Mars Atmosphere and Volatile Evolution (MAVEN) Mission

ACC

PDS Archive

Software Interface Specification

Rev. 1.2

January 30, 2016

Prepared by

Rich Zurek, Robert Tolson, Darren Baird

richard.w.zurek@jpl.nasa.gov, rhtolson@nianet.org, darren.t.baird@nasa.gov

MAVEN

ACC

PDS Archive

Software Interface Specification

Rev. 1.2

January 30, 2016

Custodian:

Feb. 23, 2016

Robert Tolson — Date

ACC Archivist

Approved:

______________________________ __________

Richard Zurek — Date

ACC Principal Investigator

______________________________ __________

Alex DeWolfe — Date

Science Data Center Lead (LASP)

David Mitchell | Date
Chair of the SDWG

Reta Beebe | Date
PDS Atmospheres Node Manager

Tom Morgan | Date
PDS Project Manager (GSFC)

Contents

List of Figures

List of Tables

1 Introduction

This software interface specification (SIS) describes the format and content of the Accelerometer Science (ACC) Planetary Data System (PDS) data archive. It includes descriptions of the data products and associated metadata, and the archive format, content, and generation pipeline.

1.1 Distribution List

Table 1: Distribution list

Name	Organization	Email
Alexandria DeWolfe	LASP/SDC	alex.dewolfe@lasp.colorado.edu
Steve Joy	UCLA/PDS/PPI	sjoy@igpp.ucla.edu
Ray Walker	UCLA/PDS/PPI	rwalker@igpp.ucla.edu
Joe Mafi	UCLA/PDS/PPI	jmafi@igpp.ucla.edu
Reta Beebe	NMSU/PDS/Atmospheres	rbeebe@nmsu.edu
Lyle Huber	NMSU/PDS/Atmospheres	lhuber@nmsu.edu
Lynn Neakrase	NMSU/PDS/Atmospheres	lneakras@nmsu.edu

1.2 Document Change Log

Table 2: Document change log

Version	Change	Date	Affected portion
0.0	Draft	2013-Mar-20	All
1.0			Added abbreviations peculiar to ACC; minor technical changes to Chapter 2; Major changes in data structures and content. Orbit numbers range increased to 99999 orbits to accommodate extended mission.

1.3 TBD Items

Table 3 lists items that are not yet finalized.

Table 3: List of TBD items

Item	Section(s)	Page(s)

1.4 Abbreviations

Table 4: Abbreviations and their meanings

Abbreviation	Meaning
ACC	Accelerometer science instrument
ASCII	American Standard Code for Information Interchange
Atmos	PDS Atmospheres Node (NMSU, Las Cruces, NM)
CCSDS	Consultative Committee for Space Data Systems
CDR	Calibrated Data Record
CFDP	CCSDS File Delivery Protocol
CK	C-matrix Kernel (NAIF orientation data)
CODMAC	Committee on Data Management, Archiving, and Computing
COM	Center of mass of spacecraft
CRC	Cyclic Redundancy Check
CU	University of Colorado (Boulder, CO)
DAP	Data Analysis Product
DDR	Derived Data Record
DMAS	Data Management and Storage
DPF	Data Processing Facility
E&PO	Education and Public Outreach
EDR	Experiment Data Record
EU	Engineering units
EUV	Extreme Ultraviolet; also used for the EUV Monitor, part of LPW (SSL)
FEI	File Exchange Interface
FOV	Field of View
FTP	File Transfer Protocol
GB	Gigabyte(s)
GSFC	Goddard Space Flight Center (Greenbelt, MD)
HK	Housekeeping

Abbreviation	Meaning
HTML	Hypertext Markup Language
ICD	Interface Control Document
IM	Information Model
IMU	Inertial Measure Unit – Accelerometers and Rate Gyros
ISO	International Standards Organization
ITF	Instrument Team Facility
IUVS	Imaging Ultraviolet Spectrograph (LASP)
JPL	Jet Propulsion Laboratory (Pasadena, CA)
LASP	Laboratory for Atmosphere and Space Physics (CU)
LID	Logical Identifier
LIDVID	Versioned Logical Identifier
LPW	Langmuir Probe and Waves instrument (SSL)
MAG	Magnetometer instrument (GSFC)
MAVEN	Mars Atmosphere and Volatile EvolutioN
MB	Megabyte(s)
MD5	Message-Digest Algorithm 5
MOI	Mars Orbit Insertion
MOS	Mission Operations System
MSA	Mission Support Area
NAIF	Navigation and Ancillary Information Facility (JPL)
NASA	National Aeronautics and Space Administration
NGIMS	Neutral Gas and Ion Mass Spectrometer (GSFC)
NMSU	New Mexico State University (Las Cruces, NM)
NSSDC	National Space Science Data Center (GSFC)
PCK	Planetary Constants Kernel (NAIF)
PDS	Planetary Data System
PDS4	Planetary Data System Version 4
PF	Particles and Fields (instruments)
PPI	PDS Planetary Plasma Interactions Node (UCLA)
RS	Remote Sensing (instruments)

Abbreviation	Meaning
SCET	Spacecraft Event Time
SDC	Science Data Center (LASP)
SCLK	Spacecraft Clock
SEP	Solar Energetic Particle instrument (SSL)
SIS	Software Interface Specification
SOC	Science Operations Center (LASP)
SPE	Solar Particle Event
SPICE	Spacecraft, Planet, Instrument, C-matrix, and Events (NAIF data format)
SPK	Spacecraft and Planetary ephemeris Kernel (NAIF)
SSL	Space Sciences Laboratory (UCB)
STATIC	Supra-Thermal And Thermal Ion Composition instrument (SSL)
SWEA	Solar Wind Electron Analyzer (SSL)
SWIA	Solar Wind Ion Analyzer (SSL)
TBC	To Be Confirmed
TBD	To Be Determined
UCB	University of California, Berkeley
UCLA	University of California, Los Angeles
URN	Uniform Resource Name
UV	Ultraviolet
XML	eXtensible Markup Language

1.5 Glossary

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

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

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

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

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

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

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

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

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

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

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

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

Manifest - A list of contents.

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

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

Object – A single instance of a class defined in the PDS Information Model.

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

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

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

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

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

XML – eXtensible Markup Language.

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

1.6 MAVEN Mission Overview

The MAVEN mission launched on an Atlas V on November 18, 2013. After a ten-month ballistic cruise phase, Mars orbit insertion will occurred on September 21, 2014. Following a 2-month transition phase, the spacecraft orbits Mars at a 75° inclination, with a 4.5 hour period and periapsis altitude of 140-170 km (density corridor of 0.05-0.15 kg/km^3). Over a one-Earth-year period, periapsis will precess over a wide range of latitude and local time, while MAVEN obtains detailed measurements of the upper atmosphere, ionosphere, planetary corona, solar wind, interplanetary/Mars magnetic fields, solar EUV and solar energetic particles, thus defining the interactions between the Sun and Mars. MAVEN will explore down to the homopause during a series of five 5-day “deep dip” campaigns for which periapsis will be lowered to an atmospheric density of near 2 kg/km^3 (~125 km altitude) in order to sample the transition from the collisional lower atmosphere to the collisionless upper atmosphere. These five campaigns will be interspersed though the mission to sample the subsolar region, the dawn and dusk terminators, the anti-solar region, and the North Pole. Final scheduling will be done during flight operations to accommodate changes in mission profile and s/c situation.

1.6.1 Mission Objectives

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

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

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

1.6.2 Payload

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

- NGIMS Package:
    - Neutral Gas and Ion Mass Spectrometer (NGIMS) measures the composition, isotope ratios, and scale heights of thermal ions and neutrals.

- Remote Sensing Package:
    - Imaging Ultraviolet Spectrograph (IUVS) remotely measures UV spectra in four modes: limb scans, planetary mapping, coronal mapping and stellar occultations. These measurements provide the global composition, isotope ratios, and structure of the upper atmosphere, ionosphere, and corona.

- Particles and Fields Package:
    - Supra-Thermal and Thermal Ion Composition (STATIC) instrument measures the velocity distributions and mass composition of thermal and suprathermal ions from below escape energy to pickup ion energies.
    - Solar Energetic Particle (SEP) instrument measures the energy spectrum and angular distribution of solar energetic electrons (30 keV – 1 MeV) and ions (30 keV – 12 MeV).
    - Solar Wind Ion Analyzer (SWIA) measures solar wind and magnetosheath ion density, temperature, and bulk flow velocity. These measurements are used to determine the charge exchange rate and the solar wind dynamic pressure.
    - Solar Wind Electron Analyzer (SWEA) measures energy and angular distributions of 5 eV to 5 keV solar wind, magnetosheath, and auroral electrons,

as well as ionospheric photoelectrons. These measurements are used to constrain the plasma environment, magnetic field topology and electron impact ionization rate.

- Langmuir Probe and Waves (LPW) instrument measures the electron density and temperature and electric field in the Mars environment. The instrument includes an EUV Monitor that measures the EUV input into Mars atmosphere in three broadband energy channels.
- Magnetometer (MAG) measures the vector magnetic field in all regions traversed by MAVEN in its orbit.

In addition, engineering data will be used by the ACC team to reconstruct atmospheric density during Deep Dip campaigns and, to the extent possible, during science orbits.

