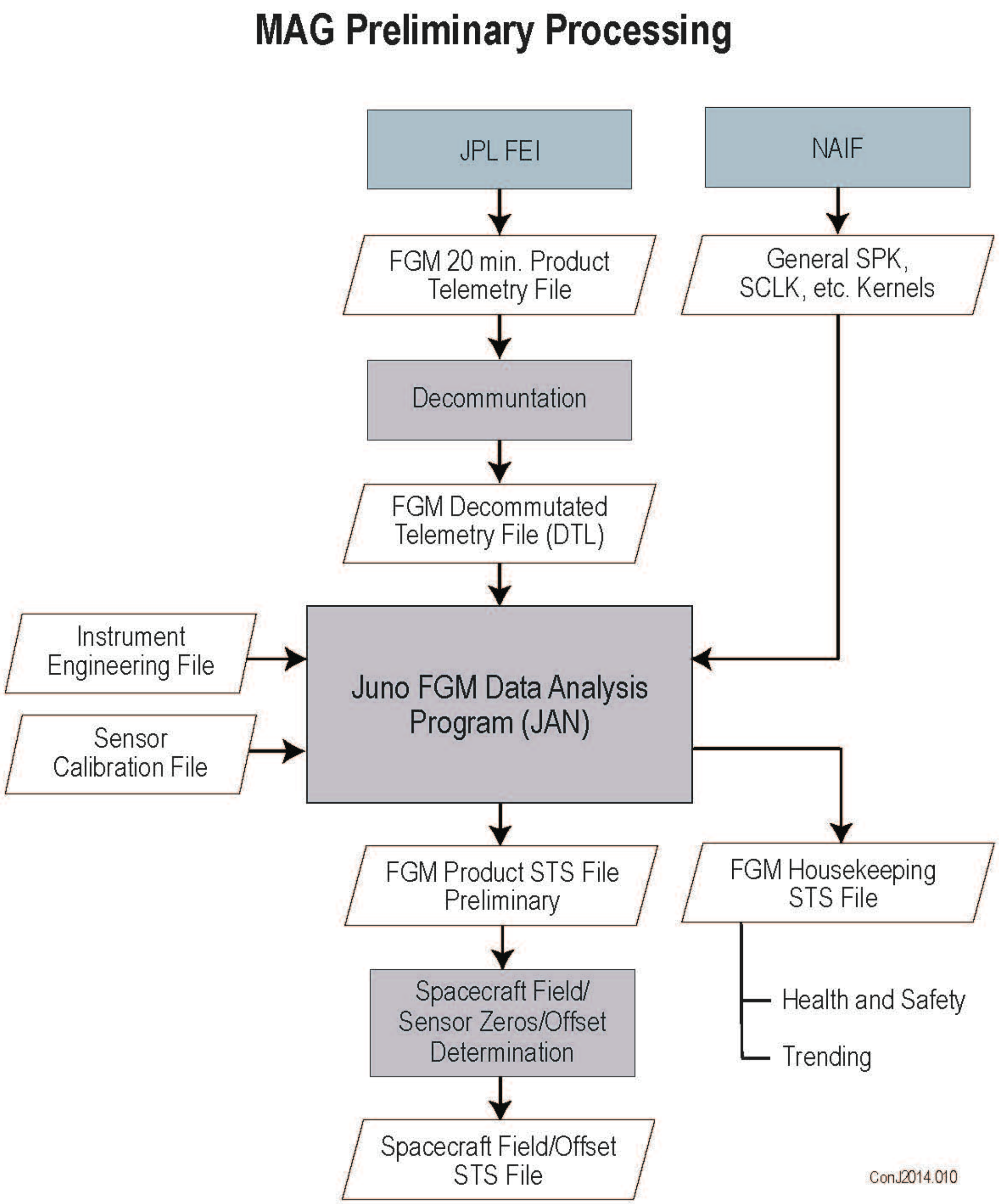
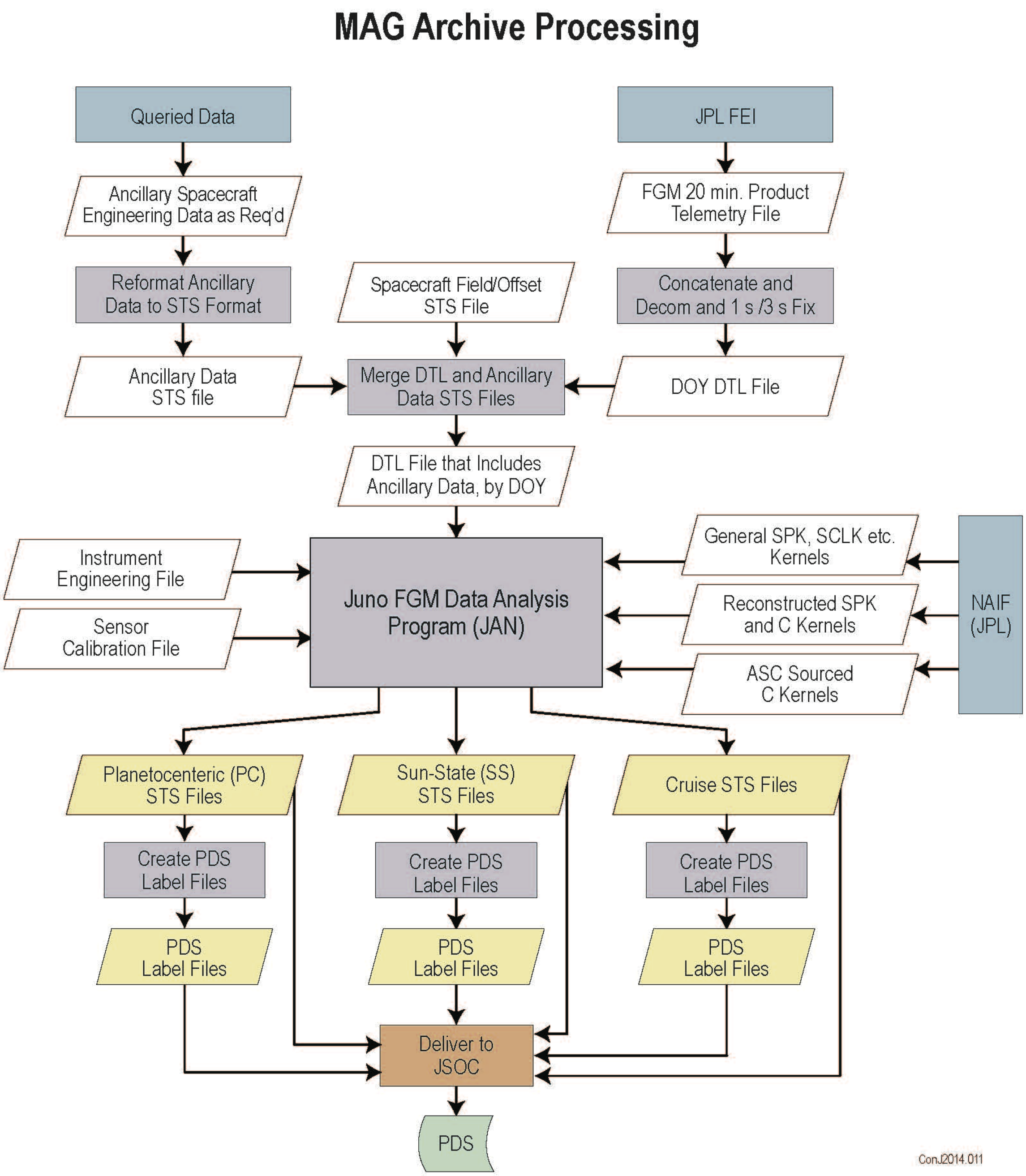


