MAVEN
Mars Atmosphere and Volatile Evolution Mission
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Mars Atmosphere and Volatile Evolution (MAVEN) Mission

Solar Energetic Particle (SEP) Instrument

PDS Archive

Software Interface Specification

Latest version: 18 October 2018

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Software Interface Specification

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1 Introduction

This software interface specification (SIS) describes the format and content of the Solar Energetic Particle Instrument (SEP) 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

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1.2 Document Change Log

Table 2: Document change log

Version	Change	Date	Affected portion
0.0	Initial template	2012-Aug-24	All
0.1	Updated template	2013-Feb-13	All
0.2	Final template	2013-Feb-15	All
0.3	Revised for SEP	2013-Aug-01	All
0.11	Substantial edits	2014-Mar-24	All
1.4	Further edits	2014-Jun-24	All
1.5	First Official Release	2014-Jul-08	All
1.7	Post-PDS Preliminary review	2014-Nov-10	All
1.8	Post-PDS Delta review	2017-Feb-02	All
1.9	Final Peer Review Edits	2018-Oct-18	All

1.3 TBD Items

Table 3 lists items that are not yet finalized.

Table 3: List of TBD items

Item	Section(s)	Page(s)

1.4 Abbreviations

Table 4: Abbreviations and their meaning

Abbreviation	Meaning
ADC	Analog-Digital Converter (values)
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
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
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
HTML	Hypertext Markup Language
ICD	Interface Control Document
IM	Information Model
ISO	International Standards Organization
ITF	Instrument Team Facility

Abbreviation	Meaning
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 Identifer
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
MSE	Mars Solar Ecliptic Coordinate System
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)
SCET	Spacecraft Event Time
SDC	Science Data Center (LASP)
SCLK	Spacecraft Clock
SEP	Solar Energetic Particle instrument (SSL)
SIS	Software Interface Specification

Abbreviation	Meaning
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
THEMIS	NASA heliophysics mission: ‘Time History of Events and Macroscale Interactions during Substorms’
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 occurred on September 21, 2014. Following an 8-week transition phase, the spacecraft began orbiting 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). Periapsis precesses 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 explores down to the homopause during a series of five 5-day "deep dip" campaigns for which periapsis will be lowered to an atmospheric density of 2 kg/km^3 (~125 km altitude) in order to sample the transition from the collisional lower atmosphere to the collisionless upper atmosphere. These five campaigns are interspersed though the mission to sample the subsolar region, the dawn and dusk terminators, the anti-solar region, and the northpole.

1.6.1 Mission Objectives

The primary science objectives of the MAVEN project is 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 is enabling scientists, for the first time, to reliably project processes backward in time to study atmosphere and volatile evolution. MAVEN is delivering 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 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 accomplishes 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 achieves 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 samples 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 are 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 allows thorough identification of the role that atmospheric escape plays today and to extrapolate to earlier epochs.

1.6.2 Payload

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

- NGIMS Package:
  - Neutral Gas and Ion Mass Spectrometer (NGIMS) measures the composition, isotope ratios, and scale heights of thermal ions and neutrals.
- RS Package:
  - Imaging Ultraviolet Spectrograph (IUVS) remotely measures 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.
- PF 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.

1.7 SIS Content Overview

Section 2 describes the Solar Energetic Particle Instrument (SEP) sensor. 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 6.2. 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. Appendix F describes SEP archive product PDS delivery formats and conventions. Appendix G contains PDS metadata conventions for describing the logical of the SEP data files.

1.8 Scope of this document

The specifications in this SIS apply to all SEP 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 SEP team and by PDS.

1.9 Applicable Documents

[1] Planetary Data System Data Provider's Handbook, Version 1.4.1, February 23, 2016.

[2] Planetary Data System Standards Reference, Version 1.4.0, September 22, 2015.

[3] PDS4 Data Dictionary, – Abridged, Version 1.4.0.0, 30 March 2015.

[4] Planetary Data System (PDS) PDS4 Information Model Specification, Version 1.4.0.0.

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

[6] Larson, D.E., Lillis, R.J., Hatch, K., Robinson, M., Glaser, D., Dunn, P., Curtis, D.W., 2014. The MAVEN Solar Energetic Particle Investigation. Submitted to Space Science Reviews.

[7] Archive of MAVEN CDF in PDS4, Version 3, T. King and J. Mafi, March 13, 2014.

1.10 Audience

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

2 SEP Instrument Description

The Solar Energetic Particle Instrument (SEP) (see Figure 1, Figure 2) consists of 2 sensors, each consisting of a pair of double-ended solid-state telescopes, measuring electrons and ions over the energy ranges ~30-1000 keV and ~30-12,000 keV/nuc respectively. The SEP sensors are closely based on the Solid State Telescope (SST) sensors on the THEMIS probes and also share significant heritage with the SupraThermal Electron (STE) detectors on STEREO and the SST detectors on the Wind spacecraft.

The SEP sensors are mounted on two corners of the top deck of the spacecraft as shown in Figure 3, positioned to ensure that the fields of view (FOVs) adequately cover the canonical Parker spiral direction (around which solar energetic particle distributions are typically centered), while 1) always avoiding glint from the spacecraft, other sensors and the Articulated Payload Platform (APP) and 2) avoiding direct sunlight during spacecraft attitudes typical of normal science operations.

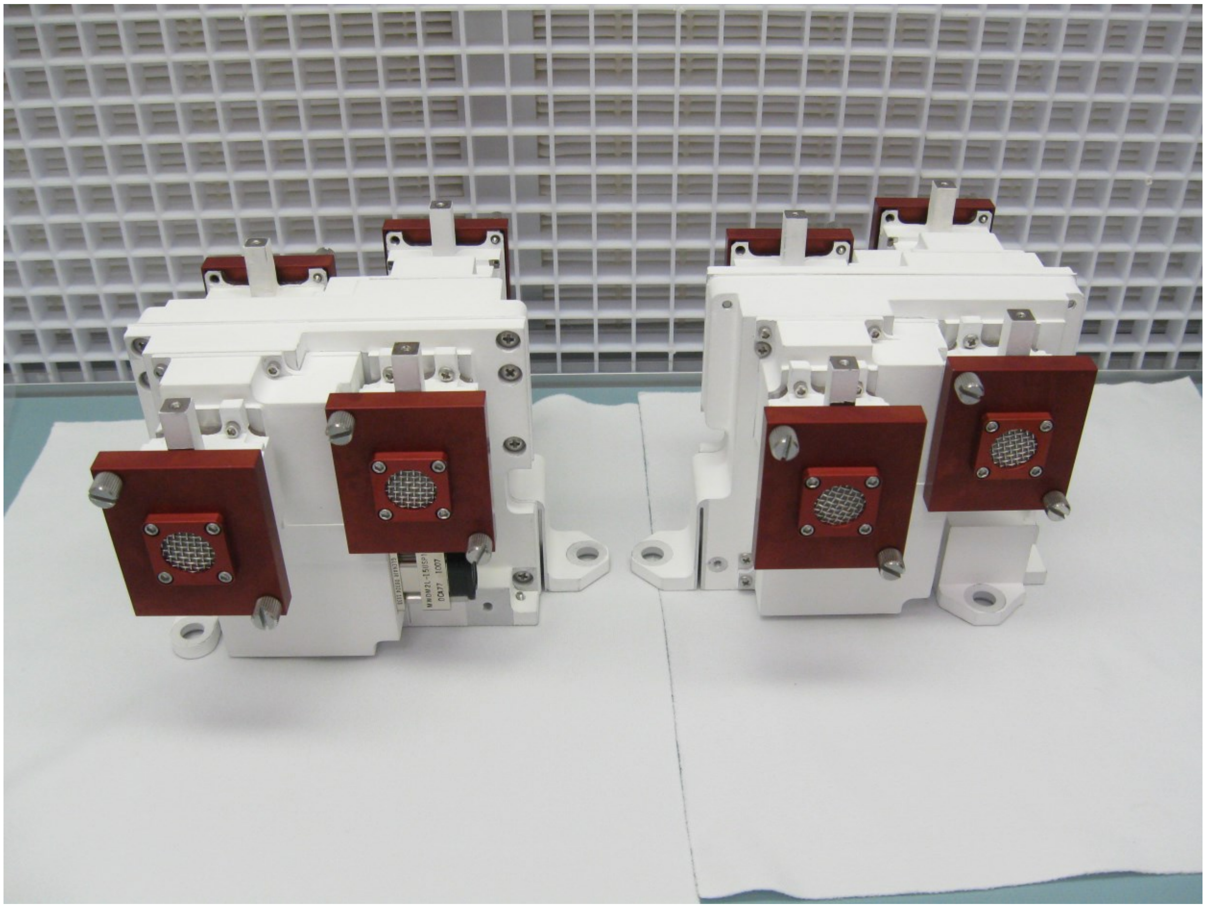


Figure 1:the two identical SEP sensors. The red aperture covers were removed before flight.

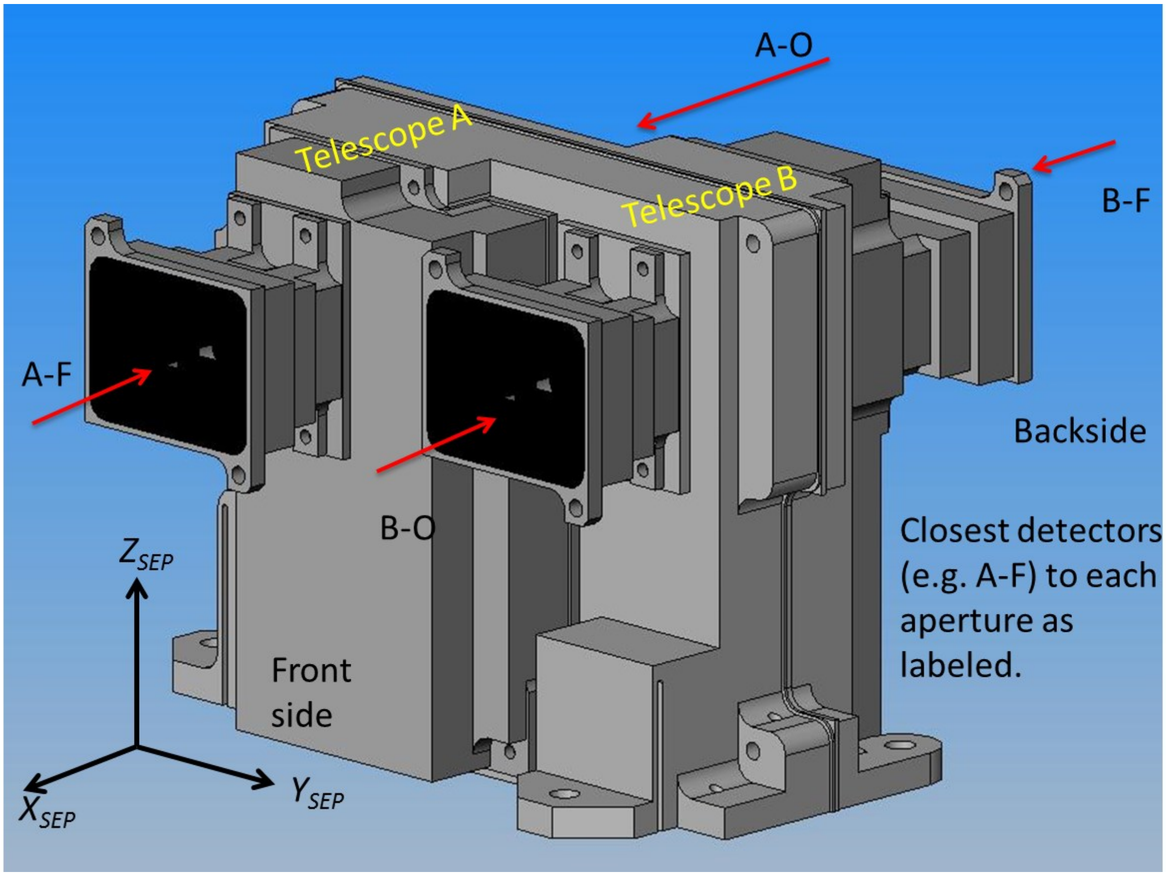
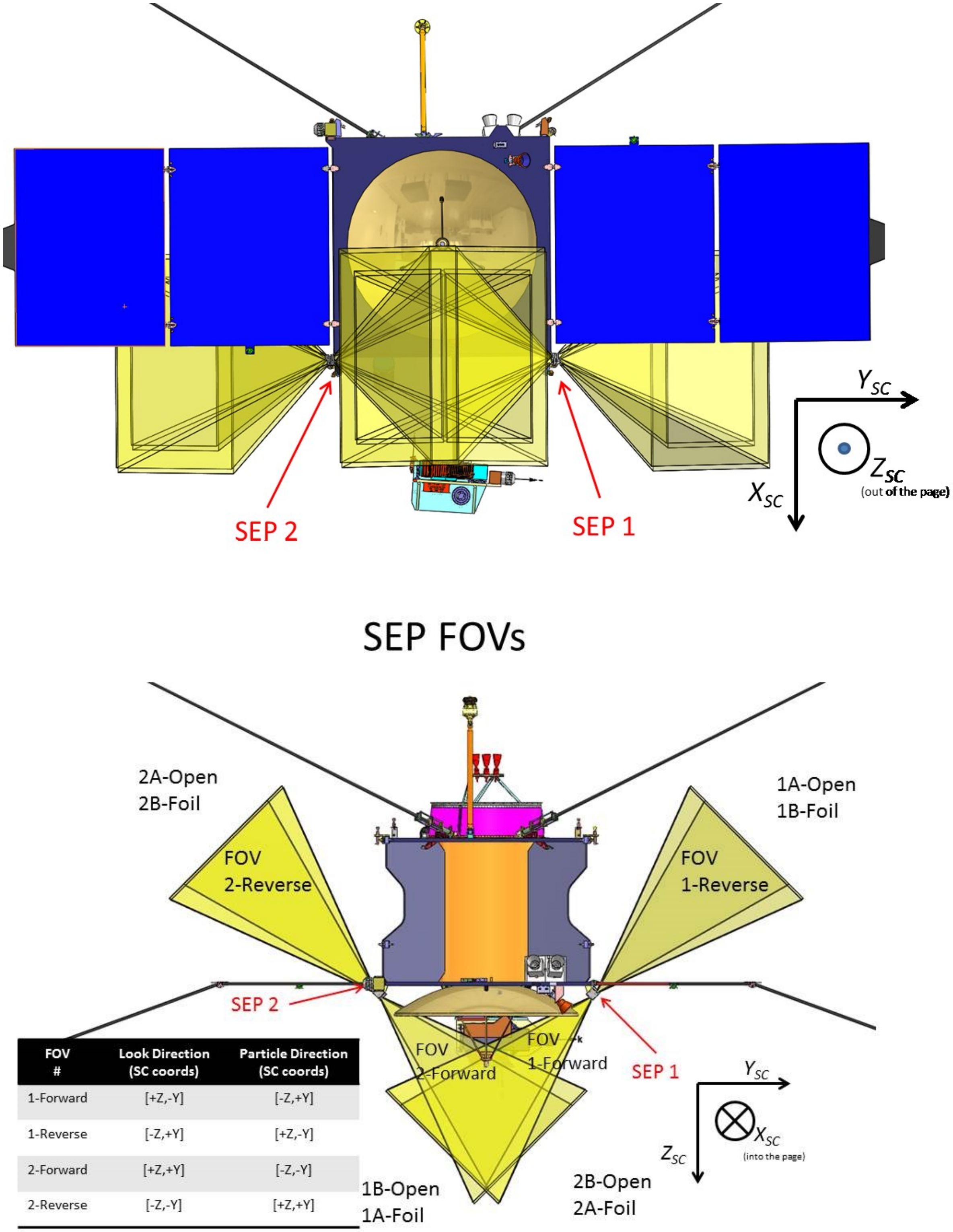