1.7 SIS Content Overview

Section 2 describes the Accelerometer Science (ACC) instrument. Section 3 gives an overview of data organization and data flow. Section 4 describes data archive generation, delivery, and validation. Section 5 describes the archive structure and archive production responsibilities. Section 6 describes the file formats used in the archive, including the data product record structures. Individuals involved with generating the archive volumes are listed in Appendix A. Appendix B contains a description of the MAVEN science data file naming conventions. Appendix C, Appendix D, and Appendix E contain sample PDS product labels. Xxx describes ACC archive product PDS deliveries formats and conventions.

1.8 Scope of this Document

The specifications in this SIS apply to all ACC products submitted for archive to the Planetary Data System (PDS), for all phases of the MAVEN mission. This document includes descriptions of archive products that are produced by both the ACC team and by PDS.

1.9 Applicable Documents

[1] Planetary Data System Data Provider's Handbook.

[2] Planetary Data System Standards Reference.

[3] Planetary Science Data Dictionary Document.

[4] Planetary Data System (PDS) PDS4 Information Model Specification, Version 1.1.0.1.

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

[6] Mars Atmosphere and Volatile Evolution (MAVEN) Mission ANCILLARY DATA, PDS Archive Software Interface Specification, Rev. 1.2, March 16, 2015.

1.10 Audience

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

2 ACC Instrument Description

An accelerometer is an instrument that measures the acceleration of the case of the sensor due to external forces. Accelerometers have a 'proof mass' and it is the tendency of the proof mass to move relative to the case that is a measure of the acceleration of the case. Early accelerometers produced output that was directly related to acceleration; but modern sensors integrate the internally measured signal, to reduce noise, and the output is proportional to the change in velocity over the integration time. In high precision accelerometers, like those on MAVEN, the proof mass is an electronically floating body. The electromagnetic field is varied to keep the proof mass stationary relative to the case. The voltage required to accomplish this is proportional to the acceleration. The accelerometers on MAVEN are sensitive to acceleration of the center of mass (COM) of the spacecraft (s/c), pseudo-accelerations (i.e. centrifugal) due to rigid motion of the s/c about the COM, and differences in gravitational force at the proof mass and the COM of the s/c (gravity gradient).

2.1 Science Objectives

During the Deep Dip campaigns, when periapsis altitude is around 125 km and density as around 3 kg/km^3, the accelerometer, rate gyro and reaction wheel data will be used to determine atmospheric density along the orbit in the vicinity of periapsis. Density will be recovered once per second. Density vs. altitude profiles will be interpreted in terms of density scale height from which local atmospheric temperature will be inferred. When appropriate, along track density and/or temperature gradients will be derived. Small spatial scale deviations in density from hydrostatic equilibrium, perhaps due to gravity waves, will be identified and characterized in terms of along track and altitudinal variations. Longitudinal variations in density and temperature, due to orbit-to-orbit periapsis longitude changes, will be used to identify and quantify longitudinal waves. Under appropriate orbit and spacecraft conditions, the cross track component of atmospheric winds can be derived from the Inertial Mass Unit (IMU) gyro data. When these conditions are satisfied, the ACC team will attempt to derive such winds. Comparisons of all derived quantities will be made with thermospheric GCM results and relevant NGIMS and RS results generated by other MAVEN team members.

During the nominal science orbit, when periapsis altitude is near 160 km and density is around 0.1 kg/km^3, both accelerometer and reaction wheel data provide likely data sources for determining atmospheric density. As above, the ability to recover density depends strongly on orbit and spacecraft conditions. The temporal and spatial resolution will be lower than during the Deep Dips because the data will likely have to be averaged to increase the S/N ratio. Nevertheless, it is expected that density in the vicinity of periapsis will be recovered from numerous orbits. The recovery of other atmospheric characteristics, as described for Deep Dips, will be attempted but will depend on the quality of the IMU and other data.

2.2 Detectors

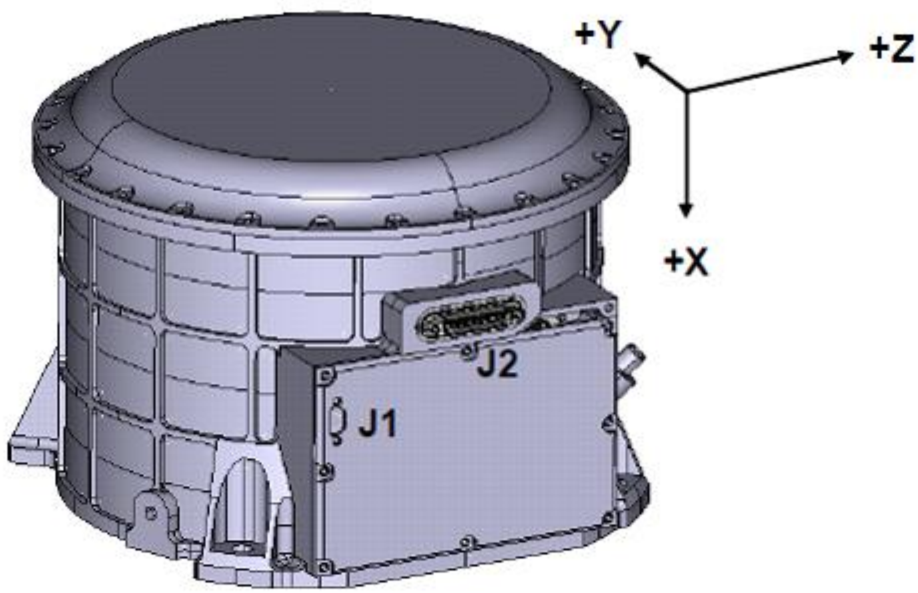
MAVEN utilizes the Honeywell Miniature Inertial Measurement Unit (MIMU), Block 3, as illustrated in the drawing below. There are two units mounted on the upper deck of the spacecraft as shown in the second drawing below. The following coordinate frame descriptions and relative orientation transformations are taken from the MAVEN Coordinate Transformation Document (LIB-11):

The local IMU coordinate frame, which is coincident with the MIMU sensing frame, is associated with the physical design of the IMU and defined as follows:

$+Y_{MIMU}$ = Collinear with the outward normal to Y axis alignment mirror (primary mirror), Anti-Normal to J1 and J2 Connectors

$+Z_{MIMU}$ = Perpendicular to the Y axis and in the plane formed by the outward normal to the Y axis mirror and the Z axis mirror (secondary mirror), positive in the outward normal direction.

$+X_{MIMU} = +Y_{MIMU} \times +Z_{MIMU}$



The accelerometers are mounted as part of the Inertial Sensor Assembly near the middle of the MIMU component stack. The Navigation Reference Point (NRP) is the intersection of the accelerometer sensor axes, and the Center of Percussion (CP) is the effective location of each accelerometer. The NRP vector is provided in the local MIMU frame. The CP vectors are provided as vectors from the NRP to the individual CP, as well as vectors in the MIMU frame.

NRP: [-42.926 7.734 5.867] (mm) MIMU mounting frame

CPx: [0.554 12.699 11.188] (mm) from NRP to CPx

CPy: [0.155 -44.591 -11.188] (mm) from NRP to CPy

CPz: [-0.155 -12.699 -42.904] (mm) from NRP to CPz

CPx: [-42.601 20.434 17.056] (mm) MIMU mounting frame

CPy: [-42.771 -36.858 -5.321] (mm) MIMU mounting frame

CPz: [-43.801 -4.966 -37.036] (mm) MIMU mounting frame

2.3 Measured Parameters

The relevant parameters measured by the IMU are the accumulated change in velocity sensed by each accelerometer and the accumulated change in attitude angular orientation sensed by each gyro. Raw data (counts of delta velocity and delta angle in the MIMU frame) will be saved by the spacecraft FSW for downlink and processing on the ground. One delta velocity count is 7.53e-5 m/s and one delta angle count is 1e-6 radians. The data rate for this raw data generation is configurable and will be selected according to mission activity and data volume constraints.

2.4 Operational Modes

During the "Deep Dip" campaigns (DD), raw IMU accelerometer count and gyro count data will be made available, by the Science Data Center (SDC), to the ACC team at 10 Hz and during the “science orbit” (SO) at 2 Hz. Raw RWA rate counts will be made available at 1 sample per second during both DD and SO. These are the rawest forms of data necessary for the ACC analysis and provide the most flexibility in density recovery. The SDC will also provide processed IMU data in engineering units, APP gimbal angles and angle rates, attitude quaternions, filtered RWA rates, fuel load, OPTG, and spacecraft mass properties as enumerated in MAVEN-SOPS-PLAN-0068C-2012-08-01.

2.5 Operational Considerations

IMU and relevant ancillary data will be gathered near periapsis so that near vacuum (altitude greater than 250 km) calibrations can be performed for 1 minute before and after periapsis at altitudes above 250 km.