Figure 8: *Fluxgate Magnetometer Archive Processing*



3.3.1.1 Decommutate

FGM packets are generated by the experiment on board the spacecraft. There are three basic packet structures generated by the experiment two of which must be identified and handled accordingly on the ground. These are the FGM science data packet structures (containing formatted science and subcommutated housekeeping data) and the FGM engineering packet structures sent by the instrument for diagnostic purposes. The FGM broadcast vector structures are not downlinked; these are transferred to the spacecraft C&DH system for distribution to the other science payloads for use in near real time aboard the spacecraft

The de-commutation (juno_fgm_pkts_read) processing element reconstructs the data placed in the packet according to the FGM packet telemetry formats described in the *Juno Fluxgate Magnetometer (FGM) Instrument Users Manual with Electronics Description, Command and Telemetry Definitions*. This science data packet includes spacecraft time (2 second clock timestamp), sub-commutated engineering information, instrument range identification, and magnetometer data time series. Sub-commutated engineering data consists of health and status information which is telemetered at a low rate; therefore, a cyclical readout of selected engineering information appears in the space allocated to the housekeeping data in the science data packet header structure.

The FGM science data is formatted in the FGM packet in one of several ways, determined by the contents of a byte in the FGM science packet header. The instrument samples the magnetometer outputs at a fixed rate of 64 vector samples per second for both inboard and outboard magnetometer. At the maximum telemetry rate, these samples all appear in the FGM science packet. A more limited telemetry allocation is satisfied by averaging and decimation of the magnetometer outputs, successively, by factors of two (64/2=32; 32/2=16; 16/2=8; etc.) all the way down to 1 sample/2 seconds which is the minimum sample rate that can be realized. The instrument is designed to telemeter a packet once every 2 seconds upon power-up; the size of the packet is determined by the extent of averaging and decimation applied to each of the magnetometers independently. There are thus 8 x 8 possible selections, 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 FGM data according to the mode selection (which is telemetered in every packet).

The output of the decom function is a readable ASCII file of the contents of the FGM telemetry packet in a “Keyword = Value” format that can be read by the Juno data processing program (jan). 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 FGM engineering data is de-commutated via the same software, creates a similar readable ASCII file which can be processed by the same Juno data processing program (jan). The engineering packet can be set to be produced once every 2 seconds up to once per every 512 seconds.

3.3.1.2 Merge Ancillary

It is our intent that all information necessary to process FGM data arrives in the FGM 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 FGM data for use in the FGM data processing (specialized routines, as needed, that correct the measured field for spacecraft-generated magnetic fields). The data input functionality of Jan 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.

This facility may or may not be needed for Juno, but it is available if needed.

3.3.1.3 Fluxgate Magnetometer Data Processing

The FGM data processing software (jan) is based on heritage FGM data processing software. The last mission it was used for regularly was the Mars Global Surveyor (MGS) Mission, in the form of a Fortran program mgan (Mars Global ANalysis). It was 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 FGM 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 FGM 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 Juno mission will primarily use Jupiter 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 Ganymede – this would be specified by inclusion of the option “-ganymede” 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, -scse); 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        time   dday   ob_b   posn
```

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

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

will result in a magnetic field vector from the outboard magnetometer and spacecraft position rendered in 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).

The argument string

-odl –sun –dz time dday ob_bpl posn

Produces records with time fields, decimal day, outboard magnetic field vectors, and spacecraft position relative to the sun ("-sun"), corrected for offsets ("-dz'). The position is rendered in J2000.

There are three principal coordinate systems used to represent the data in this archive. The SE coordinate system is a Spacecraft- Solar equatorial system and it will be used for cruise data only. The sun-state (ss) and planetocentric (pc) will be used for Earth Fly By (EFB) and Jupiter orbital data. 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 Jupiter). In what follows we will reference Jupiter as the target body, but, for example, if observations near a satellite (such as Io) are desired in Io-centric coordinates, the satellite Io may be specified as the target body.

The SE coordinate system is defined using the sun-spacecraft vector as the primary reference vector; sun's rotation axis as the secondary reference vector (z). The x axis lies along the sun-spacecraft vector, the z axis is in the plane defined by the Sun's rotation axis and the spacecraft-sun vector. The y axis completes the system.

The ss coordinate system is defined using the instantaneous Jupiter-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 Jupiter orbital velocity vector is the second vector used to define the coordinate system; the y axis lies in the plane determined by the Jupiter-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 Jupiter. This system is sometimes called a sun-state (ss) coordinate system since its principal vectors are the Sun vector and the Jupiter state vector.

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 IAU. The Y axis completes the right-handed set.

Data in the vicinity of the moons of Jupiter (Io, Europa, Ganymede, Callisto) 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 Jupiter 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 end 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.

3.4 Data Validation

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

3.4.1 Instrument Team Validation

Each FGM packet includes a checksum. The decommutation process verifies the checksum. Also, words or bytes in the FGM 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 FGM 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.

3.4.2 Science Team Validation

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

Through 2017 DOY 174, magnetometer observations in weak field environments (sensor range 0, +/- 1600 nT nominal dynamic range) are sourced from the outboard sensor. Subsequent to 2017 DOY 174, magnetometer observations in weak field environments (sensor range 0, +/- 1600 nT nominal dynamic range) are sourced from the inboard sensor to alleviate minor sporatic interference appearing in the z axis of the outboard sensor. This substitution is noted in the STS header that identifies the content of each record. The STS header should be consulted for file content each time a file is read, in the event that file content changes (this was the design purpose of the STS header). We anticipate further file format changes (in upper dynamic ranges) as additional corrections are introduced.

4 Archive volume generation

4.1 Archive Structure and Identification

PDS data set names shall conform to the following format: JUNO <target> *FGM* <data type> <calibration state> DATA V<major version>.<minor version>. For example , version one of the *Fluxgate Magnetometer* science data set will be named JUNO JUPITER FGM CALIBRATED DATA V1.0

PDS data set identifiers (dsid) will be abbreviated versions of the data set names formed according to the PDS formation rule for the DATA_SET_ID keyword. For example, the dsid for the data set above would be JNO-J-3-FGM-CAL-V1.0

Each archive volume has the same general structure, consisting of a set of fixed top-level directories, INDEX, DOCUMENT, CATALOG, CALIB, DATA. Archive volumes may optionally include BROWSE and EXTRAS directories. The BROWSE directory is contains browse data products intended to permit quick-look evaluation of the data. The EXTRAS directory contains files that are helpful but not required for interpretation of the archived data. The contents of each directory will be described below.

4.2 Data Production and Transfer Methods

The instrument operations team (IOT) 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 JSOC and placed in directories that mirror the archive organization.
JSOC subsequently transfers data products to the PDS discipline node.

4.3 Volume Creation

The PDS node collects the data files and labels provided by the JSOC team onto archive volumes. Each archive volume contains all instrument data available for the time interval covered by the archive volume. Once all of the data files, labels, and ancillary data files are organized onto an archive volume, the PDS node adds all of the PDS required files (AAREADME, INDEX, ERRATA, etc.).

4.4 Volume Validation Methods

Validation of the instrument data archive is completed in two phases. The first phase is performed by the PDS node and consists of reviewing a sample, pathfinder data set for compliance with the PDS standards.

The second phase of the validation consists of a peer review to ensure usability and completeness. The instrument team and outside science reviewers will be responsible for verifying the content of the data set, the completeness of the documentation, and the usability of the data in its archive format.

Once automated production begins, the data file content will be spot checked by members of the instrument team.

5 Archive Volume Contents

This section describes the contents of the standard product archive collection volumes, including the file names, file contents, file types, and organizations responsible for providing the files. The complete directory structure is shown in **Figure 9**, below.

Figure 9:*Archive Volume Directory Structure*