Figure 2: perspective view of SEP sensor identifying (a) particle directions (red arrows), (b) each aperture labeled with the name of the detector facing that aperture, (c) the sensor coordinate system, (d) the telescope identifier (TID) A or B and (e) the front and back sides of the sensor.



FOV #	Look Direction (SC coords)	Particle Direction (SC coords)
1-Forward	[+Z,-Y]	[-Z,+Y]
1-Reverse	[-Z,+Y]	[+Z,-Y]
2-Forward	[+Z,+Y]	[-Z,-Y]
2-Reverse	[-Z,-Y]	[+Z,+Y]

Figure 3: The location and fields of view (FOVs) of the SEP sensors on the spacecraft with the spacecraft coordinate system shown.

2.1 Science Objectives

SEP provides measurements that satisfy the MAVEN level 1 requirement to determine solar energetic particles characteristics, 50 keV to 5 MeV protons, with ~1 hr time resolution, energy resolution better than 50% and precision better than 30%.

MAVEN carries a suite of instruments that measure the significant energy inputs into the Martian system and the neutral and charged populations of escaping atmospheric gases, in order to determine how the former drives the latter, with the goal of characterizing the state of the upper atmosphere and its evolution over Mars' history. Within this framework, the main science objective for the SEP instrument is to measure the properties of the energy input to the Martian system from solar energetic particles. As they lose their energy in the atmosphere, precipitating SEPs cause heating, ionization, dissociation and excitation of atmospheric neutrals, thereby substantially affecting atmospheric and ionospheric dynamics and chemistry. Those with energies below ~200 keV deposit energy above the homopause and can therefore directly affect atmospheric escape. Therefore, characterizing SEP fluxes is an important goal of the MAVEN mission.

In order to achieve these science goals, SEP satisfies and in most cases significantly exceeds the following MAVEN Level 3 measurement requirements:

- SEP shall measure energy fluxes from 10 to 10^6 eV/[cm^2 s sr eV].
- SEP shall measure ions from 50 keV to 5 MeV.
- SEP shall have energy resolution ΔE/E at least 50%
- SEP shall have time resolution of at least 1 hour or better

2.2 Instrument configuration and Detectors

The SEP instrument consists of two sensors (SEP 1 and SEP 2), each consisting of a pair of double-ended solid-state telescopes (referred to as 'A' and 'B'). At opposite ends of each telescope exist baffled collimators with identical apertures measuring 42° x 31°. Each telescope consists of a stacked triplet of doped silicon detectors. The outer detectors of the stack are 300 µm thick, while the middle detector consists of two 300 µm detectors wire-bonded together, making an effective thickness of 600 µm. One side of the detector stack is covered with a 2.43 µm Al-Kapton-Al foil to stop ions with energies of < 250 keV/nuc, and is known as the "Foil" side. The 300 µm detector on the "Foil" side of the stack (i.e. closest to the foil) is referred to as the "F" detector. On the other side of the detector stack is a strong magnetic field (~0.25T), created by yoked Sm-Co magnets, to sweep away all electrons with energies <350 keV, and is known as the "Open" side. The 300 µm detector on the "Open" side is known as the "O" detector and is coated with ~900 Å of aluminum to prevent reflected light from sunlit Mars from creating detector noise. The 600 µm middle detector is known as the "Thick" or "T" detector. Each sensor unit has 4 co-moving attenuator paddles with small pinholes which can be rotated into the FOVs of both sides of both detector stacks to reduce particle fluxes by a factor of ~60 and to prevent direct sunlight from damaging the detectors. The yoked magnets are housed in a central magnet cage with oppositely directed magnetic fields for each telescope in order to minimize external DC magnetic fields.

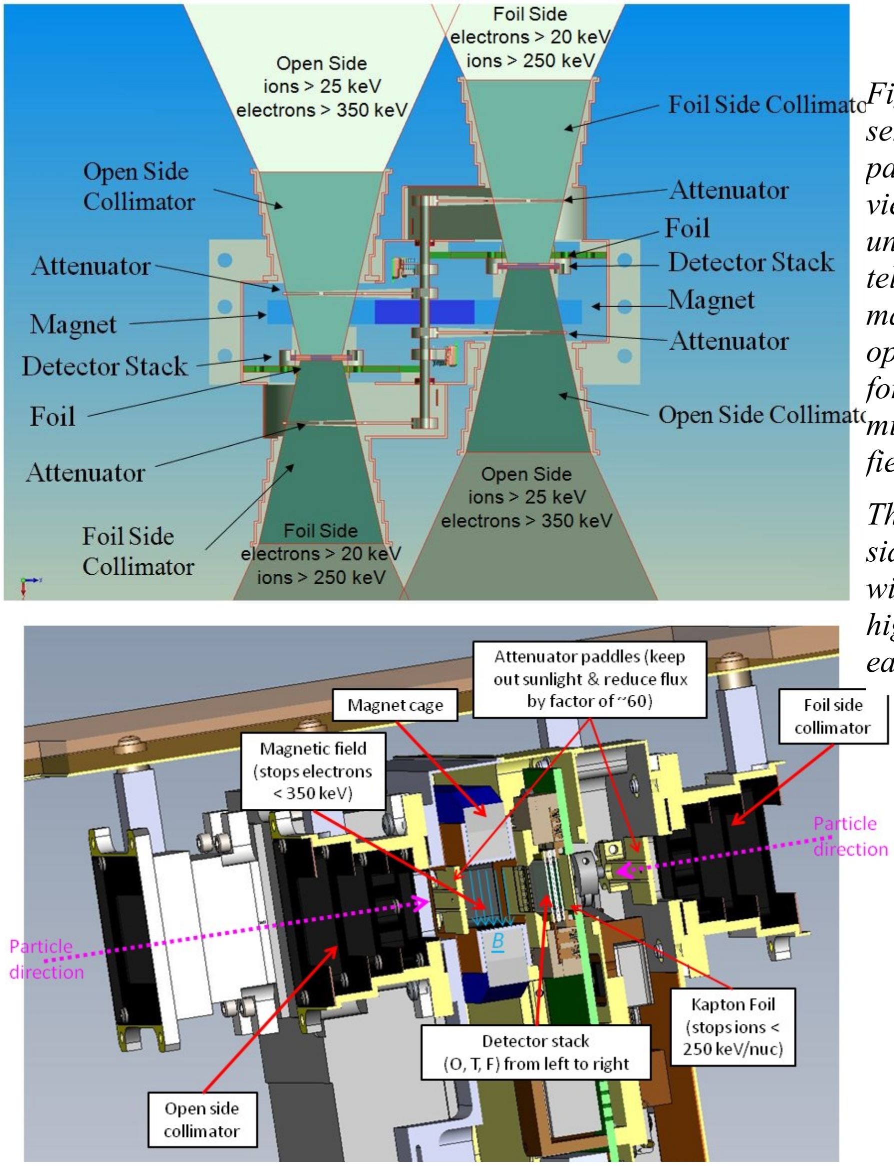


Figure 4: Views of SEP sensor optics. The top panel shows a top-down view of one SEP sensor unit. Note that both telescopes share a single magnet cage with oppositely-directed fields for each telescope, to minimize external magnetic fields.

The bottom panel shows a side view of one SEP sensor with a cross section to highlight the features of each telescope.

2.3 Detector signal processing

SEP does not calculate electron or ion count rates on board because electrons and ions can mimic each other in terms of the amount of energy deposited and the detector in which it is deposited. Instead, each sensor divides all possible combinations of energy deposited and the detector (or detectors) triggered, into 256 bins called event counters. An example of a counter would be “all events triggering only the A-F detector and depositing between 27 keV and 31 keV”. We will describe below the process by which an incident particle striking a detector results in the incrementing of one of these counters.

SEP uses a signal processing chain typical of particle detectors as shown schematically in Figure 5. When a charged particle passes through or stops in one of the silicon detectors, it results in the creation of a quantity of electron-hole pairs proportional to the energy deposited. These pairs are accelerated by a ~40 V bias potential across the detector and result in a voltage/current pulse, which is then amplified using Amptek 250F charge sensitive amplifiers. The signal is transmitted by coaxial cables to the Data Acquisition and Processing (DAP) board where it is shaped to a 2.5 µs (zero to peak) unipolar Gaussian pulse. A threshold comparator is used to trigger a measurement if the pulse exceeds an adjustable threshold value. Peak detect circuitry is used to detect the peak in pulse height to sample the pulse magnitude with a 16 bit Analog-to-Digital Converter (ADC). A Field Programmable Gate Array (FPGA) controls the ADC triggering and readout and all subsequent event binning and telemetry production. Since the pulse height is proportional to the energy deposited, the ADC value is proportional to the energy deposited in the detector. All the detectors have depletion layers (or 'dead' layers) of a few hundred angstroms thickness at their surfaces, where no electron-hole pairs are present to record energy deposition. The open detectors have an additional ~900 Å of vapor-deposited aluminum that acts as an additional effective dead layer, hence the energy deposited in the 'active' volume of the detector is always lower than the total energy deposited. Energy lost to phonons and nuclear recoils is also not measured. These factors all contribute to pulse height defect and are accounted for in the instrument modelling. Note that more precise thicknesses of these dead layers were determined by laboratory calibrations and simulations (see section 3.2). Each signal chain also includes a gated baseline restoration circuit that insures the baseline stays at zero voltage even at high count rates. The FPGA is programmed to periodically measure the baseline signal in the absence of particle events and generates a 10 bin histogram for each channel. The baseline (aka pedestal) and noise level are determined from these histograms which are returned in the telemetry. The baseline level of every channel was tuned with trim resistors during assembly to produce an average bin value centered at zero.

Each channel has a test pulser with adjustable amplitude for testing in the absence of ionizing radiation. The test pulser can be used to verify the gain and baseline of each channel has not changed. It cannot be used to detect changes in overall calibration since it does not respond to changes in pulse height defect in the detectors.

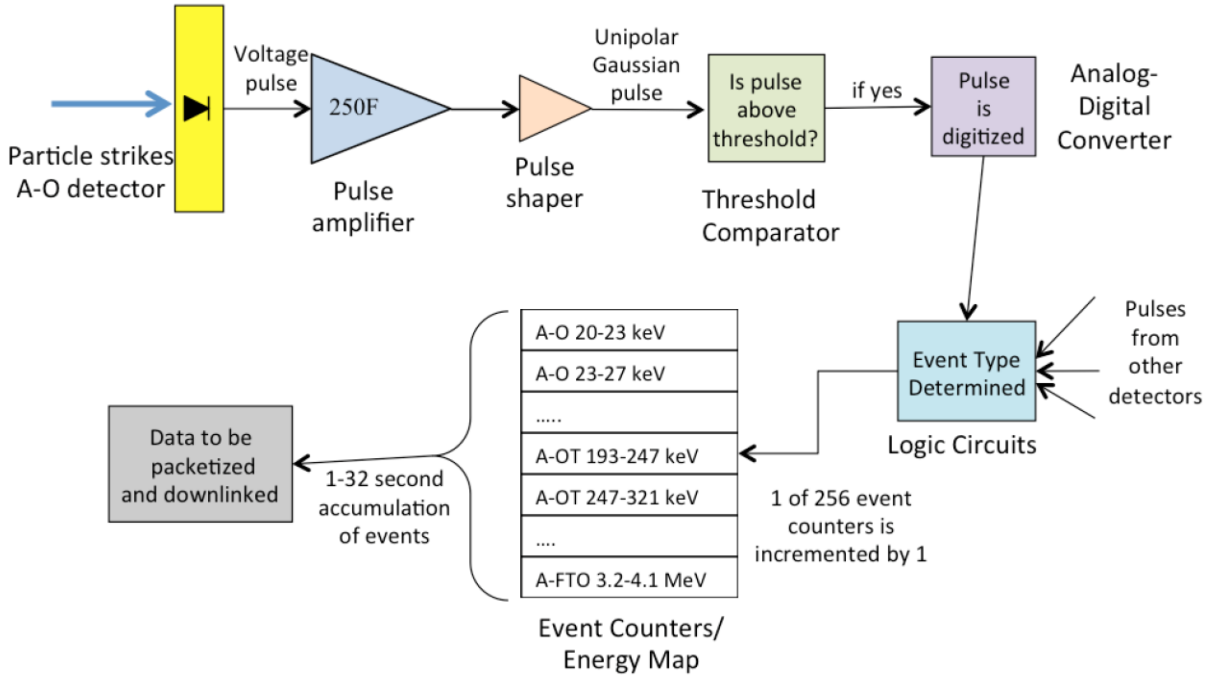


Figure 5 Schematic description of the SEP signal processing for the example of the A-O detector.