2.6 Ground Calibration

The design orientations of the two MIMUs with respect to the mechanical frame are defined as a series of successive rotations as follows (Note that these rotations are performed with a **rotating** coordinate frame):

MIMU 1: 1) No Rotation: $+X_{M'} = -Z_M$

$+Y_{M'} = -X_M$

$+Z_{M'} = +Y_M$

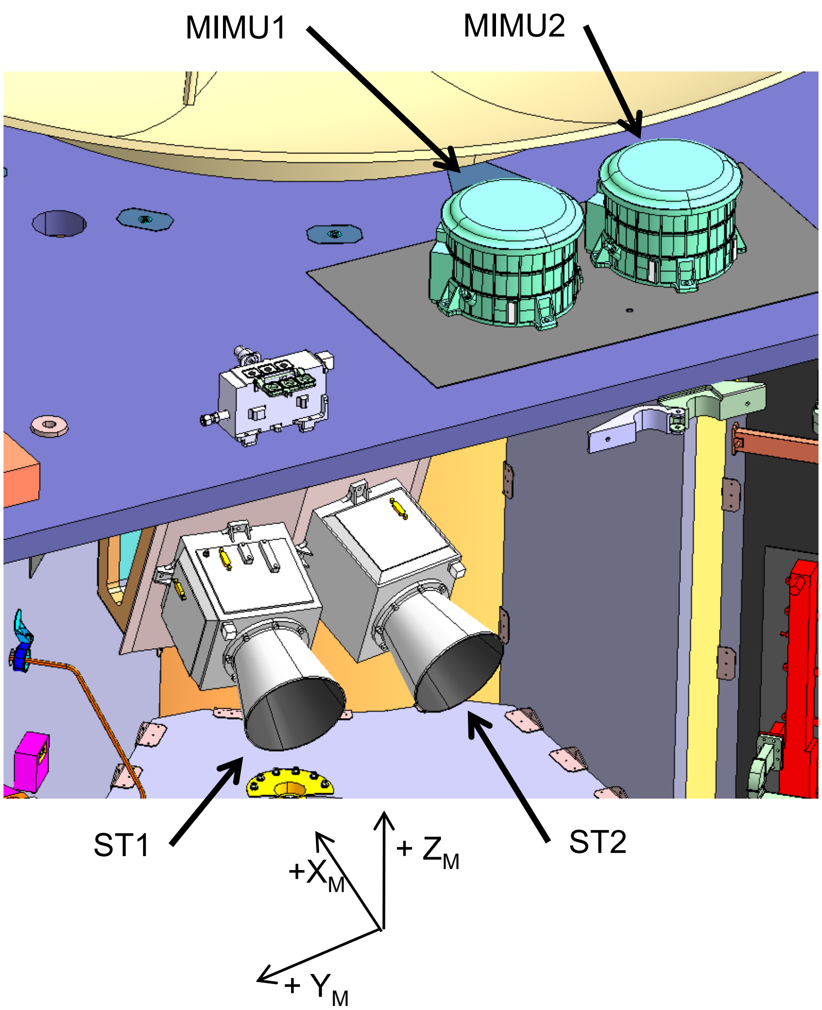
2) First Rotation: -45° about $+X_{M'}$

MIMU 2: 1) No Rotation: $+X_{M'} = -Z_M$

$+Y_{M'} = -X_M$

$+Z_{M'} = +Y_M$

2) First Rotation: -30° about $+X_{M'}$



The transformation from the spacecraft mechanical frame to the local IMU frame (for each IMUs) is then calculated as the direction cosine matrix defined by these rotations:

$$ {}^{IMU1}_{M}T = \left(\begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(-45^\circ) & \sin(-45^\circ) \\ 0 & -\sin(-45^\circ) & \cos(-45^\circ) \end{bmatrix} \begin{bmatrix} 0 & 0 & -1 \\ -1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \right) $$

$$ {}^{IMU2}_{M}T = \left(\begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(-30°) & \sin(-30°) \\ 0 & -\sin(-30°) & \cos(-30°) \end{bmatrix} \begin{bmatrix} 0 & 0 & -1 \\ -1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \right) $$

The transformation from the local IMU frame to the spacecraft mechanical frame is the transpose of the above matrix:

$$ {}^{M}_{IMU1}T = \left({}^{IMU1}_{M}T \right)^T = \begin{bmatrix} 0.0000 & -0.7071 & -0.7071 \\ 0.0000 & -0.7071 & 0.7071 \\ -1.0000 & -0.0000 & -0.0000 \end{bmatrix} $$

$$ {}^{M}_{IMU2}T = \left({}^{IMU2}_{M}T \right)^T = \begin{bmatrix} 0.0000 & -0.8660 & -0.5000 \\ 0.0000 & -0.5000 & 0.8660 \\ -1.0000 & -0.0000 & -0.0000 \end{bmatrix} $$

The above transformations will be updated after Post-Environmental alignment measurements are made. Refer to Document Number: MAV-RP-10-0100, Rev. D, *Coordinate Systems Definition Document* for more information.

2.7 In Flight Calibration

There are a number of times during the mission, prior to the first Deep Dip campaign, that the accelerometer biases are determined. These are generally done prior to any propulsive maneuver where the accelerometers are used to terminate the maneuver. The record of these bias estimations will be provided to the ACC team along with any relevant data that might explain changes in bias, e.g. IMU or accelerometer temperatures. Gyro rate bias and scale factors are also determined during flight and these and any relevant ancillary data will also be supplied to the ACC team as the calibrations are performed.

At the start of each periapsis pass the accelerometer bias is determined and telemetered as part of the ancillary data set available to the ACC team. This is done for both operational and scientific data purposes. Further, during ACC team post flight analysis, the bias is re-determined by fitting a line to the data before and after periapsis when the vehicle is little affected by atmospheric drag. Comparisons are made with the onboard bias determination. Prior missions have shown slight drift in bias with time, perhaps due to IMU temperature changes. This bias correction is done for all density recoveries.

Using gyro data outside the atmosphere, IMU to center-of-mass distance is estimated and compared with the values used for operations. The dry bus mass is about 810 kg and about 300 kg of fuel remained after reaching the science orbital period and periapsis altitude on Oct. 3, 2014. During atmospheric entry and exit, this fuel try to reach an equilibrium distribution consistent with all forces. The fuel may slosh around in the tank as the dominate forces change from surface tension to external force and then back to surface tension. This produces four undesirable effects. First the fuel motion causes the center of mass of the vehicle to move relative to the s/c frame making transferring the accelerometer measurements to the center of mass less accurate. Second, fuel motion toward equilibrium produces an apparent reduction in the mass acted upon by the aerodynamic forces, resulting in an overestimate of atmospheric density. Third, the aerodynamic moment coefficients in the aero data base are dependent on COM location. Finally, oscillations in accelerometer measurements due to fuel slosh can be easily misinterpreted as atmospheric waves.

3 Data Overview

This section provides a high level description of archive organization under the PDS4 Information Model (IM) as well as the flow of the data from the spacecraft through delivery to PDS.

3.1 Data Reduction Levels

A number of different systems may be used to describe data processing level. This document refers to data by their PDS4 reduction level. Table 5 provides a description of these levels along with the equivalent designations used in other systems.

Table 5: Data reduction level designations

PDS4 reduction level	PDS4 reduction level description	MAVEN Processing Level	CODMAC Level	NASA Level
Raw	Original data from an instrument. If compression, reformatting, packetization*, or other translation has been applied to facilitate data transmission or storage, those processes are reversed so that the archived data are in a PDS approved archive format.	0	1	0
Reduced	Data that have been processed beyond the raw stage but which are not yet entirely independent of the instrument.	1	2	1A
Calibrated	Data converted to physical units entirely independent of the instrument.	2	3	1B
Derived	Results that have been distilled from one or more calibrated data products (for example, maps, gravity or magnetic fields, or ring particle size distributions). Supplementary data, such as calibration tables or tables of viewing geometry, used to interpret observational data should also be classified as 'derived' data if not easily matched to one of the other three categories.	3+	4+	2+

* PDS does not accept packetized data (CODMAC level 1/NASA level 0) as fulfilling the requirement for the archive of raw data. The PDS, however, has agreed to an exception for the MAVEN mission with the understanding that the MAVEN packetized data are not compressed, and may be described as fixed width binary tables. Typically the minimum reduction level accepted by PDS for "raw" data is CODMAC level 2, or NASA level 1A.

3.2 Products

A PDS product consists of one or more digital and/or non-digital objects, and an accompanying PDS label file. Labeled digital objects are data products (i.e. electronically stored files). Labeled non-digital objects are physical and conceptual entities which have been described by a PDS label. PDS labels provide identification and description information for labeled objects. The PDS label defines a Logical Identifier (LID) by which any PDS labeled product is referenced throughout the system. In PDS4 labels are XML formatted ASCII files. More information on the formatting of PDS labels is provided in Section 6.3. More information on the usage of LIDs and the formation of MAVEN LIDs is provided in Section 5.1.

3.3 Product Organization

The highest level of organization for PDS archive is the bundle. A bundle is a list of one or more related collection products which may be of different types. A collection is a list of one or more related basic products which are all of the same type. Figure 1 below illustrates these relationships.