```
root - fgm —|- aareadme.txt
            |- errata.txt
            |- document
            |- index
            |- data  - |- cruise -|- se  -|- 1sec -|- 2011
            |          |          |       |        |- 2012
            |          |          |       |        |- 2013
            |          |          |       |        |- 2014
            |          |          |       |        |- 2015
            |          |          |       |        |- 2016
            |          |          |      -|- 1min -|- 2011
            |          |          |       |        |- 2012
            |          |          |       |        |- 2013
            |          |          |       |        |- 2014
            |          |          |       |        |- 2015
            |          |          |       |        |- 2016
            |          |          |      -|- full -|- 2011
            |          |          |       |        |- 2012
            |          |          |       |        |- 2013
            |          |          |       |        |- 2014
            |          |          |       |        |- 2015
            |          |          |       |        |- 2016
            |          |          |      -|- hour
            |          |         -|- pl  -|- 1sec -|- 2011
            |          |          |       |        |- 2012
            |          |          |       |        |- 2013
            |          |          |       |        |- 2014
            |          |          |       |        |- 2015
            |          |          |       |        |- 2016
            |          |          |      -|- full -|- 2011
            |          |          |       |        |- 2012
            |          |          |       |        |- 2013
            |          |          |       |        |- 2014
            |          |          |       |        |- 2015
            |          |          |       |        |- 2016
            |          |         -|- pc  -|- 1min -|- 2013
            |          |          |       |        |- 2016
            |          |          |       |- 1sec -|- 2013
            |          |          |       |        |- 2016
            |          |          |       |- full -|- 2013
            |          |          |       |        |- 2016
            |          |         -|- ss  -|- 1min -|- 2013
```

```
|           |           |         |         |- 2016
|           |           |         |- 1sec -|- 2013
|           |           |         |         |- 2016
|           |           |         |- full -|- 2013
|           |           |         |         |- 2016