Is If an incident particle deposits more than ~11 keV (the electronic noise threshold) in a detector, the voltage pulse is large enough to trigger an ‘event’ and the amount of energy deposited is digitized with a resolution of 1.36-1.54 keV (small differences exist across the 12 channels; see Table 3). Logic circuits characterize particle events by the combination of detectors which are simultaneously triggered (i.e. into which sufficient energy is deposited so that the pulse is detected). For example, an ‘F’ event is one in which the incident particle deposits all its energy in, and hence only triggers, the F detector. An ‘FT’ event is one in which both F and T detectors are simultaneously triggered, i.e. the particle passes through (and deposits energy in) the F detector, then deposits more energy and stops in the T detector.

Each event type (O, T, FTO, etc.) can be triggered by either an electron or an ion entering from one or both ends of each telescope. Figures 6 shows, with a table (left) and associated diagram (right), the approximate energy ranges and paths of electrons and ions that trigger F, FT, FTO, OT, and O events. FO events are considered to be two simultaneous separate F and O events. The energy ranges shown are taken directly from normal-incidence GEANT4 simulations. Figure 7 shows (from these simulations) the probability that a normally-incident electron or ion will be detected as a given event type. It shows that certain combinations of the event type and energy are unambiguous while others are ambiguous, i.e. an O event of 40 keV or 4 MeV must be an ion, but an O event of 500 keV could be electron or an ion. Thus the combination of the event type and energy are used as an anti-coincidence system to enable background subtraction. It also shows that FTO events cannot have a direction ascribed to them since the particle could have come through either aperture.

Incident energy ranges for counted events

	Electrons		**Ions**	
	Foil side keV	Open side keV	Foil side keV	Open side keV
No count	<20	<350	<250	<25
F	20-1000		250-6000	
FT	300-2000		6000-11,000	
FTO	>600		>11,000	
OT		400-2000		6000-11,000
O		200-800		25-6000

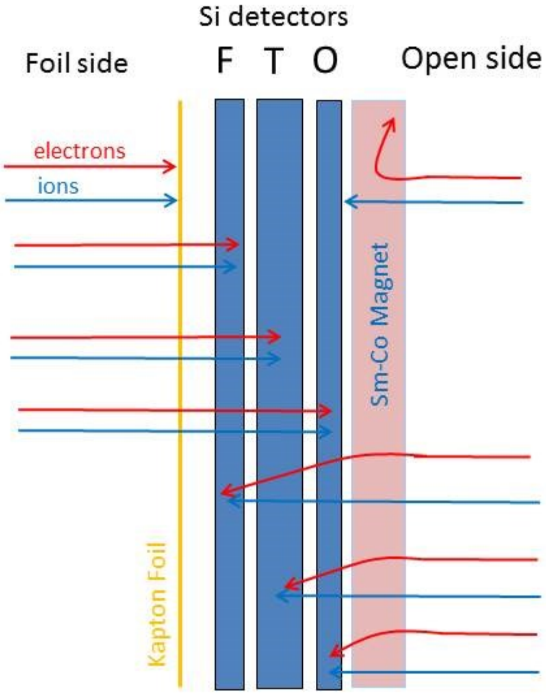


Figure 6: The particles and energies that result in different event types. (a) The table on the left shows the approximate ranges of energies of electrons or ions coming from the foil or open side that will result in the different types of events (F, FT, FTO, OT, and O) recorded by the SEP sensor. The schematic diagram on the top right is aligned with each row of the table showing the paths of electrons (red) and ions (blue) from the foil or open side which results in these types of recorded events.

The energy and type of each event determines which event counter will be incremented following the event. Each SEP sensor (i.e. SEP1 and SEP 2) has 256 16-bit event counters which are shared by two telescopes (typically 128 bins per telescope). The event type and energy boundaries of each counter (e.g. all F events in the range 20 - 23 keV) are known as the 'energy map'. Energy bins are spaced approximately logarithmically to provide a roughly constant dE/E. The better resolution at the low end of the SEP energy range allows better characterization of energy deposition to the Martian thermosphere. Figure 8 shows an example of an energy map, named “Flight3”. This map was used from Mars orbit insertion (September 21, 2014) until at least the end of 2016.

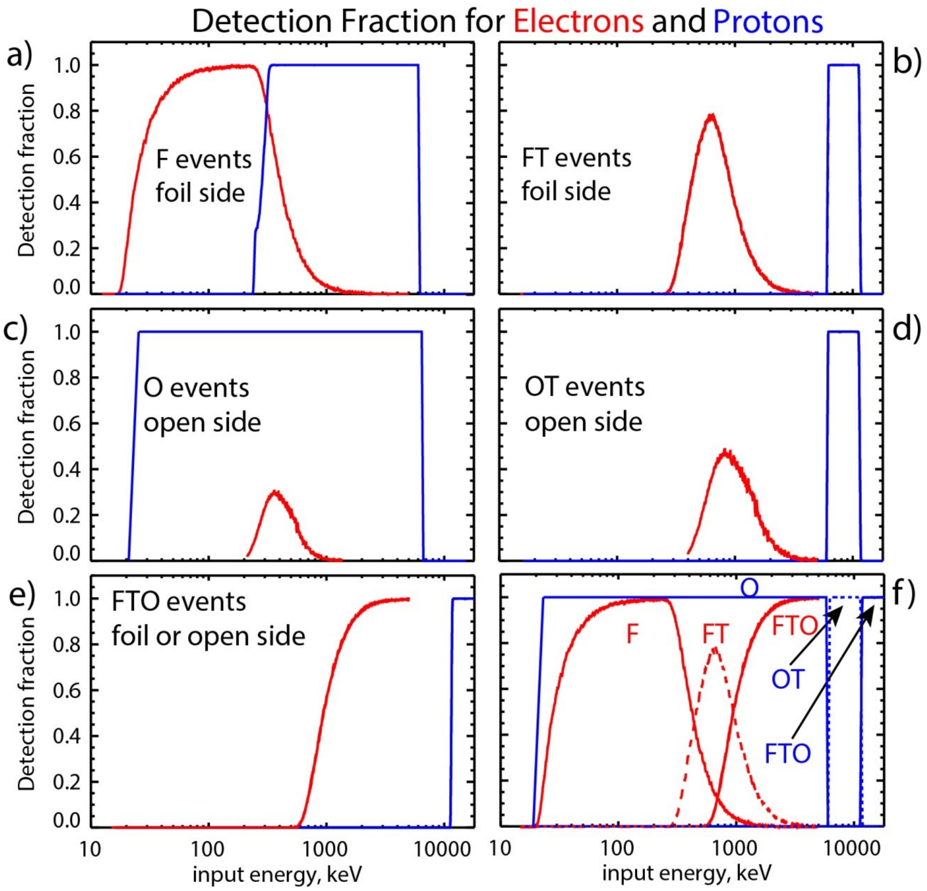


Figure 7 the probability that a normal-incidence electron or ion will be detected as a given type of event. Electron curves are shown in red and ion curves are shown in blue. Panels a) and b) in the top row show the fraction of electrons or ions from the foil side (see figure 4 and 6 schematic) that are detected a F or FT events respectively, as a function of energy. Panels c) and d) in the second row show the fraction of electrons or ions from the open side that are detected as O or OT events respectively, as a function of energy. Panel e) shows the fraction of electrons or ions that are detected as FTO events; curves are nearly identical for foil or open side and so are not shown separately. Panel f) shows in red probability curves for electrons coming from the foil side to be detected as F, FT or FTO events and in blue probability curves for protons coming from the open side to be detected as O, OT or FTO events.

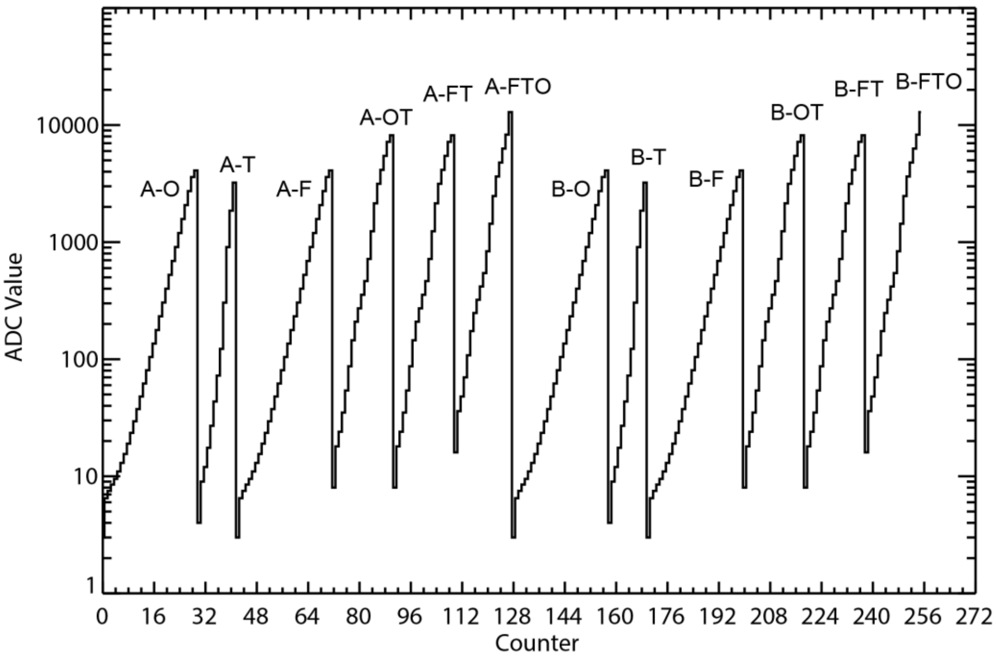


Figure 8: "Flight 3" instrument map showing the range of ADC values and event types for each of the 256 counters for each SEP sensor. The conversion from ADC value to particle energy is shown in Table 3. This map was used from Mars orbit insertion (September 21, 2014) until at least the end of 2016

The 128 counters are read out via serial interface to the Particles in Fields Digital Processing Unit (PFDPU) every 1 second, where they are summed over the data acquisition interval of 2, 8 or 32 seconds before being packetized and sent to the ground in science data packets (APID 0x70 or 0x71). These arrays of event counters form the SEP Level 1 data. Level 2 data (i.e. fluxes of electrons and ions) require on-the-ground processing of these arrays of event counters, as described in section 4.

2.4 Detector Response and Calibration

On the ground, the aforementioned arrays of event counters must be processed into calibrated ion and electron spectra. This processing requires an accurate instrument calibration, i.e. measuring the detector response to particles of different types with a well-known energy. This calibration requires two distinct steps.

2.4.1 Absolute energy calibration

The first step is the absolute energy calibration, i.e. determining the relationship between the energy deposited and the digitized height of the amplified, shaped pulse output by the ADC. This is achieved by measuring the response to x-ray lines whose energies are very well-known, in this case the 59.54 keV line of radioactive Americium-241. Photons deposit energy in material primarily through three mechanisms: photoelectric effect, Compton scattering and pair production. Unlike charged particles, photons do not lose energy as they transit the dead layer. The cross section of low energy photons is dominated by the photoelectric effect and this interaction produces a narrow energy response at the photon energy, making them ideal for absolute energy calibration. Table 3 shows the number of ADC units per keV and their uncertainties for each of the 12 SEP detectors. ADC units per keV are given instead of their inverse (often thought of as 'gain') because their uncertainties are symmetric. The baseline values (not shown) are all within 0.1 bins.

Detector	A-F	A-T	A-O	B-F	B-T	B-O
SEP 1	0.690± .025	0.646± .032	0.735±.024	0.711±.024	0.677±.032	0.705±.022
SEP 2	0.738±.026	0.741±.034	0.676±.023	0.705±.023	0.739±.034	0.726±.024

Table 5: number of ADC units per keV for each detector in each of the 2 SEP sensors.

2.4.2 Ion energy and detector dead layer calibration

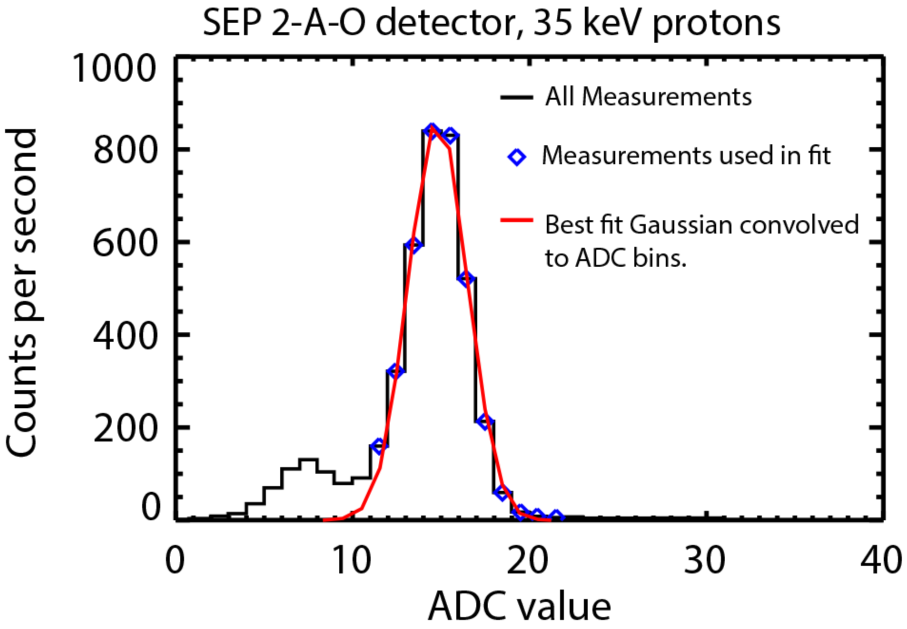


Figure 9: ion calibration example. Counts per second are plotted as a function of ADC value for an ion gun energy of 35 keV for detector SEP 2-A-O. The modeled values (red) are plotted against the measured values (black). The minor peak on the left is an artifact of the ion gun which produced a low energy population of protons. The low energy peak was not used in the fit.