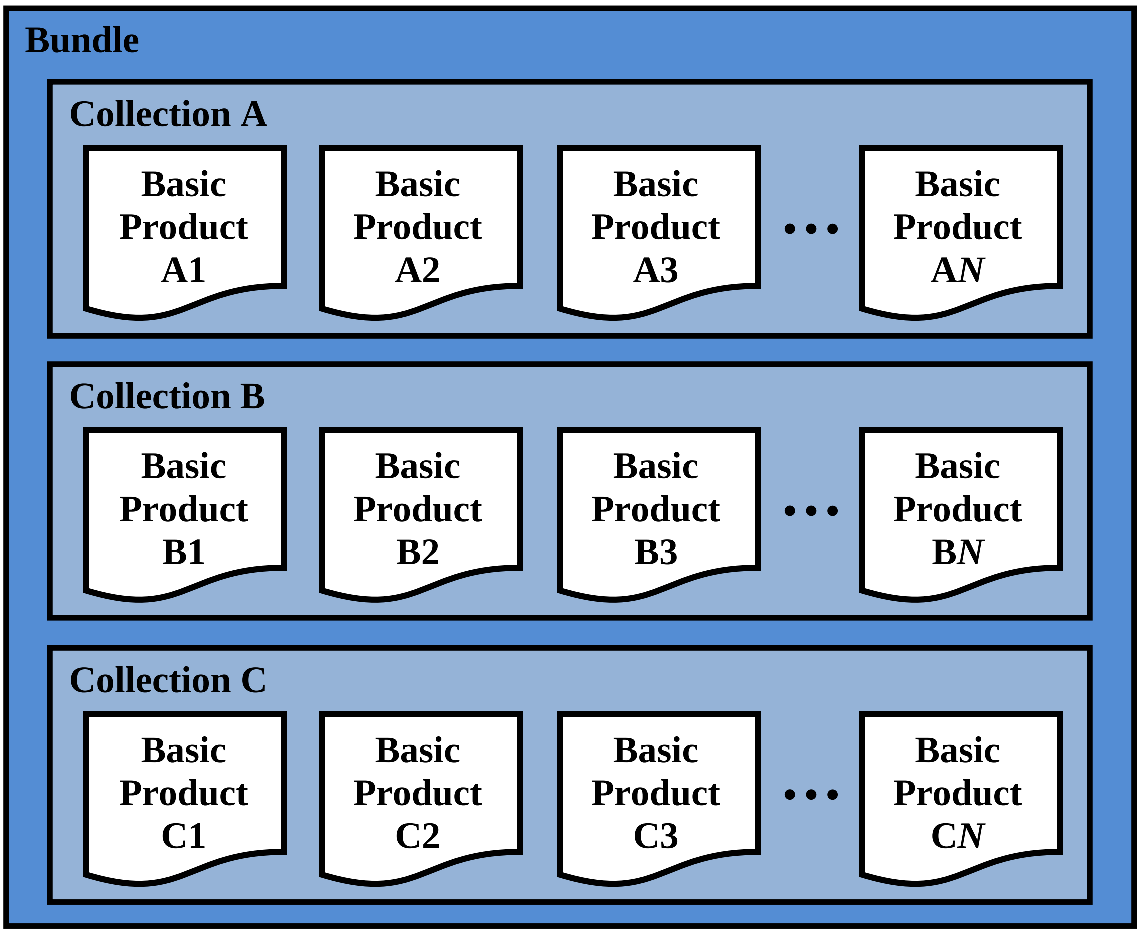


Figure 1: A graphical depiction of the relationship among bundles, collections, and basic products.

Bundles and collections are logical structures, not necessarily tied to any physical directory structure or organization. Bundle and collection membership is established by a member inventory list. Bundle member inventory lists are provided in the bundle product labels themselves. Collection member inventory lists are provided in separate collection inventory table files. Sample bundle and collection labels are provided in Appendix C and Appendix D, respectively.

3.3.1 Collection and Basic Product Types

Collections are limited to a single type of basic products. The types of archive collections that are defined in PDS4 are listed in Table 6.

Table 6. Collection product types.

Collection Type	Description
Browse	Contains products intended for data characterization, search, and viewing, and not for scientific research or publication.
Context	Contains products which provide for the unique identification of objects which form the context for scientific observations (e.g. spacecraft, observatories, instruments, targets, etc.).
Document	Contains electronic document products which are part of the PDS Archive.
Data	Contains scientific data products intended for research and publication.
SPICE	Contains NAIF SPICE kernels.
XML_Schema	Contains XML schemas and related products which may be used for generating and validating PDS4 labels.

3.4 Bundle Products

The ACC data archive is organized into one Level 3 bundle. The bundle contains the derived atmospheric density versus time from periapsis for each orbit. A more detailed description of the contents and format of each bundle is provided in Section 5.2. The raw data from which these results are derived are described in the Ancillary Data SIS, where the data sets are listed in the "GNC DRF data file structure" table and the "IMU file structure" table.

Table 7: ACC Bundle

Bundle Logical Identifier	PDS4 Reduction Level	Description	Data Provider
urn:nasa:pds:maven_acc:bundle	Derived (MAVEN L3)	Atmospheric density profiles	ITF

3.5 Data Flow

This section describes only those portions of the MAVEN data flow that are directly connected to archiving. A full description of MAVEN data flow is provided in the MAVEN Science Data Management Plan [5]. A graphical representation of the full MAVEN data flow is provided in Figure 2 below.

Reduced (MAVEN Level 1) data will be produced by RS and NGIMS as an intermediate processing product, and are delivered to the SDC for archiving at the PDS, but will not be used by the MAVEN team.

All Instrument Team Facilities (ITFs), except ACC, will produce calibrated products. Following an initial 2-month period at the beginning of the mapping phase, the ITFs will routinely deliver preliminary calibrated data products to the SDC for use by the entire MAVEN team within two weeks of ITF receipt of all data needed to generate those products. The SOC will maintain an active archive of all MAVEN science data, and will provide the MAVEN science team with direct access through the life of the MAVEN mission. After the end of the MAVEN project, PDS will be the sole long-term archive for all public MAVEN data.

Updates to calibrations, algorithms, and/or processing software are expected to occur regularly, resulting in appropriate production system updates followed by reprocessing of science data products by ITFs for delivery to SDC. Systems at the SOC, ITFs and PDS are designed to handle these periodic version changes.

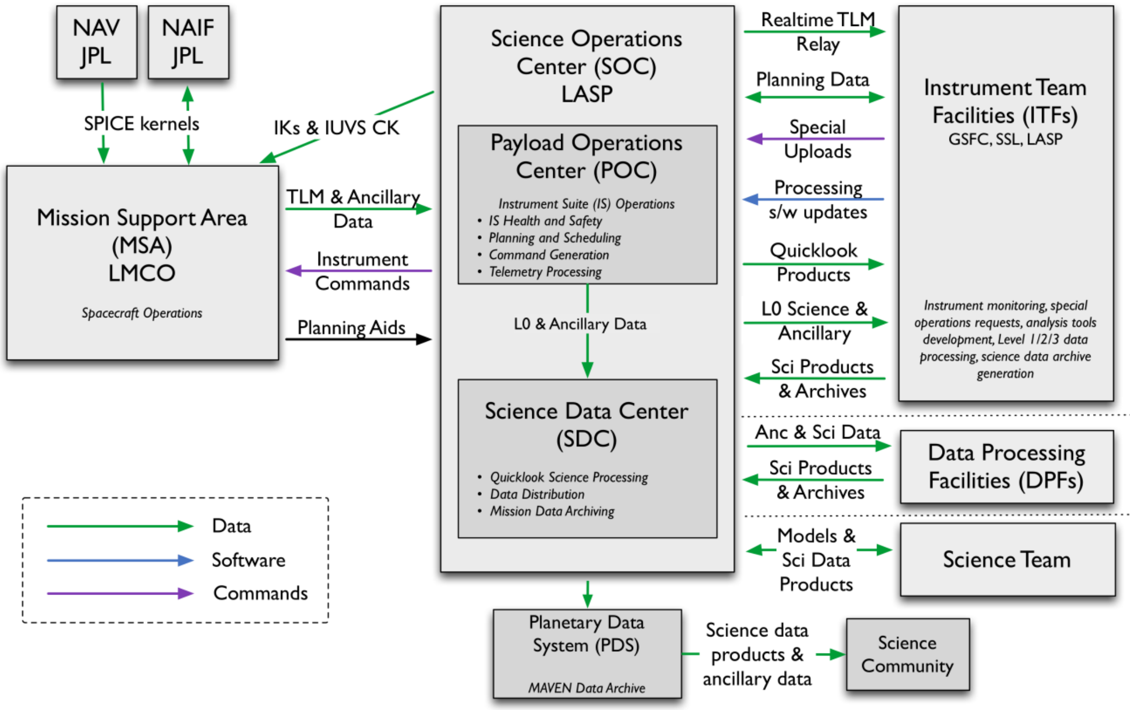


Figure 2: MAVEN Ground Data System responsibilities and data flow. Note that this figure includes portions of the MAVEN GDS which are not directly connected with archiving, and are therefore not described in Section 3.5 above.

4 Archive Generation

The ACC archive products are produced by the ACC DPF in cooperation with the SDC, and with the support of the PDS Atmospheres Node at New Mexico State University. The archive volume creation process described in this section sets out the roles and responsibilities of each of these groups. The assignment of tasks has been agreed upon by all parties. Archived data received by the Atmosphere Node from the ACC team are made available to PDS users electronically as soon as practicable but no later than two weeks after the delivery and validation of the data.

4.1 Data Processing and Production Pipeline

The following sections describe the process by which data products in each of the ACC bundles listed in Table 8 are produced.

4.1.1 Raw Data Production Pipeline

The ACC raw data consist of non-channelized IMU accelerometer and rate gyro measurements, raw and filtered and raw RW speeds, and attitude quaternion from the engineering telemetry stream as described in Table 4-3, MAVEN-SOPS-plan-0068C-2012-08-01. Other ancillary data include OPTG, planetary constants, APP gimbal angles and rates, fuel load, and mass properties. All these data will be collected by the SDC and made available for download to the ACC DPF. Raw data archive is provided to the PDS by the SDC.