|           |- Jupiter |- pc   -|- 1min -|- peri-1
|           |           |         |         |- peri-2
|           |           |         |         |- peri-n
|           |           |         |- 1sec -|- peri-1
|           |           |         |         |- peri-2
|           |           |         |         |- peri-n
|           |           |         |- full -|- peri-1
|           |           |         |         |- peri-2
|           |           |         |         |- peri-n
|           |           |- ss   -|- 1min -|- peri-1
|           |           |         |         |- peri-2
|           |           |         |         |- peri-n
|           |           |         |- 1sec -|- peri-1
|           |           |         |         |- peri-2
|           |           |         |         |- peri-n
|           |           |         |- full -|- peri-1
|           |           |         |         |- peri-2
|           |           |         |         |- peri-n
|           |           |- pl   -|- 1sec -|- peri-1
|           |           |         |         |- peri-2
|           |           |         |         |- peri-n
|           |           |         |- full -|- peri-1
|           |           |         |         |- peri-2
|           |           |         |         |- peri-n
|- catalog
|- geometry
|- extras -|- stutter
```

When a day is in two perijove time periods, the data files will be placed in the directory for the earlier perijove. The NAIF orbit (orb) file is used to determine the perijove time period.

5.1 Root Directory Contents

The following files are contained in the root directory, and are produced by the PDS discipline node. With the exception of the hypertext file and its label, all of these files are required by the PDS Archive Volume organization standards.

Table 10: Root Directory Contents

File Name	File Contents	Provided By
AAREADME.TXT	This file completely describes the Volume organization and contents (PDS label attached).	PDS node
ERRATA.TXT	A cumulative listing of comments and updates concerning all Standard Data Products on all Volumes in the Volume set published to date.	PDS node
VOLDESC.CAT	A description of the contents of this Volume in a PDS format readable by both humans and computers.	PDS node

5.2 INDEX Directory Contents

The following files are contained in the index directory and are produced by the PDS discipline node. The INDEX.TAB file contains a listing of all data products on the archive volume. The index and index information (INDXINFO.TXT) files are required by the PDS volume standards. The index tables include both required and optional columns.

Table 11: Index Directory Contents

File Name	File Contents	Provided By
INDXINFO.TXT	A description of the contents of this directory	PDS node
INDEX.TAB	A table listing all Data Products on this Volume	PDS node
INDEX.LBL	A PDS detached label that describes INDEX.TAB	PDS node

5.3 Document Directory Contents

The document directory contains documentation that is considered to be either necessary or simply useful for users to understand the archive data set. These documents are not necessarily appropriate for inclusion in the PDS catalog. Documents may be included in multiple forms (ASCII, PDF, MS Word, Hypertext Markup Language (HTML) with image file pointers, etc.). PDS standards require that any documentation deemed required for use of the data be available in some ASCII format. Clean HTML is acceptable as ASCII formats in addition to plain text. The following files are contained in the DOCUMENT directory and are produced or collected by the PDS discipline node.

Table 12: Document Directory Contents

File Name	File Contents	Provided By
DOCINFO.TXT	A description of the contents of this directory	PDS node
VOLSIS.PDF	The Archive Volume SIS (this document) in PDF format	IOT
VOLSIS.LBL	A PDS detached label that describes VOLSIS.ASC, VOLSIS.HTM and VOLSIS.DOC.	PDS node
Other Documents	Additional documents describing data processing, calibration etc.	IOT
Other Document labels	Detached PDS labels for any additional documents	PDS node

5.4 CATALOG Directory Contents

The completed PDS catalog files in the catalog directory provide a top-level understanding of the Juno mission and its data products.

Each file in the catalog directory contains an individual PDS catalog object. These objects provide a top-level understanding of the Juno mission, the instrument and its data products. The data set catalog files will be provided by the instrument team, and the CATINFO.TXT by the PDS discipline node.

Table 13: Catalog Directory Contents

File Name	File Contents	Provided By
CATINFO.TXT	A description of the contents of this directory	PDS node
JNO_FGM_DS.CAT	PDS Data Set catalog description of appropriate to the data set	IOT
INSTHOST.CAT	PDS instrument host (spacecraft) catalog description of the Juno spacecraft	Juno Project
JNO_FGM_INST.CAT	PDS instrument catalog description of the instrument	IOT
MISSION.CAT	PDS mission catalog description of the Juno mission	Juno Project
JNO_FGM_PERSON.CAT	PDS personnel catalog description of instrument Team members and other persons involved with generation of Data Products	IOT
JNO_FGM_REF.CAT	Instrument-related references mentioned in other *.CAT files Additional bibliographic references, as appropriated	IOT
PROJREF.CAT	Juno related references mentioned in other *.CAT files.	Juno Project

5.5 DATA (Standard Products) Directory Contents and Naming Conventions

The data directory contains the actual data products produced by the instrument. The data directory will be divided into a subdirectory for each perijove pass, containing data for the entire orbit containing that perijove. The data directory will also have a subdirectory for cruise data divided into a subdirectory for each calendar year.

Every subdirectory beneath the data directory contains a file named INFO.TXT that is an ASCII text description of the directory contents. Every file in the data path of an Archive Volume must be described by a PDS label. All files (except ".TXT" which have embedded attached labels) will also have detached labels to comply with PDS requirements. These detached label files will contain the same information as the attached labels (headers) that precede the columns of data. These PDS detached label files will have the same root name as the file they describe with the suffix ".LBL".

5.5.1 DATA Directory Contents

The data directory contains a separate subdirectory for each orbit. The subdirectories will be named with the number of the perijove contained in the orbit. There may be more than one data file in each subdirectory, depending on what events take place in a given orbit. In addition to the data files, there will be a brief text file (INFO.TXT) that describes the directory contents.

Table 14: Data Directory Contents

File Name	File Contents	Provided By
INFO.TXT	Brief description of directory contents and naming conventions.	PDS node
README.TXT	Description of data	IOT
fgm_jno_LL_CCYYDDDse_vVV.sts	Cruise science data file in Spacecraft – Solar equator coordinate system	IOT
fgm_jno_LL_CCYYDDDse_r1s_vVV.sts	Cruise science data file in Spacecraft – Solar equator coordinate system resampled to 1 seconds	IOT
fgm_jno_LL_CCYYDDDse_r60s_vVV.sts	Cruise science data file in Spacecraft – Solar equator coordinate system resampled to 60 seconds	IOT
fgm_jno_LL_CCYYDDDse_r1h_CCYYDDD_vVV.sts	Cruise science data file in Spacecraft – Solar equator coordinate system resampled to 1 hour (one file for cruise time period – filename includes end date)	IOT
fgm_jno_LL_CCYYDDDpl_vVV.sts	Cruise, EFB, and orbital science data in Spacecraft payload coordinate system	IOT
fgm_jno_LL_CCYYDDDpl_r1s_vVV.sts	Cruise, EFB, and orbital science data in Spacecraft payload coordinate system resampled to 1 second	IOT
fgm_jno_LL_CCYYDDDpc_vVV.sts	Orbital science data in Planetocentric coordinate system	IOT
fgm_jno_LL_CCYYDDDpc_r1s_vVV.sts	Orbital science data in Planetocentric coordinate system resampled to 1 second	IOT
fgm_jno_LL_CCYYDDDpc_r60s_vVV.sts	Orbital science data in Planetocentric coordinate system resampled to 60 seconds	IOT
fgm_jno_LL_CCYYDDDss_vVV.sts	Orbital science data in Sun-state coordinate system	IOT
fgm_jno_LL_CCYYDDDss_r1s_vVV.sts	Orbital science data in Sun-state coordinate system resampled to 1 second	IOT
fgm_jno_LL_CCYYDDDss_r60s_vVV.sts	Orbital science data in Sun-state coordinate system resampled to 60 seconds	IOT

File Name	File Contents	Provided By
fgm_jno_LL_CCYYDDDse_vVV.lbl *fgm_jno_LL_CCYYDDDse_r1s_vVV.lbl* *fgm_jno_LL_CCYYDDDse_r60s_vVV.lbl* *fgm_jno_LL_CCYYDDDse_r1h_CCYYDDDvVV.lbl* *fgm_jno_LL_CCYYDDDpl_vVV.lbl* *fgm_jno_LL_CCYYDDDpl_r1s_vVV.lbl* *fgm_jno_LL_CCYYDDDpc_vVV.lbl* *fgm_jno_LL_CCYYDDDpc_r1s_vVV.lbl* *fgm_jno_LL_CCYYDDDpc_r60s_vVV.lbl* *fgm_jno_LL_CCYYDDDss_vVV.lbl* *fgm_jno_LL_CCYYDDDss_r1s_vVV.lbl* *fgm_jno_LL_CCYYDDDss_r60s_vVV.lbl*	PDS label for data files of same base name.	IOT

Table 15: Filename Convention Elements

Token	Description
fgm	Fluxgate Magnetometer three character instrument abbreviation
jno	Juno
LL	Data level, for example, 'l3' for level 3
CC	The century portion of a date, 19 or 20
YY	The year of century portion of a date, 00-99
DDD	The day of year, 001-366
 se se_rN[N]s se_r1h pc pc_rN[N]s ss ss_rN[N]s pl pl_rN[N]s	Coordinate system of data. SE (Solar equatorial) SE resampled number of seconds (1 or 60) SE resampled 1 hour PC (Planetocentric) PC resampled number of seconds (1 or 60) SS (Sun-State) SS resampled number of seconds (1 or 60) PL (Payload) PL resampled number of seconds (1 or 60)
v	separator to denote Version number
VV	version
sts	Standard Time Series (ASCII) file
lbl	Label file

Table 16: Filename Extensions

Extension	Description
ASC	Plain ASCII documentation file
CAT	Catalog object
CSV	Spreadsheet (comma-separated value)
DAT	Binary data, not otherwise specified
FMT	Include file for describing data objects, normally referred to by labels
GIF	GIF image
IMG	Image data
JPG	JPEG image data
LBL	Detached label
PDF	Portable document format data
PNG	Portable network graphics data
STS	Standard Time Series (ASCII)
TIF	Tagged Image File data
TXT	Plain text documents

Table 17: Instrument Mnemonic

Instrument Name	Mnemonic
Advanced Stellar Compass	ASC
Fluxgate Magnetometer	FGM
Gravity Science	GRV
Jovian Auroral plasma Distributions Experiment	JAD
Jupiter Energetic-Particle Detector Instrument	JED
Jovian Infrared Auroral Mapper	JIR
Juno EPO Camera	JNC
Microwave Radiometer	MWR
Ultraviolet Spectrometer	UVS
Radio and Plasma Waves Instrument	WAV

5.6 EXTRAS Directory Contents

The EXTRAS directory contains files that are helpful, but are not required to interpret the INSTRUMENT data. Files in the EXTRAS directory are exempt from labeling requirements. Subdirectories are used to organize the items into groups of related files.

After the end of the Juno mission, a STS format file detailing the 1 second 3 second spacecraft time stutters for the duration that FGM science data is available will be supplied.

6 Archive volume format

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 Volume format

The MAG team does not control the volume format to be used by the PDS.

6.2 File formats

The following section describes file formats for the kinds of files contained on archive volumes. For more information, see the *PDS Archive Preparation Guide* [see §1.9].

6.2.1 Document files

Document files with a TXT extension exist in nearly all directories. They are ASCII files with embedded PDS labels. 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 directory 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).

6.2.2 Tabular files

Tabular files (TAB extension) exist in the DATA and INDEX directories. Tabular files are ASCII files formatted for direct reading into database management systems on various computers. Columns are fixed length, separated by commas or white space, and character fields are enclosed in double quotation marks ("). Character fields are padded with spaces to keep quotation marks in the same columns of successive records. Character fields are left justified, and numeric fields are right justified. The “start byte” and “bytes” values listed in the labels do not include the commas between fields or the quotation marks surrounding character fields. The records are of fixed length, and the last two bytes of each record contain the ASCII carriage return and line feed characters. This line format allows a table to be treated as a fixed length record file on computers that support this file type and as a text file with embedded line delimiters on those that don't support it.

Detached PDS label files will be provided for all tabular files. A detached label file has the same name as the data file it describes, but with the extension LBL. For example, the file INDEX.TAB is accompanied by the detached label file INDEX.LBL in the same directory.

6.2.3 PDS labels

All data files in the MAG Standard Product Archive Collection have associated detached PDS [see the *Planetary Science Data Dictionary* and the *PDS Standards Reference* in §1.9]. These label files are named using the same prefix as the data file together with an `LBL` extension. 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.

A PDS label, whether embedded or detached from its associated file, provides descriptive information about the associated file. The PDS label is an object-oriented structure consisting of sets of keyword = value declarations. The object that the label refers to (*e.g.* IMAGE, TABLE, etc.) is denoted by a statement of the form:

```
^object = location
```

in which the carat character (^, also called a pointer in this context) indicates where to find the object. In a PDS label, the location denotes the name of the file containing the object, along with the starting record or byte number, if there is more than one object in the file. For example:

```
^HEADER = ("98118.TAB", 1)
^TABLE = ("98118.TAB", 1025 <BYTES>)
```

indicates that the HEADER object begins at record 1 and that the TABLE object begins at byte 1025 of the file 98118.TAB. The file 98118.TAB must be located in the same directory as the detached label file. Below is a list of the possible formats for the ^object definition in labels in this product.

```
^object     = n
^object     = n <BYTES>
^object     = "filename.ext"
^object     = ("filename.ext", n)
^object     = ("filename.ext", n <BYTES>)
```

where

- *n* is the starting record or byte number of the object, counting from the beginning of the file (record 1, byte 1),
- <BYTES> indicates that the number given is in units of bytes (the default is records),
- *filename* is the up-to-27-character, alphanumeric upper-case file name,
- *ext* is the up-to-3-character upper-case file extension,
- and all detached labels contain ASCII records that terminate with a carriage return followed by a line feed (13_{10}, 10_{10}). This allows the files to be read by most computer operating systems, e.g., UNIX, MacOS, MSWindows, etc.

Examples of PDS labels required for the MAG archive are shown in Appendix B.

6.2.4 Catalog files

Catalog files (extension CAT) exist in the Root and CATALOG directories. They are plain text files formatted in an object-oriented structure consisting of sets of "keyword = value" declarations.

6.2.5 Index files

The PDS team provides PDS index files. The format of these files is described in this SIS document for completeness.

A PDS index table contains a listing of all data products on an archive volume. When a data product is described by a detached PDS label, the index file points to the label file, which in turn points to the data file. When a data product is described by an attached PDS label, the index file points directly to the data product. A PDS index is an ASCII table composed of required columns and optional columns (user defined). When values are constant across an entire volume, it is permissible to promote the value out of the table and into the PDS label for the index table.

To facilitate users' searches of the MAG data submission, a few optional columns will be included in the index table. In particular, the file start and stop times will be included. Table 16 contains a description of the MAG archive volume index files. Index files are by definition fixed length ASCII files containing comma-delimited fields. Character strings are quoted using double quotes, and left justified in their field, followed where necessary by trailing blanks. The "Start Byte" column gives the location of the first byte (counting from 1) of the column within the file, skipping over delimiters and quotation marks.

Table 18: Format of index files

Column Name	Start Byte	Bytes	Description
DATA_SET_ID			The PDS ID of the data set of which this file is a member.
FILE_SPECIFICATION_NAME			The full specification name of the PDS label file (including the file name and the path) that describes the product, relative to the root of the archive volume.
PRODUCT_ID			
STANDARD_DATA_PRODUCT_ID			The "type" of the data file - SE, PL, PC, or SS.
PRODUCT_CREATION_TIME			Creation time of the PDS labeled data product.
START_TIME			Coordinated Universal Time (UTC) of the first record in the data file.
STOP_TIME			Time (UTC) of the last record in the data file.

6.2.6 NASA Level 1B/CODMAC Level 3 data files

A MAG product is organized as a table of ASCII data for a single day or fraction of day from a single orbit. Preceding the tabular data is a text header that describes the file contents and processing parameters. Each data record contains two (2) UTC time stamps using different date/time representations, a magnetic field vector, the instrument gain (range). The products that are not in payload coordinates also contain the spacecraft position vector at the sample time.

Table 19: Format of NASA Level 1B/CODMAC Level 3 cruise science data file records

Byte	Length (bytes)	Name	Fmt*	Units	Description
2	4	Year	I4		Year
7	3	DOY	I3		Day of year
11	2	Hour	I2	Hours	Hours
14	2	Min	I2	Minutes	Minutes
17	2	Sec	I2	Seconds	Seconds
20	3	Msec	I3	Milliseconds	Milliseconds
24	13	DDAY	F13.9	Day	Decimal Day
38	12	OB_B_X or IB_B_X	F12.2	Nanotesla (nT)	Outboard or Inboard magnetic field X per file's coordinate system
51	12	OB_B_Y or IB_B_Y	F12.2	nT	Outboard or Inboard magnetic field Y per file's coordinate system
64	12	OB_B_Z or IB_B_Z	F12.2	nT	Outboard or Inboard magnetic field Z per file's coordinate system
77	3	OB_B_range or IB_B_range	F3.0	N/A	Outboard or Inboard magnetic field range
81	14	POSN_X	F14.3	Kilometers (km)	Spacecraft position X
96	14	POSN_Y	F14.3	Km	Spacecraft position Y
111	14	POSN_Z	F14.3	Km	Spacecraft position Z

Appendix A Support staff and cognizant persons

Table 20a: 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/Space Research Corporation 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/ADNET Systems Inc. Greenbelt, MD 20771	301-286-1788	Pat.Lawton@nasa.gov

Table 20b: 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 PDS label files - Cruise

All MAG instrument data files are accompanied by PDS label files, possessing the same names are the files they describe, but with the extension LBL. The basic content for these label files is as follows:

```
PDS_VERSION_ID                  = PDS3
RECORD_TYPE                     = STREAM
DATA_SET_ID                     = "JNO-SS-3-FGM-CAL-V1.0"
TARGET_NAME                     = "SOLAR SYSTEM"
MISSION_PHASE_NAME              = "OUTER CRUISE"
ORBIT_NUMBER                    = "N/A"
SPACECRAFT_NAME                 = "JUNO"
START_TIME                      = 2014-040T00:00:01.151
STOP_TIME                       = 2014-041T00:00:00.981
SPACECRAFT_CLOCK_START_COUNT    = "UNK"
SPACECRAFT_CLOCK_STOP_COUNT     = "UNK"
INSTRUMENT_ID                   = FGM
INSTRUMENT_NAME                 = MAGNETOMETER
^HEADER                         = ("fgm_jno_l3_2014040pl_v01.sts", 1<BYTES>)
^TABLE  = ("fgm_jno_l3_2014040pl_v01.sts", 28024<BYTES>)
PRODUCT_ID                      = "FGM_JNO_L3_2014040PL"
ORIGINAL_PRODUCT_ID             = "fgm_jno_l3_2014040pl_v01.sts"
STANDARD_DATA_PRODUCT_ID        = "PAYLOAD"
PRODUCT_VERSION_ID              = "01"
PRODUCT_CREATION_TIME           = 2016-11-02T14:02:49
MD5_CHECKSUM                    = "8461e6207e9083f759f044102f0c54f9"
PROCESSING_LEVEL_ID             = "3"
FILE_RECORDS                    = 1382752

DESCRIPTION                     = "
This file contains vector magnetic field data acquired by the
Fluxgate Magnetometer instrument aboard the Juno 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.
"

/* Processing Information */

SPICE_FILE_NAME                 = {
               "juno_rec_140101_141107_161031a.tm",
               "mission_juno.ker",
               "sc_mod.ker",
               "juno_mags_20131008.ker",
               "naif0012.tls",
               "pck00010.tpc",
               "JNO_SCLKSCET.00047.tsc",
               "juno_v09.tf",
               "de434s.bsp",
               "jup310.bsp",
               "juno_struct_v02.bsp",
               "spk_rec_131114_140918_141208.bsp",
               "spk_rec_140903_151003_160118.bsp",
               "juno_chud_rec_131230_140105_v01.bc",
               "juno_chud_rec_140106_140112_v01.bc",
               "juno_chud_rec_140113_140119_v01.bc",
               "juno_chud_rec_140120_140126_v01.bc",
               "juno_chud_rec_140127_140202_v01.bc",
               "juno_chud_rec_140203_140209_v01.bc",
               "juno_chud_rec_140210_140216_v01.bc",
               "juno_chud_rec_140217_140223_v01.bc",
               "juno_chud_rec_140224_140302_v01.bc",
               "juno_chud_rec_140303_140309_v01.bc",
```

```
"juno_chud_rec_140310_140316_v01.bc",
"juno_chud_rec_140331_140406_v01.bc",
"juno_chud_rec_140407_140413_v01.bc",
"juno_chud_rec_140414_140420_v01.bc",
"juno_chud_rec_140421_140427_v01.bc",
"juno_chud_rec_140428_140504_v01.bc",
"juno_chud_rec_140505_140511_v01.bc",
"juno_chud_rec_140512_140518_v01.bc",
"juno_chud_rec_140519_140525_v01.bc",
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NOTE                            = "
This note contain further information about the processing of the
data, as provided by the MAG Team.  Please see the SPICE_FILE_NAME
keyword above for the names of the SPICE kernels used.
```

```
  PROGRAM   =  jan
  CMD_LINE  =  -odl -dz time dday ob_bpl

                    *** END OF NOTE ***
"
OBJECT                          = HEADER
 BYTES                           = 28023
 HEADER_TYPE                     = TEXT
END_OBJECT                      = HEADER

/* Data Structure Description Information */

OBJECT                          = TABLE
  NAME                          = "MAG DATA"
  INTERCHANGE_FORMAT            = ASCII
  ROWS                          = 1382400
  ROW_BYTES                     = 83
  COLUMNS                       = 6
  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
  dynamic range identifiers."

  OBJECT                        = COLUMN
    NAME                         = "SAMPLE UTC"
    COLUMN_NUMBER                = 1
    DATA_TYPE                    = CHARACTER
    PPI:TIME_FORMAT              = "%YEAR% %DOY% %HR% %MIN% %SEC% %MSEC%"
    START_BYTE                   = 3
    BYTES                        = 21
    UNIT                         = "N/A"
    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"
  END_OBJECT                    = COLUMN

  OBJECT                        = COLUMN
    NAME                         = "DECIMAL DAY"
    COLUMN_NUMBER                = 2
    DATA_TYPE                    = "ASCII_REAL"
    FORMAT                       = "F13.9"
    START_BYTE                   = 25
    BYTES                        = 13
    UNIT                         = "N/A"
    DESCRIPTION                  = "
Decimal day of year.  This column provides a second representation of
the sample time."
  END_OBJECT                    = COLUMN

  OBJECT                        = COLUMN
    NAME                         = "BX PAYLOAD"
    COLUMN_NUMBER                = 3
    DATA_TYPE                    = "ASCII_REAL"
    FORMAT                       = "F12.2"
    START_BYTE                   = 40
    BYTES                        = 12
    UNIT                         = "NT"
    DESCRIPTION                  = "
B-field X-component in spacecraft Payload coordinate system."
  END_OBJECT                    = COLUMN
```

```
  OBJECT                          = COLUMN
    NAME                           = "BY PAYLOAD"
    COLUMN_NUMBER                  = 4
    DATA_TYPE                      = "ASCII_REAL"
    FORMAT                         = "F12.2"
    START_BYTE                     = 53
    BYTES                          = 12
    UNIT                           = "NT"
    DESCRIPTION                    = "
B-field Y-component in spacecraft Payload coordinate system."
  END_OBJECT                      = COLUMN

  OBJECT                          = COLUMN
    NAME                           = "BZ PAYLOAD"
    COLUMN_NUMBER                  = 5
    DATA_TYPE                      = "ASCII_REAL"
    FORMAT                         = "F12.2"
    START_BYTE                     = 66
    BYTES                          = 12
    UNIT                           = "NT"
    DESCRIPTION                    = "
B-field z-component in spacecraft Payload coordinate system."
  END_OBJECT                      = COLUMN

  OBJECT                          = COLUMN
    NAME                           = "INSTRUMENT RANGE"
    COLUMN_NUMBER                  = 6
    DATA_TYPE                      = "ASCII_REAL"
    FORMAT                         = "F3.0"
    START_BYTE                     = 79
    BYTES                          = 3
    UNIT                           = "N/A"
    DESCRIPTION                    = "
Instrument dynamic range identifier at time of the sample.
Pertains to B components."
  END_OBJECT                      = COLUMN

END_OBJECT                        = TABLE

END
```

Appendix C NASA Level 1B/CODMAC Level 3 data samples - Cruise

This section is a sample of a payload Standard Time Series file.