The second calibration step is to determine the sensor response to charged particles, which can deposit energy in more than one detector and in other parts of the instrument. Since it was not possible to expose the SEP sensor to electrons and ions of all relevant energies (up to 1 MeV for electrons and ~13 MeV for protons), it is necessary to compare the charged particle response over a limited energy range with GEANT4 modelling [*Agostinelli et al.*, 2003; *Allison et al.*, 2006] of the detector response to the same range and find the model that provides the best fit to the instrument data.

Ground calibration for protons was performed with an ion gun at fixed proton energies of 25, 30, 35 and 40 keV (other ion species were filtered out using a Wien filter). Figure 9 shows an example for the detector A-O on the SEP 2 sensor of counts as a function of ADC value from the calibration test using the ion gun at 35 keV. The purpose of this was to characterize the thickness of the effectively dead layer of Si and Al on each of the four O detectors. The Al dead layer was held fixed at the manufacturer-specified 900 Å and the Si dead layer (modeled as a step-function transition from active to dead) was varied from 50 to 800 Å in the GEANT4 proton simulations. All contributions to pulse height defect (phonons, nuclear recoils, energy lost in the dead layer) are modeled by GEANT4 and therefore included in the calibration. The misfit between the energy measured by the instrument and the energy deposited in the detector in the simulation was calculated. Figure 10 shows the shape of the misfit curves as a function of modeled dead layer thickness (left) and the comparison of the best-fit modeled proton response curves to the measured proton response (right). The best-fit effective dead layer thicknesses for SEP1A, SEP1B, SEP2A and SEP2B are 150, 280, 640 and 270 Å respectively. In a real detector the transition from dead to active silicon is not a step function (i.e. it occurs over a finite distance) but our modeling of this sharp 'effective' dead layer is sufficient to characterize the response of the 'open' detectors.

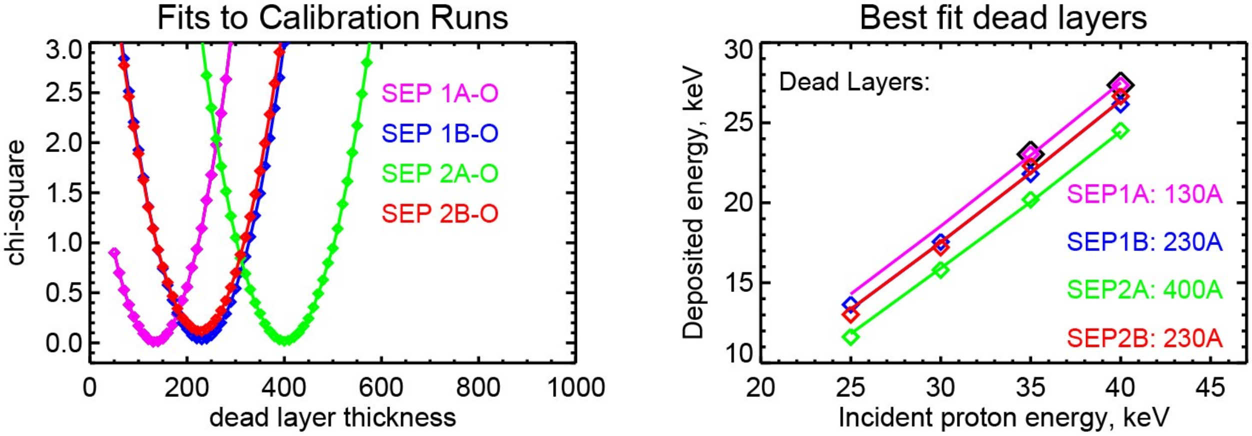


Figure 10: The left panel shows the data-to-model misfit as a function of dead layer thickness for the O detectors of each of the SEP detector stacks: 1A-pink, 1B-blue, 2A-green, 2B-red. The right panel shows, as unjoined diamonds, the measured deposited versus incident proton energy. The solid lines are the model results for the silicon dead layer thickness that best fits the measurements, using the same color legend.

2.4.3 SEP electron calibration

The third calibration step is to determine the sensor response to electrons. An electron gun was aimed at the sensor in vacuum, while the electron energy was slowly increased from 10 keV up to 40 keV (Figure 11, top panel). The raw calibration results are shown in Figure 11 (middle panel). The first detectable counts (i.e. energy depositions that produce a signal above the electronic noise threshold of ~11 keV) begin around the incident electron energies of ~14 keV, as shown in the middle panel). The peak in the spectrum was determined for each incident energy. Sensitivity of the sensors to electrons is robust for incident energies above 20 keV. The middle panel shows there is a significant response in ADC bins at all energies below the peak (overlayed with a black line). This is a typical response caused by electrons that enter the active region of the detector and then backscatter out of the detector before they can deposit their full energy. This effect is observed in GEANT4 simulations. There is an additional, though much weaker, response in ADC bins that correspond to deposited energies at 2 or 3 times the incident electron energy (see blue/violet shaded region of Figure 11, middle panel). This is the result of the pulse pileup when two or more electrons hit the detector at the same time. This effect is accentuated by the generation of electrons in the gun. These electrons are generated by UV photons impinging on a photocathode that is held at a large negative voltage. Since the photocathode is powered by an AC supply there is an increased probability of the production of simultaneous photons and subsequent electrons. The bottom panel shows the total count rate summed over all bins.

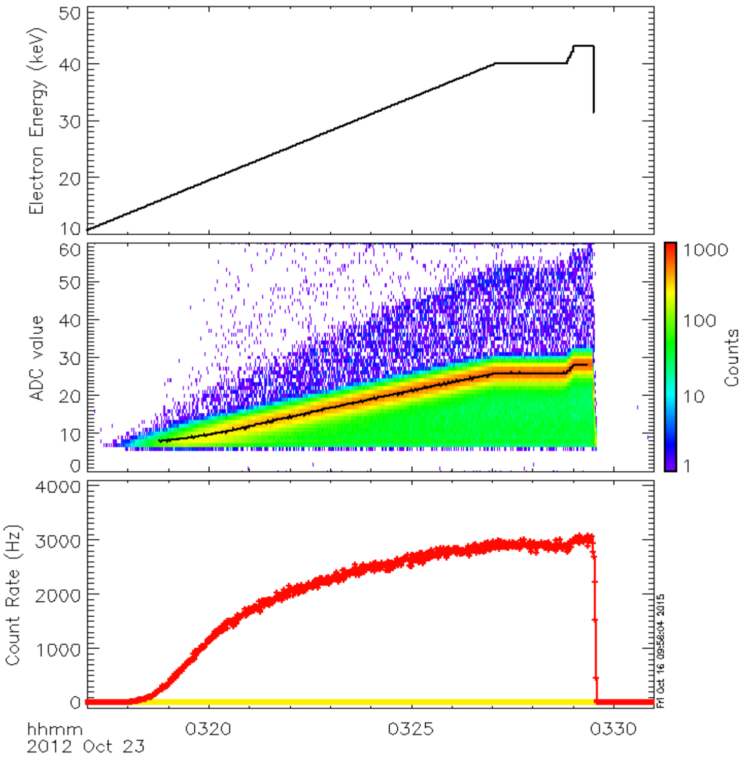


Figure 11: Raw data showing the SEP2B instrument response to incident electrons. The top panel shows the incident electron energy. The middle panel shows the count rate in each ADC bin. The black line shows the ADC bin where the maximum in counts occurs. The bottom panel shows the total count rate (proportional to total efficiency).

Figure 12 (top panel) shows the peak in the response function (Figure 11, middle panel) plotted against the corresponding incident electron energy (Figure 11, top panel), compared with a perfect 'lossless' detector (dashed line). The difference between the dashed line and the solid line represents the energy lost in the Kapton foil (and dead layer), which is typically less that 5 keV). The response curve should not be trusted near the low-energy end where the measured energy is just above the electronic noise threshold value (~11 keV, marked by the horizontal dashed line). The bottom panel of Figure 12 shows the count rate as a function of incident electron energy, representing the relative detection efficiency as a function of electron energy. Note that the absolute efficiency can only be determined from GEANT4 modeling.

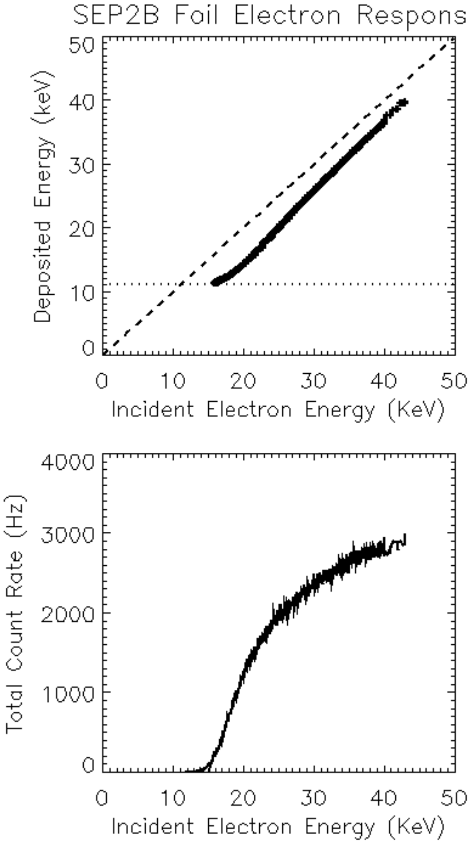


Figure 12: (top panel) Measured electron energy vs incident electron energy derived from the data shown in Figure 11 and using the gain from Table 3. The horizontal dotted line marks the electronic noise threshold of ~11 keV. (bottom panel) Total count rate vs incident electron energy.

2.4.4 Deconvolution of electron and ion spectra

Knowledge of the dead layer thicknesses of each of the O detectors, along with a detailed knowledge of the mechanical structure and material properties of the sensor, allows for accurate modeling of the detector response to a wide range of electron and ion energies via GEANT4 simulations. It is particularly important to separate the contamination effects of electrons and ions on the same event type (e.g. a 250 keV proton entering the foil side collimator loses between 170 and 250 keV in the foil and deposits 0 to 80 keV in the F detector, mimicking an electron of that energy) and to model background counts caused by galactic cosmic rays penetrating the instrument housing.

Even though the electronic noise threshold is ~11 keV, the energy losses mentioned above mean the effective low-energy threshold is ~20 keV for electrons and ~25 keV for ions and varies slightly by detector (see Figure 6a , left).

For each of the instrument maps (e.g., Figure 8) and for each SEP sensor, a set of response matrices were derived from GEANT4 simulations. Matrices were derived for both telescopes within each sensor (A and B), 6 event types (F, T, O, FT, OT, FTO), 4 particle types (electrons, protons, alphas and photons), 2 attenuator states (open and closed) and 2 particle directions (forward and reverse look directions), totaling 192 response matrices. These matrices constitute a forward model for converting electron and ion energy spectra in 4 look directions into count rates in 256 counters in each SEP sensor. Figure 13 shows 4 of such response matrices for the "Flight3" instrument map shown in Figure 8.

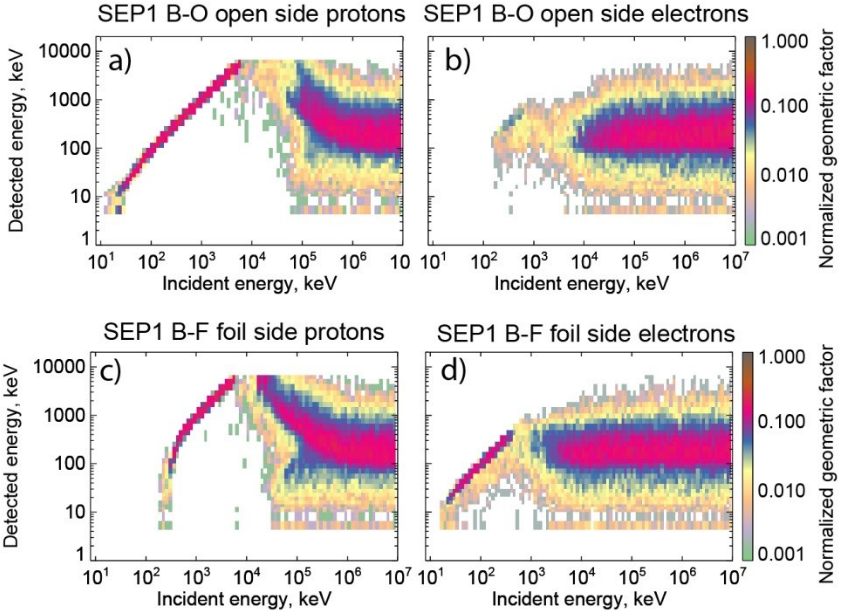


Figure 13: Four example response matrices derived from GEANT4 simulations. Panels a) and b) show the normalized geometric factor for protons and electrons respectively, coming from the front side of the SEP 1 sensor and causing 'O' energy deposition events in the 'B' telescope while the attenuator is open. Panels c) and d) show the normalized geometric factor for protons and electrons respectively, coming from the rear side of the SEP 1 sensor and causing 'F' energy deposition events in the 'B' telescope. This demonstrates that electrons never significantly contaminate the ion measurement in the O detector, but that ions can and do significantly contaminate the electron measurement in the F detector.