4.1.2 Derived Data Production Pipeline

During the DD campaigns, atmospheric density is derived at 1 second intervals during the periapsis phase of each orbit. Useful data sample interval during the science orbit may be longer and variable depending on data quality for each orbit. Standard deviation are derived for each data sample using deviations from locally smoothed values. These data are provided in the "PROFILE" product and supplied to the SDC for bundling and subsequent PDS archiving.

4.2 Data Validation

Data validation is performed for each Deep Dip campaign internal to the ACC team. Once internally validated ACC results will be compared with neutral density and temperature results from other MAVEN instruments and with thermospheric model results.

4.2.1 Instrument Team Validation

The ACC instrument team produces numerous validation products during the processing of each orbit of data. During the DD campaigns a daily summary report will be produced that will be reviewed by the full team. The report provides basic periapsis information like altitude, latitude, longitude, SZA and LST. Derived data include (1) periapsis density and scale height along with the 1-σ uncertainties, (2) maximum density and time of maximum, (3) along track density and scale height gradients, (4) accelerometer bias and noise level, (5) total ΔV and periapsis density comparison with OPTG values, (6) density and scale height at preselected reference altitudes, (7) disturbance level, i.e. short wave length density variations compared to a "smoothed" atmospheric profile, and other information. Numerous plots are provided to the team including data for each orbit in that day's report along with the history of each DD campaign up to that day.

4.2.2 MAVEN Science Team Validation

In addition to the ACC instrument team validation, comparisons will likely be made with neutral density profiles derived from the NGIMS and IUVS as part of the routine science analysis of MAVEN data.

4.2.3 PDS Peer Review

The Atmosphere node will conduct a full peer review of all of the data types that the ACC team intends to archive. The review data will consist of fully formed bundles populated with candidate final versions of the data and other products and the associated metadata.

Table 8: MAVEN PDS review schedule

Date	Activity	Responsible Team
2014-May	Preliminary raw data sample product delivery	SDC
2014-Jul	Raw data delivery	SDC
2014-Aug	Raw data archive peer review (2014-Jul to 2014-Aug)	PDS
2014-Sep	Preliminary derived sample data product delivery	ITF/SDC
2014-Oct	Derived archive sample data delivery	ITF/SDC
2014-Nov	Derived archive sample data review (2014-Oct to 2014-Nov)	PDS

Reviews will include a preliminary delivery of sample products for validation and comment by PDS Atmosphere and Engineering node personnel. The data provider will then address the comments coming out of the preliminary review, and generate a full archive delivery to be used for the peer review.

Reviewers will include MAVEN Project and ACC team representatives, researchers from outside of the MAVEN project, and PDS personnel from the Engineering and Atmosphere nodes. Reviewers will examine the sample data products to determine whether the data meet the stated science objectives of the instrument and the needs of the scientific community and to verify that the accompanying metadata are accurate and complete. The peer review committee will identify any liens on the data that must be resolved before the data can be ‘certified’ by PDS, a process by which data are made public as minor errors are corrected.

In addition to verifying the validity of the review data, this review will be used to verify that the data production pipeline by which the archive products are generated is robust. Additional deliveries made using this same pipeline will be validated at the Atmosphere node, but will not require additional external review.

As expertise with the instrument and data develops the ACC team may decide that changes to the structure or content of its archive products are warranted. Any changes to the archive products or to the data production pipeline will require an additional round of review to verify that the revised products still meet the original scientific and archival requirements or whether those criteria have been appropriately modified. Whether subsequent reviews require external reviewers will be decided on a case-by-case basis and will depend upon the nature of the changes. A comprehensive record of modifications to the archive structure and content is kept in the Modification_History element of the collection and bundle products.

The instrument team and other researchers are encouraged to archive additional ACC products that cover specific observations or data-taking activities. The schedule and structure of any additional archives are not covered by this document and should be negotiated with the Atmosphere node.

4.3 Data Transfer Methods and Delivery Schedule

The SOC is responsible for delivering data products to the PDS for long-term archiving. While ITFs are primarily responsible for the design and generation of calibrated and derived data archives, the archival process is managed by the SOC. The SOC (in coordination with the ITFs) will also be primarily responsible for the design and generation of the raw data archive. The first PDS delivery will take place within 6 months of the start of science operations. Additional deliveries will occur every following 3 months and one final delivery will be made after the end of the mission. Science data are delivered to the PDS within 6 months of its collection. If it becomes necessary to reprocess data which have already been delivered to the archive, the ITFs will reprocess the data and deliver them to the SDC for inclusion in the next archive delivery. A summary of this schedule is provided below.

Table 9: Archive bundle delivery schedule

Bundle Logical Identifier	First Delivery to PDS	Delivery Schedule	Estimated Delivery Size
urn:nasa:pds:maven_acc:bundle	3 months after the first Deep Dip campaign	3 months after each Deep Dip campaign	10 MB per DD campaign
urn:nasa:pds:maven_acc:bundle	First science orbit density profiles no later than 6 months after the official start of science operations, i.e. ~Nov. 2014	Every 3 months depending on data quality	<60 MB per month

Each delivery will comprise both data and ancillary data files organized into directory structures consistent with the archive design described in Section 5, and combined into a deliverable file(s) using file archive and compression software. When these files are unpacked at the Atmosphere Node in the appropriate location, the constituent files will be organized into the archive structure.

Archive deliveries are made in the form of a “delivery package”. Delivery packages include all of the data being transferred along with a transfer manifest, which helps to identify all of the products included in the delivery, and a checksum manifest which helps to insure that integrity of the data is maintained through the delivery. The format of these files is described in Section 6.4.

Data are transferred electronically (using the *ssh* protocol) from the SOC to an agreed upon location within the Atmosphere file system. Atmosphere will provide the SOC a user account for this purpose. Each delivery package is made in the form of a compressed *tar* or *zip* archive. Only those files that have changed since the last delivery are included. The Atmosphere operator will decompress the data, and verify that the archive is complete using the transfer and MD5 checksum manifests that were included in the delivery package. Archive delivery status will be tracked using a system defined by the Atmosphere node.

Following receipt of a data delivery, Atmosphere will reorganize the data into its PDS archive structure within its online data system. Atmosphere will also update any of the required files associated with a PDS archive as necessitated by the data reorganization. Newly delivered data are made available publicly through the Atmosphere online system once accompanying labels and other documentation have been validated. It is anticipated that this validation process will require no more than fourteen working days from receipt of the data by Atmosphere. However, the first few data deliveries may require more time for the Atmosphere Node to process before the data are made publicly available.

4.4 Data Product and Archive Volume Size Estimates

ACC Level 3 products consist of files that span one orbit. Density at reference altitudes are ordered by time, starting with highest inbound altitude and ending with highest outbound altitude. The size of the profile data files depend on the telemetry rate and data quality. If no data are recovered at periapsis, no file will be delivered to the PDS.

4.5 Data Validation

Routine data deliveries to the PDS are validated at the Atmosphere node to insure that the delivery meets PDS standards, and that the data conform to the standards defined in this SIS, and set in the peer review. As long as there are no changes to the data product formats, or data production pipeline no additional external review will be conducted.

4.6 Backups and Duplicates

The Atmosphere Node keeps three copies of each archive product. One copy is the primary online archive copy, another is an onsite backup copy, and the final copy is an off-site backup copy. Once the archive products are fully validated and approved for inclusion in the archive, copies of the products are sent to the National Space Science Data Center (NSSDC) for long-term archive in a NASA-approved deep-storage facility. The Atmosphere Node may maintain additional copies of the archive products, either on or off-site as deemed necessary. The process for the dissemination and preservation of ACC data is illustrated in Figure 3. The chart combines the delivery of Level 3 archive products from the ACC ITF to the SDC and then from the SDC to the PDS.