```
OBJECT      =  FILE
OBJECT   =  HEADER
  PROGRAM   =  jan

  CMD_LINE  =  -odl -dz time dday ob_bpl
  DATE      =  Wed Nov  2 14:02:49 2016
  HOST      =  gauss.gsfc.nasa.gov
  COMMENT   =  This version jan compiled with gfortran (gcc version 4.4.7
               and spicelib  (GENERIC_TOOLKIT V.N0065) on Oct 20, 2014 by
               P. Lawton (ADNET at NASA/GSFC).
  TITLE     =  JUNO MAG
OBJECT      =  KERNEL_LIST
  META       21015  Mon Oct 31 13:39:12 2016  juno_rec_140101_141107_161031a.tm
  TEXT        3720  Sat Jul  2 12:14:43 2011  mission_juno.ker
  TEXT        6331  Mon Jun 12 09:24:29 2000  sc_mod.ker
  TEXT       10917  Tue Oct  8 20:17:52 2013  juno_mags_20131008.ker
  TEXT        5257  Fri Jul 22 04:21:25 2016  naif0012.tls
  TEXT      126143  Fri Apr 10 16:23:14 2015  pck00010.tpc
  TEXT       15530  Mon Oct 31 10:58:04 2016  JNO_SCLKSCET.00047.tsc
  TEXT      149242  Tue Oct 18 12:32:12 2016  juno_v09.tf
  SPK     21807104  Wed Feb 24 04:21:18 2016  de434s.bsp
  SPK    976620544  Fri Mar  6 04:21:43 2015  jup310.bsp
  SPK        10240  Sat Oct 11 04:21:05 2014  juno_struct_v02.bsp
  SPK      1468416  Tue Dec 16 04:21:07 2014  spk_rec_131114_140918_141208.bsp
  SPK      1129472  Tue Jan 19 04:21:07 2016  spk_rec_140903_151003_160118.bsp
  CK      12016640  Wed Jan 15 04:21:35 2014  juno_chud_rec_131230_140105_v01.bc
  CK      12092416  Wed Jan 22 04:21:30 2014  juno_chud_rec_140106_140112_v01.bc
  CK      11906048  Wed Jan 29 04:21:43 2014  juno_chud_rec_140113_140119_v01.bc
  CK      11962368  Wed Feb  5 04:21:31 2014  juno_chud_rec_140120_140126_v01.bc
  CK      12343296  Wed Feb 12 04:21:33 2014  juno_chud_rec_140127_140202_v01.bc
  CK      18768896  Wed Feb 19 04:21:35 2014  juno_chud_rec_140203_140209_v01.bc
  CK      12942336  Wed Feb 26 04:21:39 2014  juno_chud_rec_140210_140216_v01.bc
  CK      12579840  Wed Mar  5 04:22:38 2014  juno_chud_rec_140217_140223_v01.bc
  CK      12942336  Wed Mar 12 04:21:43 2014  juno_chud_rec_140224_140302_v01.bc
  CK      12942336  Wed Mar 19 04:21:32 2014  juno_chud_rec_140303_140309_v01.bc
  CK       6843392  Wed Mar 26 04:20:28 2014  juno_chud_rec_140310_140316_v01.bc
  CK       8704000  Wed Apr 16 04:21:27 2014  juno_chud_rec_140331_140406_v01.bc
  CK      12942336  Wed Apr 23 04:21:21 2014  juno_chud_rec_140407_140413_v01.bc
  CK      16218112  Thu May  1 11:32:33 2014  juno_chud_rec_140414_140420_v01.bc
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  CK       5553152  Wed May 28 04:21:21 2014  juno_chud_rec_140512_140518_v01.bc
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  CK       5553152  Wed Jun 11 04:21:20 2014  juno_chud_rec_140526_140601_v01.bc
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  CK       5553152  Wed Jun 25 04:21:17 2014  juno_chud_rec_140609_140615_v01.bc
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  CK       5553152  Wed Jul  9 04:21:21 2014  juno_chud_rec_140623_140629_v01.bc
  CK       5553152  Wed Jul 16 04:21:18 2014  juno_chud_rec_140630_140706_v01.bc
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  CK       4689920  Wed Sep 10 04:21:18 2014  juno_chud_rec_140825_140831_v01.bc
  CK       2164736  Wed Sep 17 04:21:19 2014  juno_chud_rec_140901_140907_v01.bc
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  CK        500736  Wed Oct 22 04:21:15 2014  juno_chud_rec_141006_141012_v01.bc
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CK        5553152  Wed Jul 16 04:21:16 2014  juno_chuc_rec_140630_140706_v01.bc
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CK        3276800  Wed Aug 20 04:21:18 2014  juno_chuc_rec_140804_140810_v01.bc
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CK        5553152  Wed Sep  3 04:21:20 2014  juno_chuc_rec_140818_140824_v01.bc
CK        4689920  Wed Sep 10 04:21:16 2014  juno_chuc_rec_140825_140831_v01.bc
CK        2164736  Wed Sep 17 04:21:16 2014  juno_chuc_rec_140901_140907_v01.bc
CK          89088  Wed Sep 24 04:21:11 2014  juno_chuc_rec_140908_140914_v01.bc
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CK	5553152	Wed Sep 3 04:21:17 2014	juno_chub_rec_140818_140824_v01.bc
CK	4689920	Wed Sep 10 04:21:14 2014	juno_chub_rec_140825_140831_v01.bc
CK	2164736	Wed Sep 17 04:21:12 2014	juno_chub_rec_140901_140907_v01.bc
CK	89088	Wed Sep 24 04:21:10 2014	juno_chub_rec_140908_140914_v01.bc
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CK	5553152	Wed Jun 18 04:21:10 2014	juno_chua_rec_140602_140608_v01.bc
CK	5553152	Wed Jun 25 04:21:10 2014	juno_chua_rec_140609_140615_v01.bc
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CK	5553152	Wed Sep 3 04:21:15 2014	juno_chua_rec_140818_140824_v01.bc
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CK	89088	Wed Sep 24 04:21:09 2014	juno_chua_rec_140908_140914_v01.bc
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CK	12939264	Wed Feb 12 04:21:42 2014	juno_mobob_rec_140127_140202_v01.bc
CK	19699712	Wed Feb 19 04:21:45 2014	juno_mobob_rec_140203_140209_v01.bc
CK	12912640	Wed Feb 26 04:21:50 2014	juno_mobob_rec_140210_140216_v01.bc
CK	12508160	Wed Mar 5 04:23:00 2014	juno_mobob_rec_140217_140223_v01.bc
CK	12733440	Wed Mar 12 04:21:52 2014	juno_mobob_rec_140224_140302_v01.bc
CK	12572672	Wed Mar 19 04:21:45 2014	juno_mobob_rec_140303_140309_v01.bc
CK	6553600	Wed Mar 26 04:20:45 2014	juno_mobob_rec_140310_140316_v01.bc
CK	7763968	Wed Apr 16 04:21:32 2014	juno_mobob_rec_140331_140406_v01.bc
CK	12510208	Wed Apr 23 04:21:28 2014	juno_mobob_rec_140407_140413_v01.bc
CK	15373312	Thu May 1 11:32:40 2014	juno_mobob_rec_140414_140420_v01.bc
CK	11808768	Wed May 7 04:23:04 2014	juno_mobob_rec_140421_140427_v01.bc
CK	11045888	Wed May 14 04:21:50 2014	juno_mobob_rec_140428_140504_v01.bc
CK	12596224	Wed May 21 04:22:05 2014	juno_mobob_rec_140505_140511_v01.bc
CK	5552128	Wed May 28 04:21:29 2014	juno_mobob_rec_140512_140518_v01.bc
CK	5490688	Wed Jun 4 04:21:32 2014	juno_mobob_rec_140519_140525_v01.bc
CK	5486592	Wed Jun 11 04:21:24 2014	juno_mobob_rec_140526_140601_v01.bc
CK	5453824	Wed Jun 18 04:21:23 2014	juno_mobob_rec_140602_140608_v01.bc
CK	5472256	Wed Jun 25 04:21:22 2014	juno_mobob_rec_140609_140615_v01.bc
CK	5553152	Wed Jul 2 04:21:25 2014	juno_mobob_rec_140616_140622_v01.bc
CK	5548032	Wed Jul 9 04:21:29 2014	juno_mobob_rec_140623_140629_v01.bc
CK	5544960	Wed Jul 16 04:21:24 2014	juno_mobob_rec_140630_140706_v01.bc
CK	3817472	Wed Jul 23 04:21:21 2014	juno_mobob_rec_140707_140713_v01.bc
CK	5551104	Mon Aug 11 04:21:23 2014	juno_mobob_rec_140714_140720_v01.bc
CK	4333568	Wed Aug 6 04:21:26 2014	juno_mobob_rec_140721_140727_v01.bc
CK	5536768	Wed Aug 13 04:21:22 2014	juno_mobob_rec_140728_140803_v01.bc
CK	3265536	Wed Aug 20 04:21:25 2014	juno_mobob_rec_140804_140810_v01.bc
CK	5545984	Tue Sep 2 04:21:24 2014	juno_mobob_rec_140811_140817_v01.bc
CK	5551104	Wed Sep 3 04:21:31 2014	juno_mobob_rec_140818_140824_v01.bc
CK	4690944	Wed Sep 10 04:21:23 2014	juno_mobob_rec_140825_140831_v01.bc
CK	2172928	Wed Sep 17 04:21:27 2014	juno_mobob_rec_140901_140907_v01.bc
CK	90112	Wed Sep 24 04:21:13 2014	juno_mobob_rec_140908_140914_v01.bc
CK	3544064	Wed Oct 1 04:21:21 2014	juno_mobob_rec_140915_140921_v01.bc
CK	3559424	Wed Oct 8 04:21:28 2014	juno_mobob_rec_140922_140928_v01.bc
CK	3568640	Wed Oct 15 04:21:22 2014	juno_mobob_rec_140929_141005_v01.bc
CK	502784	Wed Oct 22 04:21:18 2014	juno_mobob_rec_141006_141012_v01.bc
CK	3574784	Wed Oct 29 04:21:21 2014	juno_mobob_rec_141013_141019_v01.bc
CK	4419584	Wed Nov 5 04:21:27 2014	juno_mobob_rec_141020_141026_v01.bc
CK	5550080	Wed Nov 12 04:21:28 2014	juno_mobob_rec_141027_141102_v01.bc