The GEANT4 modeling provides the best estimate of original particle energy and detection efficiency for each accumulation bin. Using these values, the count rates in each of the 'O' channels provide a zero order estimate of the ion flux in four look directions (all ions are assumed to be protons). Likewise the 'F' channel count rates provides a zero order estimate of electron fluxes. Typically the 'O' channels do not have a significant level of contamination from electrons because the broom magnets are very effective at sweeping away lower energy electrons (<250 keV) and the more energetic electrons (>350 keV) will typically pass through the first 'O' detector and are not counted as 'O' events due to anticoincidence (this is shown in figure 13b where electrons have a tiny geometric factor for B-O events below ~10 MeV). In addition, the ions fluxes are typically higher for a given energy than the electron fluxes. However, the zero order electron fluxes are often heavily contaminated by ions - especially at energies greater than ~250 keV because these ions, up to 6 MeV, cause 'F' events (see figures 6, 7 and 13c). The zero order ion flux estimate is convolved with the appropriate response matrix to estimate the level of contamination in the foil detector with the same FOV. These contamination counts are subtracted and the electron fluxes are then recomputed. A similar process is used to estimate contamination of ions from the electrons. The first order corrections correspond to the Level 2 data archived at the PDS as of the date of publication of this article. Uncertainties in the fluxes are based on standard Poisson statistics. Figure 14 shows an example of data from the SEP 1 sensor. The top panel shows both the raw count rate in each of the 256 counters (see Figure 5). In the third to sixth panels, the data have been converted to differential energy flux spectra (mostly proton and up to 20% alpha particle) and electron differential energy flux spectra resulting from the aforementioned process are shown.

A more refined method of computing the ion and electron fluxes is to use the forward model to fit for the electrons and ion fluxes that simultaneously best fit the measured count rates in each of the 256 counters. In other words, this fitting is an attempt to subtract ion contributions from the electron spectra and vice versa. This method has not yet been implemented for the Level 2 data product.

Upon arrival at Mars, it was learned that Pick-Up Oxygen (PUO) ions sometimes represents a very significant contribution to the ion fluxes especially in the Forward looking detectors at (measured) energies less than 100 keV. These PUO can only be observed during periods of high solar wind velocity (>500 km/s) and with favorable magnetic field orientation. The PUO flux can have a very narrow angular extent and the observed flux can vary by orders of magnitude in as little as 8 seconds. The disambiguation between Oxygen and Protons has not been resolved in the L2 data distribution at this time.

Other forms of contamination are present. X-rays from large flares can produce counts in all non-coincident channels ('O', 'T' and 'F') these are particularly apparent in the 'T' channels since this channel is essentially devoid of contamination from electrons and ions. Penetrating particles, i.e. Galactic Cosmic Rays (GCRs) can produce events in all channels but are most likely to generate coincident ('OT', 'FT' and 'FTO') events. The GCRs produce a nearly constant FTO rate of 1.4 events/sec. Since GCRs are minimum ionizing events (~120 kev deposited per detector) the FTO events typically deposit ~500 keV in the FTO channel (i.e. 4 times the minimum ionizing energy from two thin F and O detectors and the double-thickness T detector).

Another source of contamination is the attenuator actuation. Every actuation produces ~40 counts in a single accumulation cycle. Whenever the PFDPU actuates (or polls the status of) the attenuators on STATIC or SWIA there can be contamination counts. These are typically rare and can only be noticed during quiet times. When the spacecraft is oriented such that the Sun is in the FOV of one of the open detectors the increased leakage current results in an increase in detector noise and also a subsequent increase in the count rate of the lowest energy channel.

2.5 Measured Parameters

The primary science products are ion and electron spectra of differential energy flux, in 4 orthogonal look directions, convolved from onboard energy bins to regular, logarithmically-spaced energy bins from 20-2000 keV for electrons and 20- 13500 keV/nuc for ions.

2.6 Operational Modes

SEP has altitude-dependent sampling rates, but only one hardware mode. It is a 'dumb' instrument in the sense that it collects data continuously in the same manner.

2.7 Operational Considerations

During normal operation, SEP operates continuously in the same hardware mode, as described above in section 2.6. Since SEP has no high voltage, atmospheric pressure is not a consideration. However, to protect against detector degradation, the attenuators closed whenever the FOV of the SEP detectors are within 45° of the RAM direction below 500 km. In addition, when the sun is in one of the SEP FOVs, a spacecraft zone alert is triggered and the attenuator paddles automatically rotate to cover the field of view.

2.8 In-Flight calibration

Cross-calibration of absolute flux cannot be performed with the SWIA instrument as SWIA’s field of view above 20 keV does not overlap with either of the SEP instruments (the center of SWIA’s FOV is pointed at the sun during nominal pointing, whereas the SEP FOVs are angled at 45° to the sun direction).

Cross-calibration can be performed with STATIC, which measures ions up to 30 keV ions, albeit with a geometric factor ~330 times smaller than SEP. Therefore, when the flux of such ions is sufficiently elevated (such as during the passage of a CME shock), measured fluxes from the same direction can be compared. **Note: as of November 2016, a comprehensive cross-calibration several MAVEN instruments was still ongoing**.

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. Unless specified elsewhere in this document, the MAVEN SEP archive conforms with version 1.4.0.0 of the PDS4 IM [4], and version 1.0.3.0 or later of the MAVEN mission schema. A list of the XML Schema and Schematron documents associated with this archive are provided in Table 6 below.

Table 6: MAVEN SEP Archive Schema and Schematron

XML Document	Steward	Product LID
PDS4 Core Schema, v. 1.4.0.0	PDS	urn:nasa:pds:system_bundle:xml_schema:pds-xml_schema
PDS4 Core Schematron, v. 1.4.0.0	PDS	urn:nasa:pds:system_bundle:xml_schema:pds-xml_schema
MAVEN Mission Schema, v. 1.0.3.0	PPI	urn:nasa:pds:system_bundle:xml_schema:mvn-xml_schema
MAVEN Mission Schematron, v. 1.0.3.0	PPI	urn:nasa:pds:system_bundle:xml_schema:mvn-xml_schema
Particle Discipline Schema, v. 1.1.0.0	PPI	urn:nasa:pds:system_bundle:xml_schema:particle-xml_schema
Particle Discipline Schematron, v. 1.1.0.0	PPI	urn:nasa:pds:system_bundle:xml_schema:particle-xml_schema
Alternate Discipline Schema, v. 1.0.0.0	PPI	urn:nasa:pds:system_bundle:xml_schema:alt-xml_schema
Alternate Discipline Schematron, v. 1.0.0.0	PPI	urn:nasa:pds:system_bundle:xml_schema:alt-xml_schema

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 7 provides a description of these levels along with the equivalent designations used in other systems.

Table 7: 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	2	1A
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+

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 collections of 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 14 below illustrates these relationships.

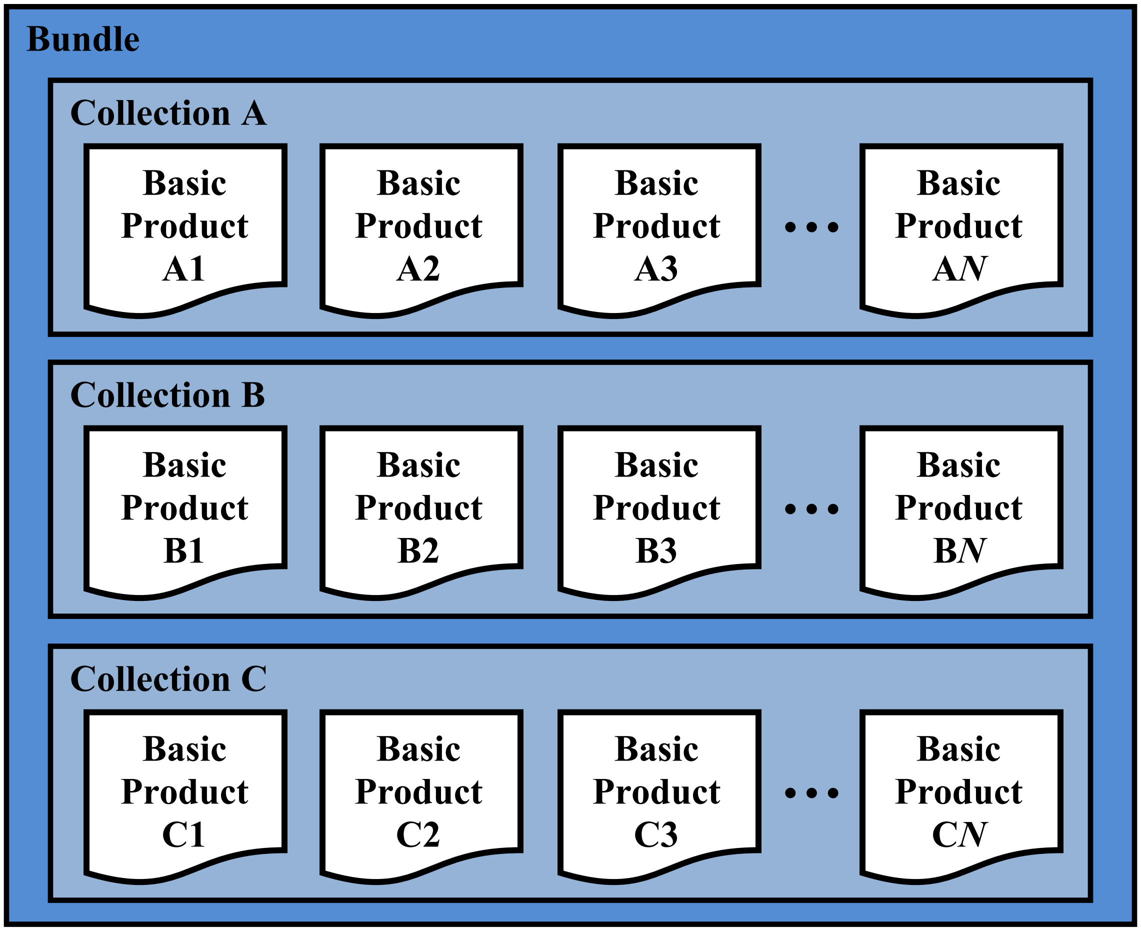


Figure 14: A graphical depiction of the relationship among bundles, collections, and basic products.

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 8.

Table 8: 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 SEP data archive is organized into a single calibrated bundle. A description of this bundle is provided in *Table 9*, and a more detailed description of the contents and format is provided in Section 5.2.

Table 9: SEP Bundles

Bundle Logical Identifier	PDS4 Reduction Level	Description	Data Provider
urn:nasa:pds:maven.sep.calibrated	Calibrated	Counts in each SEP sensor (1 or 2), telescope (A or B) and detector (F, T, O, OT, FT or FTO) at native time resolution, fully calibrated ion and electron energy flux spectra in 4 orthogonal look directions, and ancillary data necessary for interpreting SEP reduced and calibrated data.	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 15 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 ITFs 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.

Data bundles intended for the archive are identified in *Table 9*.

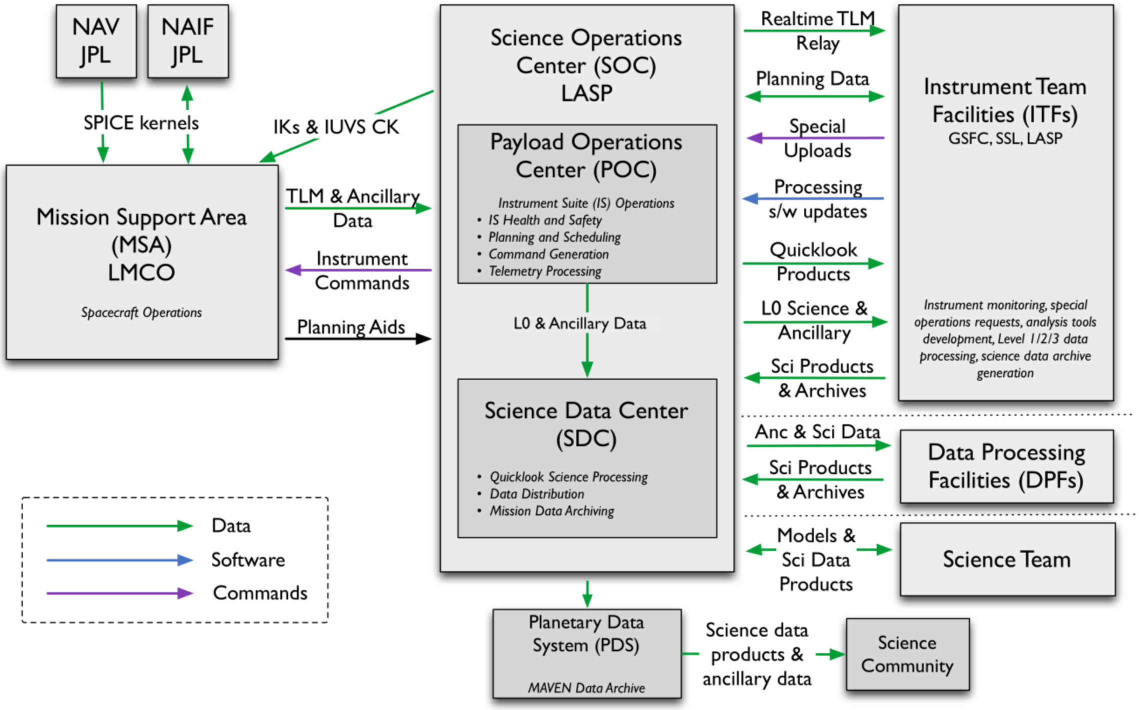


Figure 15: MAVEN Ground Data System responsibilities and data flow. Note that this figure includes portions of the MAVEN GDS which are not directly connected with archiving, and are therefore not described in Section 3.5 above.