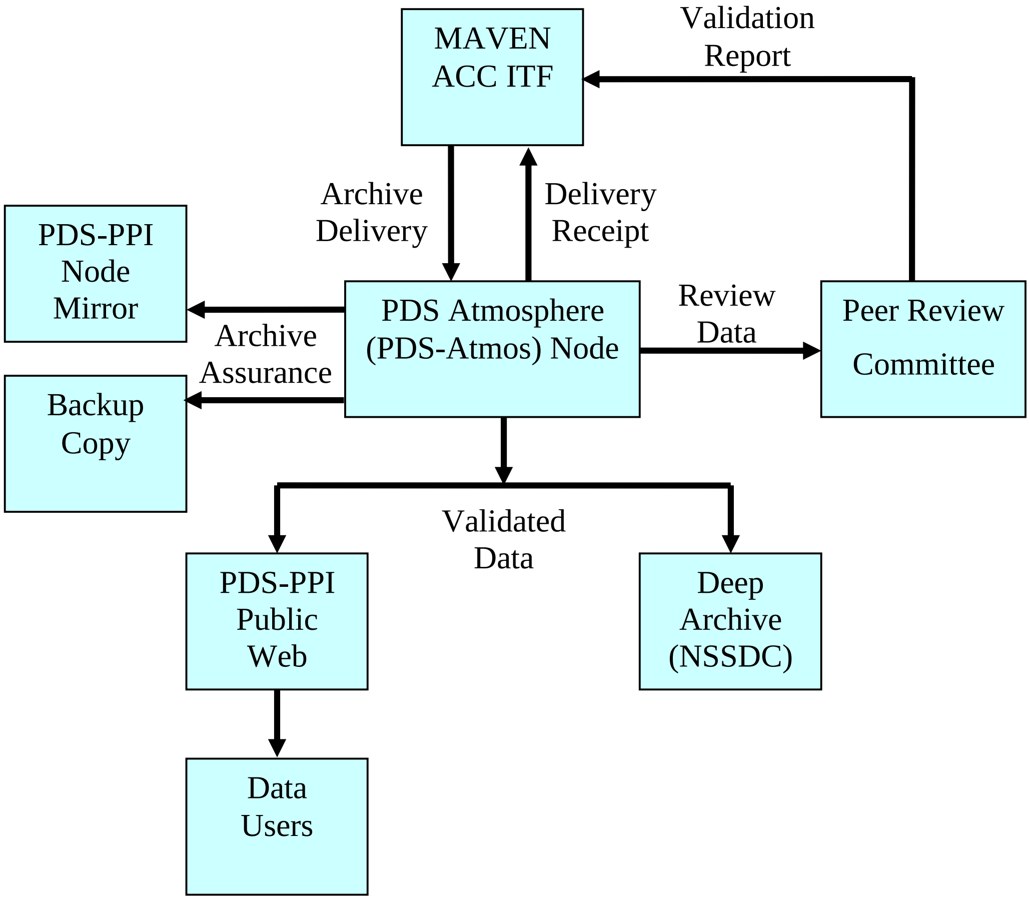


Figure 3: Duplication and dissemination of ACC archive products at PDS/Atmosphere.

5 Archive Organization and Naming

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

5.1 Logical Identifiers

Every product in PDS is assigned an identifier which allows it to be uniquely identified across the system. This identifier is referred to as a Logical Identifier or LID. A VID (Versioned Logical Identifier) includes product version information, and allows different versions of a specific product to be referenced uniquely. A product's LID and VID are defined as separate attributes in the product label. LIDs and VIDs are assigned by the entity generating the labels and are formed according to the conventions described in sections 5.1.1 and 5.1.2 below. The uniqueness of a product's LIDVID may be verified using the PDS Registry and Harvest tools.

5.1.1 LID Formation

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

MAVEN ACC LIDs are formed according to the following conventions:

- Since ACC only uses one bundle, the bundle LID is given in Table 7 as

  urn:nasa:pds:maven:acc:bundle

  Since all PDS bundle LIDs are constructed this way, the combination of mvn:acc:bundle must be unique across all products archived with the PDS.

- Basic product LIDs are formed by appending a product specific ID to the product's parent collection LID:

  urn:nasa:pds:maven:acc:bundle >:<collection ID>:<product ID>

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

5.1.2 VID Formation

Product version ID's consist of major and minor components separated by a "." (e.g. M.n). Both components of the VID are integer values. The major component is initialized to a value of "1", and the minor component is initialized to a value of "1". The minor component resets to "1" when the major component is incremented.

ACC major component changes are reserved for changes in the fundamental data processing methods or parameters. These might occur if subsequent analysis indicated previously used aerodynamic data bases were incorrect or incorrectly interrogated, if conversions from instrument count to engineering units changed, or whenever any new information suggested modifications to recovered density would change beyond the uncertainties described in the previously archived data products. Minor component changes might include extensions of a data set to longer time or altitude ranges without any changes in fundamental processing methods or parameters.

5.2 ACC Archive Contents

The ACC archive includes the single bundle. The following table describes the contents of the bundle in greater detail.

Table 10: ACC collections

Collection LID	Description
urn:nasa:pds:maven_acc:bundle:content	Descriptions of instrument, host, mission and content inventory.
urn:nasa:pds:maven_acc:bundle:data	Raw data, profile data, reference altitude data and respective inventories.
urn:nasa:pds:maven_acc:bundle:document	Formats for the three data set products and relevant archival publications

6 Archive Products Formats

Data that comprise the ACC archives are formatted in accordance with PDS specifications [see *Planetary Science Data Dictionary* [4], *PDS Data Provider's Handbook* [2], and *PDS Standards Reference* [3]. This section provides details on the formats used for each of the products included in the archive.

6.1 Data File Formats

This section describes the format, record structure and name of each of the Level 3 data file types.

ACC produces either one or two derived data files for each orbit for which there is adequate data. The profile or "pro" files provide the time ordered derived density for each orbit. Since density can be derived from both accelerometer and reaction wheel data, an "acc" or a "rwa" is embedded in each file name to identify the source. For a few orbit, both data sets might be used. Density scale height can be derived from each profile, but interpretation in terms of an isothermal temperature may not be direct since mean molecular weight is required for such a calculation and this will vary substantially for MAVEN orbits. In addition, while in the sensible atmosphere, the MAVEN orbit covers more than 30 degrees along track and an altitude range of a few density scale heights. Along track gradients will also corrupt the interpretation of density scale height as a measure of local temperature. The "acc" and "rwa" files have the same format as given below.

The complete file name will be of the form

mvn_acc_l3_pro-rwa-p01234_20150516_v01_r01.tab

for version 1, release 1 of the reaction wheel derived density profile for orbit 1234 on May 16, 2015 and

mvn_acc_l3_pro-acc-p01234_20150516_v01_r01.tab

for the accelerometer derived data on the same orbit.

Table 11: Profile data record structure

Field Name	Start Byte	Bytes	Description
time	1	4	seconds from periapsis
areodetic latitude	6	5	degrees
longitude, E	12	5	degrees
true local solar time, TLST	18	4	hours
solar zenith angle, SZA	23	5	degrees
areodetic altitude	29	5	km
density	35	7	kg/km^3
1 sec sigma density	43	6	kg/km^3

6.2 Data File Examples

The data record formats are given below, along with an example of how the data should appear in the file.

```
DERIVED - L3 Profile
   %4.0f %5.1f %5.1f %4.1f %5.1f %5.1f %7.3f %6.3f\n
   -100  -1.8  76.5 11.1  25.5 132.6   0.781  0.018
    -99  -1.8  76.5 11.1  25.5 132.4   0.800  0.012
    -98  -1.7  76.5 11.1  25.4 132.3   0.834  0.016
    -97  -1.6  76.6 11.1  25.3 132.1   0.839  0.015
```

6.3 PDS Labels

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

The structure of PDS label files is governed by the XML documents described in Section 6.3.1.

6.3.1 XML Documents

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

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

Examples of PDS labels required for the ACC archive are shown in Appendix C (bundle products), Appendix D (collection products), and Appendix E (data products).

6.4 Delivery Package

Data transfers, whether from data providers to PDS or from PDS to data users or to the deep archive, are accomplished using delivery packages. Delivery packages include the following required elements:

1. The package which consists of a compressed bundle of the products being transferred.
2. A transfer manifest which maps each product's LIDVID to the physical location of the product label in the package after decompression.
3. A checksum manifest which lists the MD5 checksum of each file included in the package after decompression.

ACC archive delivery packages (including the transfer and checksum manifests) for delivery to PDS are produced at the MAVEN SDC.

6.4.1 The Package

The directory structure used in for the delivery package is described in Appendix F. Delivery packages are compressed using "zip" and are transferred electronically using the ssh protocol.

6.4.2 Transfer Manifest

The “transfer manifest” is a file provided with each transfer to, from, or within PDS. The transfer manifest is external to the delivery package. It contains an entry for each label file in the package, and maps the product LIDVID to the file specification name for the associated product’s label file. Details of the structure of the transfer manifest are provided in Appendix F.1.

The transfer manifest is external to the delivery package, and is not an archive product. As a result, it does not require a PDS label.

6.4.3 Checksum Manifest

The checksum manifest contains an MD5 checksum for every file included as part of the delivery package. This includes both the PDS product labels and the files containing the digital objects which they describe. The format used for a checksum manifest is the standard output generated by the md5deep utility. Details of the structure of the checksum manifest are provided in Appendix F.1.

The checksum manifest is external to the delivery package, and is not an archive product. As a result, it does not require a PDS label.

Appendix A Support Staff and Cognizant Persons

Table 12: Archive support staff

ACC team			
Name	**Address**	**Phone**	**Email**
Bob Tolson	National Institute of Aerospace 100 Exploration Way Hampton, VA 23666, USA	937.872.9037	rhtolson@nianet.org
Darren Baird	Johnson Space Flight Center	281.244.8413	darren.t.baird@nasa.gov
Alicia Cianciolo	Langley Research Center	816.662.1247	alicia.m.dwyercianciolo@ nasa.gov
Rafael Lugo	Analytical Mechanics Associates	757.864.7147	rafael.a.lugo@nasa.gov

NMSU			
Name	**Address**	**Phone**	**Email**
Dr. Reta Beebe ATM Node Manager	Astronomy Department New Mexico State University P.O. Box 30001, MSC 4500 Las Cruces, NM 88003	575 646-1938	rbeebe@nmsu.edu
Mr. Lyle Huber ATM Node Archive Manager	Astronomy Department New Mexico State University P.O. Box 30001, MSC 4500 Las Cruces, NM 88003	575 646-1862	lhuber@nmsu.edu

Appendix B Naming Conventions for ACCEL Data Files

This section describes the naming convention used for ACCEL data files for the MAVEN mission. ACCEL will use “acc” for the 3-letter descriptor. Since ACCEL only produces Level 3 files, the general formats are not applicable. As atmospheric density can be recovered from both accelerometer (acc) and reaction wheel assembly (rwa) data, there is a need to identify the source of the density recovery. The orbit is identified in the descriptor using the periapsis number as “pxxxxx” where “xxxxx” is the periapsis number.