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  CK      15042560  Wed Nov 19 04:22:10 2014  juno_mobob_rec_141103_141109_v01.bc
  CK       5374976  Wed Nov 26 04:21:24 2014  juno_mobob_rec_141110_141116_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,F12.2
    UNITS  =  NT
  END_OBJECT
  OBJECT   =  SCALAR
    NAME   =  Y
    FORMAT =  1X,F12.2
    UNITS  =  NT
  END_OBJECT
  OBJECT   =  SCALAR
    NAME   =  Z
    FORMAT =  1X,F12.2
    UNITS  =  NT
  END_OBJECT
  OBJECT   =  SCALAR
    NAME   =  RANGE
    FORMAT =  1X,F3.0
  END_OBJECT
END_OBJECT
END_OBJECT
END_OBJECT
  2014  40  0  0  1 151  40.000013322          1.23         3.80        -3.04  0.
  2014  40  0  0  1 213  40.000014039          1.33         3.85        -2.94  0.
  2014  40  0  0  1 276  40.000014769          1.33         3.85        -2.99  0.
  2014  40  0  0  1 338  40.000015486          1.28         3.85        -2.99  0.
  2014  40  0  0  1 401  40.000016215          1.38         3.80        -3.04  0.
  2014  40  0  0  1 463  40.000016933          1.52         3.85        -2.99  0.
  2014  40  0  0  1 526  40.000017662          1.57         3.85        -3.04  0.
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2014	40	0	0	1	588	40.000018380	1.52	3.80	-2.99	0.
2014	40	0	0	1	651	40.000019109	1.62	3.70	-2.99	0.
2014	40	0	0	1	713	40.000019826	1.62	3.70	-2.99	0.
2014	40	0	0	1	776	40.000020556	1.62	3.70	-2.99	0.
2014	40	0	0	1	838	40.000021273	1.67	3.66	-2.99	0.
2014	40	0	0	1	901	40.000022002	1.67	3.61	-2.99	0.
2014	40	0	0	1	963	40.000022720	1.72	3.61	-3.03	0.
2014	40	0	0	2	26	40.000023449	1.67	3.56	-3.03	0.
2014	40	0	0	2	88	40.000024167	1.72	3.61	-2.98	0.
2014	40	0	0	2	151	40.000024896	1.72	3.61	-2.98	0.
2014	40	0	0	2	213	40.000025613	1.82	3.61	-2.98	0.
2014	40	0	0	2	276	40.000026343	1.77	3.61	-3.03	0.
2014	40	0	0	2	338	40.000027060	1.82	3.61	-3.03	0.
2014	40	0	0	2	401	40.000027789	1.86	3.56	-2.98	0.
2014	40	0	0	2	463	40.000028507	1.91	3.56	-2.98	0.
2014	40	0	0	2	526	40.000029236	1.96	3.61	-3.03	0.
2014	40	0	0	2	588	40.000029954	2.01	3.56	-3.03	0.
2014	40	0	0	2	651	40.000030683	2.11	3.61	-2.98	0.
2014	40	0	0	2	713	40.000031400	1.96	3.51	-3.03	0.
2014	40	0	0	2	776	40.000032130	2.06	3.46	-2.98	0.
2014	40	0	0	2	838	40.000032847	2.06	3.51	-2.98	0.
2014	40	0	0	2	901	40.000033576	2.16	3.46	-2.98	0.
2014	40	0	0	2	963	40.000034294	2.11	3.46	-3.03	0.
2014	40	0	0	3	26	40.000035023	2.16	3.46	-2.98	0.
2014	40	0	0	3	88	40.000035741	2.06	3.46	-2.98	0.
2014	40	0	0	3	151	40.000036470	2.16	3.46	-2.98	0.
2014	40	0	0	3	213	40.000037187	2.16	3.41	-3.03	0.
2014	40	0	0	3	276	40.000037917	2.16	3.41	-2.98	0.
2014	40	0	0	3	338	40.000038634	2.21	3.41	-3.07	0.
2014	40	0	0	3	401	40.000039363	2.26	3.46	-3.07	0.
2014	40	0	0	3	463	40.000040081	2.26	3.36	-3.02	0.