4 Archive Generation

The SEP archive products are produced by the SEP team in cooperation with the SDC, and with the support of the PDS Planetary Plasma Interactions (PPI) Node at the University of California, Los Angeles (UCLA). 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 PPI Node from the SEP team are made available to PDS users electronically as soon as practicable but no later 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 SEP bundles listed in Table 8 are produced.

4.1.1 Reduced Data Production Pipeline

Reduced SEP Level 1 data will be produced from the raw level 0 PF data files by the PF ITF using IDL software, and provided for archiving in the PDS in appropriate formats. The data production pipeline will be run in an automated fashion to produce archival-ready files from the raw level 0 data.

Beginning as soon as possible but no later than 2 months after the start of science operations, the PF ITF will routinely generate Level 1 SEP science data products and deliver them to the SOC. As there is no need for fitting or the application of dynamic calibration factors, the PF ITF will deliver preliminary SEP Level 1 products to the SDC for distribution to the MAVEN team within two weeks of receiving all data required for science processing and no later than needed to meet the PDS delivery schedule in Table 10.

4.1.2 Calibrated Data Production Pipeline

Calibrated SEP Level 2 data will be produced from the level 1 SEP data files by the PF ITF using IDL software, and provided for archiving in the PDS in appropriate formats. The data production pipeline will be run in an automated fashion to produce archival-ready files from the raw level 0 data.

Beginning as soon as possible but no later than 2 months after the start of science operations, the PF ITF will routinely generate Level 2 SEP science data products and deliver them to the SOC. After the initial 2-month calibration period, the PF ITF will deliver preliminary SEP Level 2 products to the SDC for distribution to the MAVEN team within two weeks of receiving all data required for science processing (including all SPICE kernels and other ancillary data required for processing) by the ITFs. Final Level 2 SEP products will be delivered to the SDC as soon as they are complete, no later than needed to meet the PDS delivery schedule in Table 10.

The PF ITF will deliver validated SEP science data products and associated metadata for PDS archiving to the SOC two weeks prior to every PDS delivery deadline. The first PDS delivery will occur no later than 6 months after the start of science operations, and subsequent deliveries will take place every 3 months after the first delivery. The first delivery will include data collected during the cruise and transition phases in addition to the science data from the first 3 months of the mapping phase. Each subsequent delivery will contain data from the 3 months following the previous delivery. The final delivery may contain products involving data from the entire mission.

The PF ITF will also provide the SDC with SEP data product descriptions, appropriate for use by the MAVEN science team in using MAVEN science data products and consistent with PDS metadata standards.

4.1.3 Ancillary Data Production Pipeline

SEP Ancillary data relies mainly on SPICE kernels. It will be delivered from the PF ITF to the SDC within two weeks of ITF receipt of validated kernel files.

4.2 Data Validation

4.2.1 Instrument Team Validation

All SEP data will be calibrated and converted to physical units by the PF ITF, then spot-checked by the instrument lead and his designees for accuracy and integrity.

4.2.2 MAVEN Science Team Validation

The MAVEN science team will work with the same SEP products that will be archived in the PDS. If any calibration issues or other anomalies are noted, they will be addressed at the PF ITF by the SEP instrument lead or his designees.

4.2.3 PDS Peer Review

The PPI node has conducted a full peer review of all of the data types that the SEP team intends to archive. The review data consisted of fully formed bundles populated with candidate final versions of the data and other products and the associated metadata.

Reviews will include a preliminary delivery of sample products for validation and comment by PDS PPI 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 SEP team representatives, researchers from outside of the MAVEN project, and PDS personnel from the Engineering and PPI 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 PPI node, but will not require additional external review.

As expertise with the instrument and data develops the SEP 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 SEP 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 worked out with the PPI 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 in Table 10 below.

Table 10: Archive bundle delivery schedule

Bundle Logical Identifier	First Delivery to PDS	Delivery Schedule	Estimated Delivery Size
urn:nasa:pds:maven.sep.calibrated	No later than 6 months after the start of science operations	Every 3 months	TBD

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 PPI 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 PPI file system. PPI 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 PPI 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 PPI node.

Following receipt of a data delivery, PPI will reorganize the data into its PDS archive structure within its online data system. PPI 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 PPI 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 PPI. However, the first few data deliveries may require more time for the PPI Node to process before the data are made publicly available.

The MAVEN prime mission begins approximately 5 weeks following MOI and lasts for 1 Earth-year. Table 10 shows the data delivery schedule for the entire mission.

4.4 Data Product and Archive Volume Size Estimates

SEP data products consist of files that span one UT day, breaking at 0h UTC SCET. Files vary in size depending on the telemetry rate and allocation. In other words, the first timestamp in each file is the first one following or including 00:00:00 on that day. The last timestamp is the last one before 00:00:00 on the following day.

4.5 Data Validation

Routine data deliveries to the PDS are validated at the PPI node to insure that the delivery meets PDS standards, and that they the data conform to the standards defined in the 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 PPI 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 PPI 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 SEP data is illustrated in Figure 16.

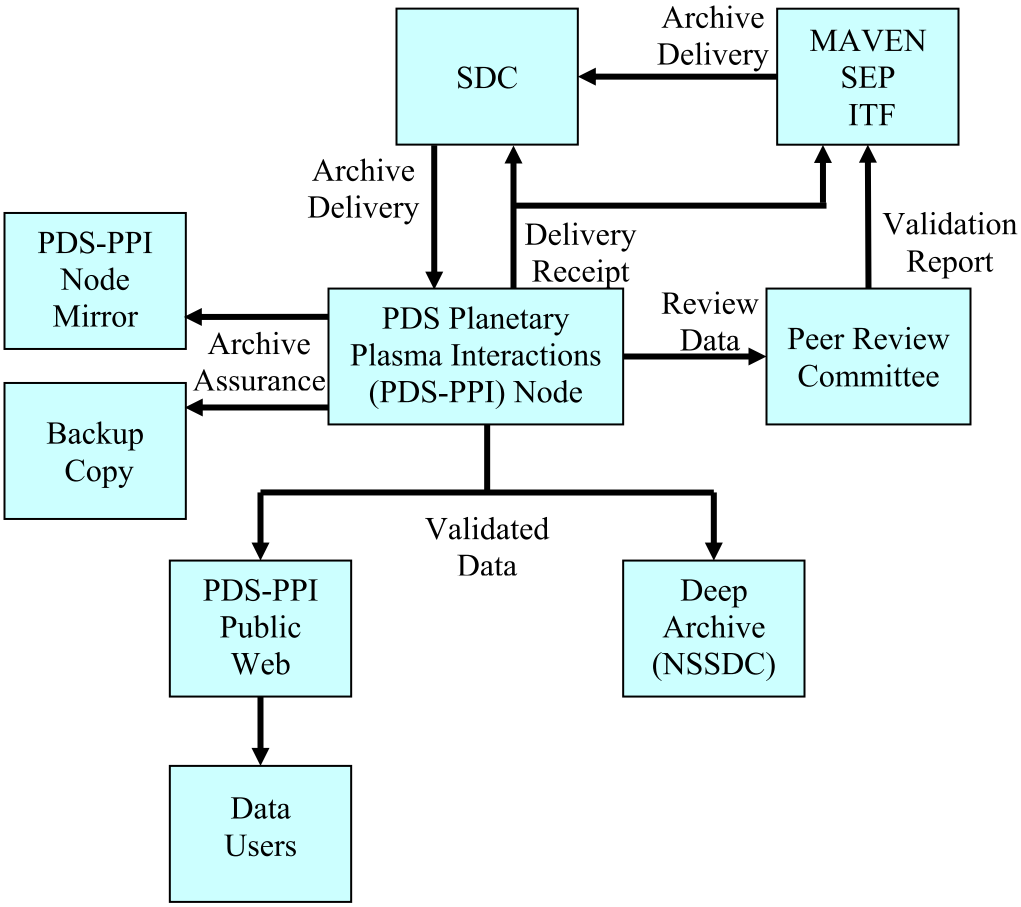


Figure 16: Duplication and dissemination of SEP archive products at PDS/PPI.

5 Archive organization and naming

This section describes the basic organization of a SEP 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 LIDVID (Logical Identifier plus Version 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 SEP LIDs are formed according to the following conventions:

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

  urn:nasa:pds:maven.sep.<bundle ID>

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

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

  urn:nasa:pds:maven.sep.<bundle ID>:<collection ID>

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

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

  urn:nasa:pds:maven.sep.<bundle ID>:<collection ID>:<product ID>

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

A list of SEP bundle LIDs is provided in *Table 9*. Collection LIDs are listed in Table 11.

5.1.2 VID Formation

Product version IDs consist of major and minor components separated by a "." (M.n). Both components of the Version Identifier (VID) are integer values. The major component is initialized to a value of "1", and the minor component is initialized to a value of "0". The minor component resets to "0" when the major component is incremented.

5.2 SEP Archive Contents

The SEP archive includes the bundle listed in *Table 9*. The following sections describe the contents of each of these bundles in greater detail.

5.2.1 MAVEN SEP Calibrated (MAVEN Level 2) Science Data Bundle

The SEP Calibrated (MAVEN Level 2) Science Data Bundle contains 3 data collections which include fully calibrated data in physical units of flux (#/cm2/s/steradian/keV), including electron and ion spectra in the 4 look directions (2 look directions for each sensor/file), data in native instrument format, i.e. raw particle counts within each accumulation bin during a single accumulation period, and supporting ephemeris data useful in the interpretation of the calibrated data.

Table 11: MAVEN SEP Calibrated Level 2 Science Data Collections

Collection LID	Description
urn:nasa:pds:maven.sep.calibrated:data.counts	Raw particle counts in each of the 256 event counters for each of the 2 SEP sensors.
urn:nasa:pds:maven.sep.calibrated:data.spec	Electron and ion energy spectra in physical units in 4 look directions from SEP survey data.
urn:nasa:pds:maven.sep.calibrated:data.anc	Ephemeris data useful for interpretation of calibrated SEP data.
urn:nasa:pds:maven.sep.calibrated:document	Documents related to the SEP calibrated bundle.

5.2.1.1 MAVEN SEP Reduced Ion and Electron Counts Data Collection

The SEP counts data collection contains files with time-ordered raw counts in each of the 256 event counters for each of the 2 SEP sensors, in addition to essential supporting data such as accumulation duration, attenuator state and energy map. The PF ITF will produce these products, with one file per UT day, with the naming convention:

SEP1: mvn_sep_l2_s1-raw-svy-full_<yyyy><mm><dd>_v<xx>_r<yy>.cdf

SEP2: mvn_sep_l2_s2-raw-svy-full_<yyyy><mm><dd>_v<xx>_r<yy>.cdf

See Appendix B for a more complete description of the file naming convention.

5.2.1.2 MAVEN SEP Calibrated Ion and Electron Spectra Data Collection

The SEP spectra survey collection contains files with time-ordered fully calibrated ion and electron spectra in units of differential particle flux derived from the SEP survey telemetry, as well as a header of ancillary information needed to interpret the data. Units for each data quantity are provided in the table. During periods of intense SEP flux, it is possible for the SEP sensors and electronics to become saturated due to deadtime effects. This becomes important when the count rate approaches or exceeds ~30,000 counts per sec. Under normal conditions the Attenuator should kick in to reduce the count rate. However care should be taken whenever a detector count rate exceeds 30,000 cnts/sec.

The PF ITF will produce these products, with one file per UT day, with the naming convention:

SEP1: mvn_sep_l2_s1-cal-svy-full_<yyyy><mm><dd>_v<xx>_r<yy>.cdf

SEP2: mvn_sep_l2_s2-cal-svy-full_<yyyy><mm><dd>_v<xx>_r<yy>.cdf

See Appendix B for a more complete description of the file naming convention.

5.2.1.3 MAVEN SEP Ancillary Data Collection

The SEP ancillary collection contains files with time-ordered ephemeris information useful in the interpretation of sep.calibrated data

The PF ITF will produce these products, with one file per UT day, with the naming convention mvn_sep_anc_<yyyy><mm><dd>_v<xx>_r<yy>.cdf. See Appendix B for a more complete description of the file naming convention.

5.3 Document Collection

The SEP calibrated data document collection contains documents which are useful for understanding and using the SEP Calibrated (MAVEN Level 2) Science Data bundle. Table 12 contains a list of the documents included in this collection, along with the LID, and responsible group. Following this a brief description of each document is also provided.

Table 12: SEP Reduced and Calibrated Science Data Documents

Document Name	LID	Responsiblity
MAVEN Science Data Management Plan	urn:nasa:pds:maven:document:sdmp	MAVEN Project
MAVEN SEP Archive SIS	urn:nasa:pds:maven.sep.calibrated:document:sis	SEP Team
MAVEN SEP Sample PDS4 Labels	urn:nasa:pds:maven.sep.calibrated:document:sample-xml	PPI
MAVEN SEP Instrument Paper	urn:nasa:pds:maven.sep.calibrated:document:sep.instrument.description	SEP Team

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

MAVEN SEP Archive SIS – describes the format and content of the SEP PDS data archive, including descriptions of the data products and associated metadata, and the archive format, content, and generation pipeline (this document).

SEP Instrument Description – describes the MAVEN SEP instrument.

While responsibility for the individual documents varies, the document collection itself is managed by the PDS/PPI node.

6 Archive products formats

Data that comprise the SEP 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 and record structure of each of the data file types. SEP reduced, calibrated and ancillary data files will be archived with PDS as Common Data Format (CDF). In order to allow the archival CDF files to be described by PDS metadata a number of requirements have been agreed to between the PF ITF and the PDS-PPI node. These requirements are detailed in the document Archive of MAVEN CDF in PDS4, Version 3, T. King and J. Mafi, March 13, 2014 [7]. These CDF files will be the same ones used and distributed by the PF ITF internally. The contents of the SEP CDF files are described in the tables below. In the ancillary tables below, 'SEP-N' refers to either 'SEP-1' or 'SEP-2', in order to avoid unnecessary duplication.