Level 3:

mvn_acc_l3_<descriptor>_<yyyy><mm><dd>_v<xx>_r<xx>.tab

mvn_acc_l3_pro-acc-p01234_20150619_v01_r01.tab

mvn_acc_l3_pro-rwa-p01234_20150619_v01_r01.tab

Code	**Description**
mvn	mission identifier
acc	data generating team
l3	data level
pro	profile type data
<inst>	‘acc’ or ‘rwa’ to identify source of density recovery
pxxxxx	periapsis identifier
<yyyy>	4-digit year
<mm>	2-digit month, e.g. 01, 12
<dd>	2-digit day of month, e.g. 01, 28
v<xx>	2-digit data version
r<yy>	2-digit software version
.<ext>	file type extension, tab

Appendix C Sample Bundle Product Label

This section provides a sample bundle product label. This sample was converted from the MRO PDS4 archive for aerobraking accelerometer data created by Lyle Huber. Templates for the final label will be provided by PDS Atmospheres.


```
<?xml version="1.0" encoding="UTF-8"?>
<?xml-model href="http://pds.nasa.gov/pds4/schema/released/pds/v03/PDS4_PDS_0300a.sch" ?>
<Product_Bundle xmlns="http://pds.nasa.gov/pds4/pds/v03"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://pds.nasa.gov/pds4/pds/v03
        http://pds.nasa.gov/pds4/schema/released/pds/v03/PDS4_PDS_0300a.xsd">
  <Identification_Area>
    <logical_identifier>urn:nasa:pds:maven:acc:bundle</logical_identifier>
    <version_id>1.0</version_id>
    <title>MAVEN Accelerometer Bundle</title>
    <information_model_version>0.3.0.0.a</information_model_version>
    <product_class>Product_Bundle</product_class>
    <Alias_List>
      <Alias>
        <alternate_id>MAVEN-M-ACCEL-2-ACCELDATA-V1.0</alternate_id>
        <comment>MAVEN ACCELEROMETER RAW DATA RECORDS V1.0</comment>
      </Alias>
      <Alias>
        <alternate_id>MAVEN-M-ACCEL-5-PROFILE-V1.0</alternate_id>
        <comment>MAVEN PROFILE DATA RECORDS V1.0</comment>
      </Alias>
      <Alias>
        <alternate_id>MAVEN-M-ACCEL-5-ALTITUDE-V1.0</alternate_id>
        <comment>MAVEN ALTITUDE DATA RECORDS V1.0</comment>
      </Alias>
    </Alias_List>
    <Citation_Information>
      <author_list>L.F. Huber</author_list>
      <publication_year>2010</publication_year>
      <description>Created PDS3 MAVEN Volume</description>
    </Citation_Information>
    <Modification_History>
      <Modification_Detail>
        <modification_date>2013-04-06</modification_date>
        <version_id>1.0</version_id>
        <description>PDS4 MAVEN Bundle</description>
      </Modification_Detail>
    </Modification_History>
  </Identification_Area>
  <Reference_List>
    <Internal_Reference>
      <lid_reference>urn:nasa:pds:maven:acc:document:ALTDS</lid_reference>
      <reference_type>bundle_to_document</reference_type>
    </Internal_Reference>
    <Internal_Reference>
      <lid_reference>urn:nasa:pds:maven:acc:document:PROFDS</lid_reference>
```

```
      <reference_type>bundle_to_document</reference_type>
    </Internal_Reference>
    <Internal_Reference>
      <lid_reference>urn:nasa:pds:maven:acc:document:RAWDS</lid_reference>
      <reference_type>bundle_to_document</reference_type>
    </Internal_Reference>
  </Reference_List>
  <Bundle>
    <bundle_type>Archive</bundle_type>
  </Bundle>
  <File_Area_Text>
    <File>
      <file_name>README.TXT</file_name>
      <local_identifier>maven_readme_text</local_identifier>
    </File>
    <Stream_Text>
      <name>README</name>
      <offset unit="byte">0</offset>
      <external_standard_id>TEXT</external_standard_id>
      <encoding_type>Character</encoding_type>
      <record_delimiter>carriage_return line_feed</record_delimiter>
    </Stream_Text>
  </File_Area_Text>
  <Bundle_Member_Entry>
    <lid_reference>urn:nasa:pds:maven:acc:data:reduced:collection</lid_reference>
    <member_status>Primary</member_status>
    <reference_type>bundle_has_data_collection</reference_type>
  </Bundle_Member_Entry>
  <Bundle_Member_Entry>
    <lid_reference>urn:nasa:pds:maven:acc:data:raw:collection</lid_reference>
    <member_status>Primary</member_status>
    <reference_type>bundle_has_data_collection</reference_type>
  </Bundle_Member_Entry>
  <Bundle_Member_Entry>
    <lid_reference>urn:nasa:pds:maven:acc:data:derived:collection</lid_reference>
    <member_status>Primary</member_status>
    <reference_type>bundle_has_data_collection</reference_type>
  </Bundle_Member_Entry>
  <Bundle_Member_Entry>
    <lid_reference>urn:nasa:pds:maven:acc:context:collection</lid_reference>
    <member_status>Primary</member_status>
    <reference_type>bundle_has_context_collection</reference_type>
  </Bundle_Member_Entry>
  <Bundle_Member_Entry>
    <lid_reference>urn:nasa:pds:maven:acc:document:collection</lid_reference>
    <member_status>Primary</member_status>
    <reference_type>bundle_has_document_collection</reference_type>
  </Bundle_Member_Entry>
</Product_Bundle>
```

Appendix D Sample Collection Product Label

This section provides a sample collection product label for the altitude data. Again, the root for this label was the MRO aerobraking accelerometer data. Templates for the final label will be provided by PDS Atmospheres.


```
<?xml version="1.0" encoding="UTF-8"?>
<?xml-model href="http://pds.nasa.gov/pds4/schema/released/pds/v03/PDS4_PDS_0300a.sch" ?>
<Product_Collection xmlns="http://pds.nasa.gov/pds4/pds/v03"
 xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
 xsi:schemaLocation="http://pds.nasa.gov/pds4/pds/v03
http://pds.nasa.gov/pds4/schema/released/pds/v03/PDS4_PDS_0300a.xsd">
 <Identification_Area>  <logical_identifier>urn:nasa:pds:maven:acc:data:derived:collection</logical_identifier>
 <version_id>1.0</version_id>
 <title>PDS4 MAVEN ACCELEROMETER Data Altitude Collection</title>
 <information_model_version>0.3.0.0.a</information_model_version>
  <product_class>Product_Collection</product_class>
  <Modification_History>
   <Modification_Detail>
    <modification_date>2014-03-15</modification_date>
    <version_id>1.0</version_id>
    <description>extracted metadata from PDS3 catalog and
     modified to comply with PDS4 Information Model</description>
   </Modification_Detail>
  </Modification_History>
 </Identification_Area>
 <Collection>
  <collection_type>Data</collection_type>
 </Collection>
 <File_Area_Inventory>
  <File>
   <file_name>maven_altitude_data_collection_inventory.TAB</file_name>
        <local_identifier>maven_altitude_data_collection_inventory_file</local_identi fier>
   <creation_date_time>2014-03-15T12:22</creation_date_time>
  </File>
  <Inventory>
   <local_identifier>maven_altitude_data_collection_inventory</local_identifier>
   <offset unit="byte">0</offset>
   <external_standard_id>PDS_DSV V1.0</external_standard_id>
   <encoding_type>Character</encoding_type>
   <records>426</records>
   <record_delimiter>carriage_return line_feed</record_delimiter>
   <field_delimiter>comma</field_delimiter>
   <Record_Delimited>
    <fields>2</fields>
    <maximum_record_length unit="byte">77</maximum_record_length>
    <Field_Delimited>
     <name>Member_Status</name>
     <field_number>1</field_number>
     <data_type>ASCII_String</data_type>
     <maximum_field_length unit="byte">1</maximum_field_length>
     <description>This column specifies the member status of the data
        products</description>
```

```
        </Field_Delimited>
        <Field_Delimited>
          <name>LIDVID_LID</name>
          <field_number>2</field_number>
          <data_type>ASCII_LIDVID_LID</data_type>
          <maximum_field_length unit="byte">75</maximum_field_length>
          <description>This column specifies the LIDVID of the files that comprise the collection.</description>
        </Field_Delimited>
      </Record_Delimited>
      <reference_type>inventory_has_member_product</reference_type>
    </Inventory>
  </File_Area_Inventory>
</Product_Collection>
```

Appendix E Sample Data Product Labels

This section provides the version 1, release 1 product label for orbit 217.

<u>*Sample label for "PROFILE" date described in Table 15*</u>


```
<?xml version='1.0' encoding='UTF-8'?>
<?xml-model href="http://pds.nasa.gov/pds4/schema/released/pds/v1/PDS4_PDS_1301.sch"
schematypens="http://purl.oclc.org/dsdl/schematron" ?>
<Product_Observational
xmlns="http://pds.nasa.gov/pds4/pds/v1"
xmlns:pds="http://pds.nasa.gov/pds4/pds/v1"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://pds.nasa.gov/pds4/pds/v1
http://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1301.xsd">
  <Identification_Area>
    <logical_identifier>urn:nasa:pds:maven_acc:profile:pro_acc_p00217</logical_identifier>
    <version_id>1.0</version_id>
    <title>MAVEN Accelerometer Profile P00217</title>
    <information_model_version>1.3.0.1</information_model_version>
    <product_class>Product_Observational</product_class>
    <Modification_History>
      <Modification_Detail>
        <modification_date>2014-04-15</modification_date>
        <version_id>1.0</version_id>
        <description>Ver01 uses onboard accel of the COM. Averaging over 99s reduces
       effects of fuel slosh. Cal. of the aero DB is incomplete, so 20% biases may
       exist for science orbits and 10% for deep dip orbits.
        </description>
      </Modification_Detail>
    </Modification_History>
  </Identification_Area>
  <Observation_Area>
    <Time_Coordinates>
      <start_date_time>2014-11-08T09:55:05Z</start_date_time>
      <stop_date_time>2014-11-08T10:05:05Z</stop_date_time>
    </Time_Coordinates>
    <Primary_Result_Summary>
      <purpose>Science</purpose>
      <processing_level>Derived</processing_level>
      <Science_Facets>
       <domain>Atmosphere</domain>
       <discipline_name>Atmospheres</discipline_name>
       <facet1>Structure</facet1>
      </Science_Facets>
    </Primary_Result_Summary>
    <Investigation_Area>
      <name>Accelerometer</name>
      <type>Mission</type>
      <Internal_Reference>
        <lid_reference>urn:nasa:pds:context:investigation:mission.maven</lid_reference>
        <reference_type>data_to_investigation</reference_type>
      </Internal_Reference>
    </Investigation_Area>
    <Observing_System>
      <name>MAVEN</name>
      <Observing_System_Component>
        <name>Accelerometer</name>
        <type>Instrument</type>
        <Internal_Reference>
          <lid_reference>urn:nasa:pds:context:instrument:acc.maven</lid_reference>
          <reference_type>is_instrument</reference_type>
        </Internal_Reference>
      </Observing_System_Component>
      <Observing_System_Component>
        <name>MAVEN</name>
        <type>Spacecraft</type>
        <Internal_Reference>
```

```
      <lid_reference>urn:nasa:pds:context:instrument_host:spacecraft.maven
      </lid_reference>
       <reference_type>is_instrument_host</reference_type>
     </Internal_Reference>
    </Observing_System_Component>
  </Observing_System>
  <Target_Identification>
    <name>Mars</name>
    <type>Planet</type>
    <Internal_Reference>
      <lid_reference>urn:nasa:pds:context:target:planet.mars</lid_reference>
      <reference_type>data_to_target</reference_type>
    </Internal_Reference>
  </Target_Identification>
</Observation_Area>
<Reference_List>
  <Internal_Reference>
    <lid_reference>urn:nasa:pds:maven_acc:document:sis_acc</lid_reference>
    <reference_type>data_to_document</reference_type>
  </Internal_Reference>
  <Internal_Reference>
    <lid_reference>urn:nasa:pds:maven_acc:document:profds</lid_reference>
    <reference_type>data_to_document</reference_type>
  </Internal_Reference>
</Reference_List>
<File_Area_Observational>
  <File>
    <file_name>mvn_acc_l3_pro-acc-P00217_20141108_v01_r01.tab</file_name>
    <local_identifier>PRO_acc_P00217_file</local_identifier>
    <creation_date_time>2015-12-03T17:21:37</creation_date_time>
    <file_size unit="byte">29449</file_size>
    <records>601</records>
  </File>
  <Table_Character>
    <local_identifier>pro_acc_P00217_table_character</local_identifier>
    <offset unit="byte">1</offset>
    <records>601</records>
    <record_delimiter>Carriage-Return Line-Feed</record_delimiter>
    <Record_Character>
      <fields>8</fields>
      <groups>0</groups>
      <record_length unit="byte">49</record_length>
      <Field_Character>
        <name>Seconds from Periapsis</name>
        <field_number>1</field_number>
        <field_location unit="byte">1</field_location>
        <data_type>ASCII_Real</data_type>
        <field_length unit="byte">4</field_length>
        <unit>Seconds</unit>
      </Field_Character>
      <Field_Character>
        <name>Areodetic Latitude</name>
        <field_number>2</field_number>
        <field_location unit="byte">6</field_location>
        <data_type>ASCII_Real</data_type>
        <field_length unit="byte">5</field_length>
        <unit>Degrees</unit>
      </Field_Character>
      <Field_Character>
        <name>Longitude</name>
        <field_number>3</field_number>
        <field_location unit="byte">12</field_location>
        <data_type>ASCII_Real</data_type>
        <field_length unit="byte">5</field_length>
        <unit>Degrees</unit>
      </Field_Character>
      <Field_Character>
        <name>True Local Solar Time</name>
        <field_number>4</field_number>
        <field_location unit="byte">18</field_location>
```

```
          <data_type>ASCII_Real</data_type>
          <field_length unit="byte">4</field_length>
          <unit>Hours</unit>
        </Field_Character>
        <Field_Character>
          <name>Solar Zenith Angle</name>
          <field_number>5</field_number>
          <field_location unit="byte">23</field_location>
          <data_type>ASCII_Real</data_type>
          <field_length unit="byte">5</field_length>
          <unit>Degrees</unit>
        </Field_Character>
        <Field_Character>
          <name>AREODETIC ALTITUDE</name>
          <field_number>6</field_number>
          <field_location unit="byte">29</field_location>
          <data_type>ASCII_Real</data_type>
          <field_length unit="byte">5</field_length>
          <unit>KM</unit>
        </Field_Character>
        <Field_Character>
          <name>DENSITY</name>
          <field_number>7</field_number>
          <field_location unit="byte">35</field_location>
          <data_type>ASCII_Real</data_type>
          <field_length unit="byte">7</field_length>
          <unit>KG/KM**3</unit>
        </Field_Character>
        <Field_Character>
          <name>SIGMA DENSITY</name>
          <field_number>8</field_number>
          <field_location unit="byte">43</field_location>
          <data_type>ASCII_Real</data_type>
          <field_length unit="byte">6</field_length>
          <unit>KG/KM**3</unit>
        </Field_Character>
      </Record_Character>
    </Table_Character>
  </File_Area_Observational>
</Product_Observational>
```

The delivery package includes two manifest files: a transfer manifest, and MD5 checksum manifest. When delivered as part of a data delivery, these two files are not PDS archive products, and do not require PDS labels files. The format of each of these files is described below.

E.1 Transfer Package Directory Structure

Folder	Files	Source	Type
ACCEL_ROOT			bundle
	maven_bundle.xml	PDS Atmos Node	
	readme.txt	"	
ACCEL_ROOT\CONTEXT			collection
	inst.xml	ACC ITF	
	insthost.xml	PDS Atmos Node	
	mission.xml	"	
	mvn.context_collection.xml	SDC	

	mvn.context_collection.inventory.tab	"	
ACCEL_ROOT\DATA	maven_profile_data_collection.xml maven_profile_data_collection_inventory.tab maven_raw_data_collection.xml maven_raw_data_collection_inventory.tab	SDC " " "	
ACCEL_ROOT\DATA\PROFILE \P0001_0099 \P0100_0199 \P0200_0299 . . . \P1200_1299 . . .	Each folder contains two files for each orbit in the 100 orbit range for which there are valid data, the file names are PRO_Pnnnn.TAB and PRO_Pnnnn.XML where nnnn is the 4 digit orbit number.	ACC ITF " " " "	collection
ACCEL_ROOT\DATA\RAW_DATA \P0001_0099\P0001, . . . P0099 \P0100_0199\P00100, . . . P0199 \P0200_0299\P0200, . . . P0299 . . . \P1200_1299\P1200, . . . P1299 . . .	There is a folder for each orbit containing four data files and four xml files ACCEL.TAB, QUAT.TAB, RATE.TAB, RWA.TAB ACCEL.XML, QUAT.XML, RATE.XML, RWA.XML	SDC " " " "	collection
ACCEL_ROOT\DOCUMENT	Folder contains ALTDS.TXT, PROFDS.TXT,RAWDS.TXT,SIS_ACC.TXT ALTDS.XML, PROFDS.XML,RAWDS.XML,SIS_ACC.XML MAVEN_DOCUMENT_COLLECTION.XML and MAVEN_DOCUMENT_COLLECTION_INVENTORY.TAB	TBD " " " "	collection
ACCEL_ROOT\SCHEMA	Folder contains three files PDS4-PDS_0300a.SCH PDS4-PDS_0300a.XSD PHX_SCHEMATRON1.SCH	TBD " " "	collection

Appendix F Transfer Package Structure

F.1 Transfer Manifest Record Structure

The transfer manifest is defined as a two field fixed-width table where each row of the table describes one of the products in the package. The first field defines the LIDVID of each product in the package. The second field defines the file specification name of the corresponding product label in the package. The file specification name defines the name and location of the product relative to the location of the bundle product.

F.2 Checksum Manifest Record Structure

The checksum manifest consists of two fields: a 32 character hexadecimal (using lowercase letters) MD5, and a file specification from the root directory of the unzipped delivery package to every file included in the package. The file specification uses forward slashes (“/”) as path delimiters. The two fields are separated by two spaces. Manifest records may be of variable length. This is the standard output format for a variety of MD5 checksum tools (*e.g*. md5deep, etc.).