6.1.1 Reduced data file structure

For each SEP sensor, there is one CDF file per UT day containing Level 1 data, i.e. counts in each of the 256 particle, at the highest time resolution at which the data was downlinked. The file formats and variable names are identical for the SEP 1 and SEP 2 sensors. *The number of data points within the SEP1 and SEP2 files are NOT necessarily the same since the two instruments can be configured to have different time resolutions and data products are not guaranteed to be in sync.*

Table 13: Contents for SEP reduced (count) data files. The first sub table contains variables that vary with time. The 2nd sub table contains relevant, non-time-varying information pertinent to the entire file. The "MAP" Quantities specify the FTO pattern and ADC values that were used to accumulate the data in each of the 256 data bins.

Field Name	Data Type	Number elements	Description
time_unix	DOUBLE	NUM_SPEC	Unix time (elapsed seconds since 1970-01-01/00:00 without leap seconds) for this data record, one element per data sample
epoch	TT2000	NUM_SPEC	TT2000 time (defined by NSSDC) total elapsed nanoseconds from start epoch. Includes leap seconds.
time_met	DOUBLE	NUM_SPEC	Mission elapsed time for this data record, one element per data sample This is not corrected for spacecraft clock drift
time_ephemeris	DOUBLE	NUM_SPEC	Ephemeris time as defined by SPICE
attenuator_state	UINT2	NUM_SPEC	Attenuator state (0=invalid, 1 = open, 2 = closed, 3=mixed), one element per data sample
accum_time	UINT2	NUM_SPEC	Number of one-second accumulations per sample. Not corrected for dead time. (Dead time should be <30 microseconds. Thus count rates <10 kHz are typically unaffected by dead time)
mapid	UINT2	NUM_SPEC	Map ID used for this spectra
seq_cntr	UINT2	NUM_SPEC	Sequence counter
raw_counts	float	NUM_SPEC x 256	Raw Counts in each of the 256 bins
Field Name	**Data Type**	**Number elements**	**Description**
MAP.BIN	INT2	256	Bin Number of data bin [0…255]
MAP.FTO	INT2	256	FTO Pattern of data in MAP.BIN 000: undefined. 001: O 010: T 011: OT 100: F 101: N/A 110: FT 111: FTO

MAP.TID	INT2	256	0: Telescope A 1: Telescope B
MAP.ADC_LOW	INT2	256	Lowest ADC value
MAP.ADC_HIGH	INT2	256	Highest ADC value +1
MAP.ADC_AVG	FLOAT	256	Average of ADC_LOW and ADC_HIGH
MAP.ADC_DELTA	FLOAT	256	Difference of lowest and highest – Same as total number of ADC bins
MAP.NRG_MEAS_AVG	FLOAT	256	Electronic energy deposited in KeV. (Scaled version of ADC_AVG)
MAP.NRG_MEAS_DELTA	FLOAT	256	Width of Energy bin in KeV. (Scaled version of ADC_DELTA)

6.1.2 Calibrated data file structure

For each SEP sensor, there is 1 CDF file per UT day containing level 2 calibrated data, i.e. electron and ion spectra in physical units (differential particle flux).

Table 14: Contents for SEP calibrated (spectra) data files. Typically there are 28 ion steps (Ni) and 15 electron steps (Ne);

Field Name	Data Type	Number elements	Description
time_unix	DOUBLE	NUM_SPEC	Unix time (elapsed seconds since 1970-01-01/00:00 without leap seconds) for this data record, one element per data sample
epoch	TIME_TT2000	NUM_SPEC	TT2000 time (defined by NSSDC) total elapsed nanoseconds from start epoch. Includes leap seconds.
time_met	DOUBLE	NUM_SPEC	Mission elapsed time for this data record, one element per data sample This is not corrected for spacecraft clock drift
time_ephemeris	DOUBLE	NUM_SPEC	Ephemeris time as defined by SPICE
attenuator_state	UINT2	NUM_SPEC	Attenuator state (0=invalid, 1 = open, 2 = closed, 3=mixed), one element per data sample
accum_time	UINT2	NUM_SPEC	Number of one-second accumulations per sample. Not corrected for dead time.

mapid	UINT2	NUM_SPEC	Map ID used for this spectra
seq_cntr	UINT2	NUM_SPEC	Sequence counter
f_ion_flux	FLOAT	NUM_SPEC x Ni	Differential ion flux in forward look direction (particles/cm2/s/ster/keV)
f_ion_flux_unc	FLOAT	NUM_SPEC x Ni	Uncertainty in flux in forward look direction
f_ion_flux_tot	FLOAT	NUM_SPEC	Total (integrated) flux in forward look direction
f_ion_flux_tot_unc	FLOAT	NUM_SPEC	Uncertainty in total flux
f_ion_energy	FLOAT	NUM_SPEC x Ni	Center of energy bin (keV)
f_ion_denergy	FLOAT	NUM_SPEC x Ni	Total width of energy bin (keV)
f_elec_flux	FLOAT	NUM_SPEC x Ne	Differential electron flux in forward look direction (particles/cm2/s/ster/keV)
f_elec_flux_unc	FLOAT	NUM_SPEC x Ne	Uncertainty in flux in forward look direction
f_elec_flux_tot	FLOAT	NUM_SPEC	Total (integrated) flux in forward look direction
f_elec_flux_tot_unc	FLOAT	NUM_SPEC	Uncertainty in total flux
f_elec_energy	FLOAT	NUM_SPEC x Ne	Center of energy bin (keV)
f_elec_denergy	FLOAT	NUM_SPEC x Ne	Total width of energy bin (keV)
r_ion_flux	FLOAT	NUM_SPEC x Ni	Differential ion flux in reverse look direction (particles/cm2/s/ster/keV)
r_ion_flux_unc	FLOAT	NUM_SPEC x Ni	Uncertainty in flux in reverse look direction
r_ion_flux_tot	FLOAT	NUM_SPEC	Total (integrated) flux in reverse look direction
r_ion_flux_tot_unc	FLOAT	NUM_SPEC	Uncertainty in total flux
r_ion_energy	FLOAT	NUM_SPEC x Ni	Center of energy bin (keV)
r_ion_denergy	FLOAT	NUM_SPEC x Ni	Total width of energy bin (keV)
r_elec_flux	FLOAT	NUM_SPEC x Ne	Differential electron flux in reverse look direction (particles/cm2/s/ster/keV)
r_elec_flux_unc	FLOAT	NUM_SPEC x Ne	Uncertainty in flux in reverse look direction

r_elec_flux_tot	FLOAT	NUM_SPEC	Total (integrated) flux in reverse look direction
r_elec_flux_tot_unc	FLOAT	NUM_SPEC	Uncertainty in total flux
r_elec_energy	FLOAT	NUM_SPEC x Ne	Center of energy bin (keV)
r_elec_denergy	FLOAT	NUM_SPEC x Ne	Total width of energy bin (keV)
a_t_rates	FLOAT	NUM_SPEC x Nx	Count rate of (non coincident) thick events (typically xrays) in stack A [cnts/sec]
b_t_rates	FLOAT	NUM_SPEC x Nx	Count rate of (non coincident) thick events (typically xrays) in stack B [cnts/sec]
a_fto_rates	FLOAT	NUM_SPEC x Ncr	Count rate of triple coincident events (typically GCR) in stack A [cnts/sec]
b_fto_rates	FLOAT	NUM_SPEC x Ncr	Count rate of triple coincident events (typically GCR) in stack B [cnts/sec]
f_o_rate	FLOAT	NUM_SPEC	Total count rate in Forward Open channel [cnts/sec]
f_f_rate	FLOAT	NUM_SPEC	Total count rate in Forward Foil channel [cnts/sec]
r_o_rate	FLOAT	NUM_SPEC	Total count rate in Rear Foil channel [cnts/sec]
r_f_rate	FLOAT	NUM_SPEC	Total count rate in Rear Foil channel [cnts/sec]
Quality_flag	UINT8	NUM_SPEC	Reserved for future use

6.1.3 Ancillary data file structure

There is one CDF file per UT day containing ancillary ephemeris information relevant for the interpretation of the calibrated data from both SEP sensors.

Table 15: Contents for SEP ancillary data files.

Field Name	Data Type	Number elements	Description
epoch	EPOCH	NUM_SPEC	Spacecraft event time for this data record (UTC Epoch time from 01-Jan-0000 00:00:00.000 without leap seconds), one element per spectrum
time_nssdc	EPOCH	NUM_SPEC	UTC time from 01-Jan-2000 12:00:00.000 including leap seconds), one element per spectrum
time_unix	DOUBLE	NUM_SPEC	Unix time (elapsed seconds since 1970-01-01/00:00 without leap seconds) for this data record, one element per spectrum
time_met	DOUBLE	NUM_SPEC	Mission elapsed time for this data record, one element per spectrum
time_ephemeris	DOUBLE	NUM_SPEC	Identical to UNIX time but with leap seconds added.
sep-1f_fov_mso	FLOAT	NUM_SPEC x 3	Unit vector of the geometric center of the 1-Forward field of view in Mars-solar-orbital coordinates
sep-1r_fov_mso	FLOAT	NUM_SPEC x 3	Unit vector of the geometric center of the 1-Reverse field of view in Mars-solar-orbital coordinates
sep-2f_fov_mso	FLOAT	NUM_SPEC x 3	Unit vector of the geometric center of the 2-Forward field of view in Mars-solar-orbital coordinates
sep-2r_fov_mso	FLOAT	NUM_SPEC x 3	Unit vector of the geometric center of the 2-Reverse field of view in Mars-solar-orbital coordinates
sep-1f_fov_sso	FLOAT	NUM_SPEC x 3	Unit vector of the geometric center of the 1-Forward field of view in Spacecraft-solar-orbital coordinates

sep-1r_fov_sso	FLOAT	NUM_SPEC x 3	Unit vector of the geometric center of the 1-Reverse field of view in Spacecraft-solar-orbital coordinates
sep-2f_fov_sso	FLOAT	NUM_SPEC x 3	Unit vector of the geometric center of the 2-Forward field of view in Spacecraft-solar-orbital coordinates
sep-2r_fov_sso	FLOAT	NUM_SPEC x 3	Unit vector of the geometric center of the 2-Reverse field of view in Spacecraft-solar-orbital coordinates
sep-1f_fov_geo	FLOAT	NUM_SPEC x 3	Unit vector of the geometric center of the 1-Forward field of view in planet-fixed IAU Mars coordinates
sep-1r_fov_geo	FLOAT	NUM_SPEC x 3	Unit vector of the geometric center of the 1-Reverse field of view in planet-fixed IAU Mars coordinates
sep-2f_fov_geo	FLOAT	NUM_SPEC x 3	Unit vector of the geometric center of the 2-Forward field of view in planet-fixed IAU Mars coordinates
sep-2r_fov_geo	FLOAT	NUM_SPEC x 3	Unit vector of the geometric center of the 2-Reverse field of view in planet-fixed IAU Mars coordinates
sep-1f_sun_angle	FLOAT	NUM_SPEC	Angle, in degrees, between the geometric center of the 1-Forward field of view and the direction of the sun.
sep-1r_sun_angle	FLOAT	NUM_SPEC	Angle, in degrees, between the geometric center of the 1-Reverse field of view and the direction of the sun.
sep-2f_sun_angle	FLOAT	NUM_SPEC	Angle, in degrees, between the geometric center of the 2-Forward field of view and the direction of the sun.
sep-2r_sun_angle	FLOAT	NUM_SPEC	Angle, in degrees, between the geometric center of the 2-Reverse field of view and the direction of the sun.
sep-1f_ram_angle	FLOAT	NUM_SPEC	Angle, in degrees, between the geometric center of the 1-Forward field of view and the spacecraft RAM direction.

sep-1r_ram_angle	FLOAT	NUM_SPEC	Angle, in degrees, between the geometric center of the 1-Reverse field of view and the spacecraft RAM direction.
sep-2f_ram_angle	FLOAT	NUM_SPEC	Angle, in degrees, between the geometric center of the 2-Forward field of view and the spacecraft RAM direction.
sep-2r_ram_angle	FLOAT	NUM_SPEC	Angle, in degrees, between the geometric center of the 2-Reverse field of view and the spacecraft RAM direction.
sep-1f_frac_fov_mars	FLOAT	NUM_SPEC	Fraction of the 1-Forward field of view taken up by the disk of Mars.
sep-1r_frac_fov_mars	FLOAT	NUM_SPEC	Fraction of the 1- Reverse field of view taken up by the disk of Mars.
sep-2f_frac_fov_mars	FLOAT	NUM_SPEC	Fraction of the 2-Forward field of view taken up by the disk of Mars.
sep-2r_frac_fov_mars	FLOAT	NUM_SPEC	Fraction of the 2- Reverse field of view taken up by the disk of Mars.
sep-1f_frac_fov_ill	FLOAT	NUM_SPEC	Fraction of the 1-Forward field of view taken up by the disk of Mars, weighted by the cosine of the illumination angle of each point on the disk.
sep-1r_frac_fov_ill	FLOAT	NUM_SPEC	Fraction of the 1-Reverse field of view taken up by the disk of Mars, weighted by the cosine of the illumination angle of each point on the disk.
sep-2f_frac_fov_ill	FLOAT	NUM_SPEC	Fraction of the 2-Forward field of view taken up by the disk of Mars, weighted by the cosine of the illumination angle of each point on the disk.
sep-2r_frac_fov_ill	FLOAT	NUM_SPEC	Fraction of the 2- Reverse field of view taken up by the disk of Mars, weighted by the cosine of the illumination angle of each point on the disk.
mars_frac_sky	FLOAT	NUM_SPEC	Fraction of the complete celestial sphere taken up by Mars.

sep-1_qrot2mso	FLOAT	NUM_SPEC x 4	Quaternions for the rotation between the SEP-1 and MSO reference frames.
sep-2_qrot2mso	FLOAT	NUM_SPEC x 4	Quaternions for the rotation between the SEP-2 and MSO reference frames.
sep-1_qrot2sso	FLOAT	NUM_SPEC x 4	Quaternions for the rotation between the SEP-1 and SSO reference frames.
sep-2_qrot2sso	FLOAT	NUM_SPEC x 4	Quaternions for the rotation between the SEP-2 and SSO reference frames.
sep-1_qrot2geo	FLOAT	NUM_SPEC x 4	Quaternions for the rotation between the SEP-1 and IAU Mars reference frames.
sep-2_qrot2geo	FLOAT	NUM_SPEC x 4	Quaternions for the rotation between the SEP-2 and IAU Mars reference frames.
mvn_pos_mso	FLOAT	NUM_SPEC x 3	Position vector of the MAVEN spacecraft in Mars-solar-orbital coordinates, in units of km.
mvn_pos_geo	FLOAT	NUM_SPEC x 3	Position vector of the MAVEN spacecraft in IAU Mars coordinates, in units of km.
mvn_pos_eclipj2000	FLOAT	NUM_SPEC x 3	Position vector of the MAVEN spacecraft in sun-centered J2000 ecliptic coordinates, in units of km
earth_pos_eclipj2000	FLOAT	NUM_SPEC x 3	Position vector of Earth in sun-centered J2000 ecliptic coordinates, in units of km
mars_pos_eclipj2000	FLOAT	NUM_SPEC x 3	Position vector of Mars in sun-centered J2000 ecliptic coordinates, in units of km
mvn_lat_geo	FLOAT	NUM_SPEC	Latitude, in degrees, of sub-spacecraft point in planet-fixed IAU Mars coordinates
mvn_elon_geo	FLOAT	NUM_SPEC	East Longitude, in degrees, of sub-spacecraft point in planet-fixed IAU Mars coordinates
mvn_sza	FLOAT	NUM_SPEC	Solar Zenith Angle, in degrees, of the MAVEN spacecraft with respect to Mars.
mvn_slt	FLOAT	NUM_SPEC	Solar Local Time, in hours, of the MAVEN spacecraft with respect to Mars.

6.2 Document Product File Formats

Documents are provided in either Adobe Acrobat PDF/A or plain ASCII text format. Other versions of the document (including HTML, Microsoft Word, etc.) may be included as well.

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 1.1.0.0 version of the PDS Information Model for structure, and the 1.1.0.0 version of the PDS Schematron for content. By use of an XML editor these documents may be used to validate the structure and content of the product labels.

Examples of PDS labels required for the SEP archive are shown in Appendix C (bundle products), Appendix D (collection products), and Appendix E (basic 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 uncompression.
3. A checksum manifest which lists the MD5 checksum of each file included in the package after uncompression.

SEP 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 the Appendix in Section F.1. Delivery packages are compressed using either zip or tar/gzip 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.

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 section F.2.

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 19: Archive support staff

SEP team			
Name	**Address**	**Phone**	**Email**
Davin Larson	Space Sciences Laboratory, 7 Gauss Way, University of California, Berkeley, CA 94720	+001-510-642-7558	davin@ssl.berkeley.edu
Robert Lillis	Space Sciences Laboratory, 7 Gauss Way, University of California, Berkeley, CA 94720	+001-510-642-6211	rlillis@ssl.berkeley.edu

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 Naming conventions for MAVEN science data files

This section describes the naming convention used for science data files for the MAVEN mission.

Raw (MAVEN Level 0):

mvn_<inst>_<grouping>_l0_< yyyy><mm><dd>_v<yy>.dat

Level 1, 2, 3+:

mvn_<inst>_<level>_<descriptor>_<yyyy><mm><dd>T<hh><mm><ss>_v<xx>_r<yy>.<ext>

Code	**Description**
<inst>	3-letter instrument ID
<grouping>	Three-letter code: options are all, svy, arc for all data, survey data, archive data. Primarily for P&F to divide their survey & archive data at Level 0.
<yyyy>	4-digit year
<mm>	2-digit month, e.g. 01, 12
<dd>	2-digit day of month, e.g. 02, 31
<hh>	2-digit hour, separated from the date by T. OPTIONAL. Will not be used
<mm>	2-digit minute. OPTIONAL. Will not be used by SEP
<ss>	2-digit second. OPTIONAL. Will not be used by SEP
r<yy>	2-digit data version: To be incremented each time a new version is submitted to the PDS. is this a new version of a previous file, though the same software version was used for both? (Likely to be used in the case of retransmits to fill in data gaps)
v<xx>	2-digit software version: which version of the software was used to create this data product?
<descriptor>	A description of the data. Defined by the creator of the dataset. There are no underscores in the value. SEP will adopt a standard: <descriptor. = <GRP-PRC-TYPE-AVG> where: INST = sep, s1, or s2 GRP = svy PRC = cal or raw TYPE = svy AVG = full, (other time resolutions might be made in the future) Not all combinations will be available
.<ext>	File type extension: .fits, .txt, .cdf, .png
<level>	A code indicating the MAVEN processing level of the data (valid values: l1, l2, l3)

Instrument name	**<instrument>**
IUVS	iuv

NGIMS	ngi
LPW	lpw
MAG	mag
SEP	sep
SWIA	swi
SWEA	swe
STATIC	sta
P&F package	pfp

Appendix C Sample Bundle Product Label

This section provides a sample bundle product label.

```
<?xml version="1.0" encoding="UTF-8"?>
<?xml-model
href="http://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1400.sch"
   schematypens="http://purl.oclc.org/dsdl/schematron"?>
<Product_Bundle
   xmlns="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_1400.xsd
   ">
   <Identification_Area>

<logical_identifier>urn:nasa:pds:maven.sep.calibrated</logical_i
dentifier>
      <version_id>1.12</version_id>
      <title>MAVEN SEP Calibrated Data Bundle</title>

<information_model_version>1.4.0.0</information_model_version>
      <product_class>Product_Bundle</product_class>
      <Citation_Information>
         <publication_year>2017</publication_year>
         <description>
            The maven.sep.calibrated Level 2 Science Data Bundle
contains fully calibrated
            SEP data, as well as the raw count data from which
they are derived, and
            ancillary ephemeris data. The calibrated data are in
physical units, and
            include electron and ion spectra in the 4 look
directions (2 look directions
            for each sensor/file).
         </description>
      </Citation_Information>
      <Modification_History>
         <Modification_Detail>
            <modification_date>2018-08-13</modification_date>
            <version_id>1.12</version_id>
            <description>
               MAVEN Release 14 (2018-08-15). Includes an
incremental release of ancillary,
               raw, and calibrated data, including the initial
release of 2018-02-15 to
```

```
               2018-05-14. Coverage for all three collections is
2014-09-22 to 2018-05-14.
            </description>
         </Modification_Detail>
         <Modification_Detail>
            <modification_date>2018-05-02</modification_date>
            <version_id>1.11</version_id>
            <description>
               MAVEN Release 13 (2018-05-15). Includes an
incremental release of ancillary,
               raw, and calibrated data, including the initial
release of 2017-11-15 to
               2018-02-14. Coverage for all three collections is
2014-09-22 to 2018-02-14.
            </description>
         </Modification_Detail>
         <Modification_Detail>
            <modification_date>2018-02-14</modification_date>
            <version_id>1.10</version_id>
            <description>
               MAVEN Release 12 (2018-02-15). Includes an
incremental release of ancillary,
               raw, and calibrated data, including the initial
release of 2017-08-15 to
               2017-11-14. Coverage for all three collections is
2014-09-22 to 2017-05-14.
            </description>
         </Modification_Detail>
         <Modification_Detail>
            <modification_date>2017-11-14</modification_date>
            <version_id>1.9</version_id>
            <description>
               MAVEN Release 11 (2017-11-15). Includes an
incremental release of
               ancillary, raw, and calibrated data, covering
2017-05-15 to 2017-08-14,
               and updated versions of the data covering 2014-
10-01 to 2016-12-31.
               Coverage for all three collections is 2014-09-22
to 2017-08-14.
            </description>
         </Modification_Detail>
         <Modification_Detail>
            <modification_date>2017-08-09</modification_date>
            <version_id>1.8</version_id>
            <description>
```

```
               MAVEN Release 10 (2017-08-15). Includes an
incremental release of
               ancillary, raw, and calibrated data. Coverage for
all three
               collections is 2014-09-22 to 2017-05-14.
            </description>
         </Modification_Detail>
         <Modification_Detail>
            <modification_date>2017-08-09</modification_date>
            <version_id>1.7</version_id>
            <description>
               This version included corrections to a 1 second
timing error
               in the data following the leap second at 2016-12-
31T23:59:60
               UTC. Coverage is the same as for version 1.6.
            </description>
         </Modification_Detail>
         <Modification_Detail>
            <modification_date>2017-05-15</modification_date>
            <version_id>1.6</version_id>
            <description>
               MAVEN Release 9 (2017-05-15). Includes an
incremental release
               of ancillary, raw, and calibrated data. Coverage
for all three
               collections is 2014-09-22 to 2017-02-14.
            </description>
         </Modification_Detail>
         <Modification_Detail>
            <modification_date>2017-02-09</modification_date>
            <version_id>1.5</version_id>
            <description>
               MAVEN Release 8 (2017-02-15). Includes an
incremental release
               of ancillary, raw, and calibrated data. Coverage
for all three
               collections is 2014-09-22 to 2016-11-14.
            </description>
         </Modification_Detail>
         <Modification_Detail>
            <modification_date>2016-11-17</modification_date>
            <version_id>1.4</version_id>
            <description>
               MAVEN Release 7 (2016-11-17). Includes an
incremental release
```

```
               of ancillary, raw, and calibrated data. Coverage
for all three
               collections is 2014-09-22 to 2016-08-14.
            </description>
         </Modification_Detail>
         <Modification_Detail>
            <modification_date>2016-08-14</modification_date>
            <version_id>1.3</version_id>
            <description>
               MAVEN Release 6 (2016-08-16). Includes an
incremental release
               of ancillary, raw, and calibrated data. Coverage
for all three
               collections is 2014-09-22 to 2016-05-14.
            </description>
         </Modification_Detail>
         <Modification_Detail>
            <modification_date>2016-05-14</modification_date>
            <version_id>1.2</version_id>
            <description>
               MAVEN Release 5 (2016-05-16). Includes an
incremental release
               of ancillary, raw, and calibrated data. Coverage
for all three
               collections is 2014-09-22 to 2016-02-14.
            </description>
         </Modification_Detail>
         <Modification_Detail>
            <modification_date>2016-02-16</modification_date>
            <version_id>1.1</version_id>
            <description>
               MAVEN Release 4 (2015-12-28). Includes an
incremental release
               of raw and calibrated data, and the intial
release of SEP ancillary data.
               Coverage for all three collections is 2014-09-22
to 2015-11-14.
            </description>
         </Modification_Detail>
         <Modification_Detail>
            <modification_date>2015-12-28</modification_date>
            <version_id>1.0</version_id>
            <description>
               MAVEN Release 3. This release includes SEP raw
and calibrated
               data covering MAVEN Releases 1-3: 2014-09-22 to
2015-08-14.
```

```
            </description>
         </Modification_Detail>
      </Modification_History>
   </Identification_Area>
   <Context_Area>
      <Time_Coordinates>
         <start_date_time>2014-09-
20T00:00:00.000Z</start_date_time>
         <stop_date_time>2018-05-
14T23:59:59.999Z</stop_date_time>
      </Time_Coordinates>
      <Primary_Result_Summary>
         <purpose>Science</purpose>
         <processing_level>Calibrated</processing_level>
         <Science_Facets>
            <domain>Magnetosphere</domain>
            <discipline_name>Particles</discipline_name>
            <facet1>Ions</facet1>
            <facet2>Solar Energetic</facet2>
         </Science_Facets>
         <Science_Facets>
            <domain>Magnetosphere</domain>
            <discipline_name>Particles</discipline_name>
            <facet1>Electrons</facet1>
            <facet2>Solar Energetic</facet2>
         </Science_Facets>
      </Primary_Result_Summary>
      <Investigation_Area>
         <name>Mars    Atmosphere    and    Volatile    EvolutioN
Mission</name>
            <type>Mission</type>
            <Internal_Reference>

<lid_reference>urn:nasa:pds:context:investigation:mission.maven<
/lid_reference>

<reference_type>bundle_to_investigation</reference_type>
            </Internal_Reference>
      </Investigation_Area>
          <Observing_System>
            <Observing_System_Component>
               <name>MAVEN</name>
               <type>Spacecraft</type>
               <Internal_Reference>

<lid_reference>urn:nasa:pds:context:instrument_host:spacecraft.m
aven</lid_reference>
```

```
<reference_type>is_instrument_host</reference_type>
               </Internal_Reference>
            </Observing_System_Component>
         <Observing_System_Component>
            <name>Solar Energetic Particle Experiment</name>
            <type>Instrument</type>
            <Internal_Reference>

<lid_reference>urn:nasa:pds:context:instrument:sep.maven</lid_re
ference>
               <reference_type>is_instrument</reference_type>
            </Internal_Reference>
         </Observing_System_Component>
      </Observing_System>
   </Context_Area>
   <Reference_List>
   </Reference_List>
   <Bundle>
      <bundle_type>Archive</bundle_type>
      <description>
         The maven.sep.calibrated Level 2 Science Data Bundle
contains fully calibrated
         SEP data, as well as the raw count data from which they
are derived, and
         ancillary ephemeris data. The calibrated data are in
physical units, and
         include electron and ion spectra in the 4 look
directions (2 look directions
         for each sensor/file).
      </description>
   </Bundle>
   <File_Area_Text>
      <File>

<file_name>readme_maven_sep_calibrated_1.12.txt</file_name>
         <creation_date_time>2018-08-
13T22:08:58</creation_date_time>

<md5_checksum>3fc210377a1b8205f1c8feed3e640784</md5_checksum>
         <comment>
            This file contains a brief overview of the MAVEN SEP
Calibrated data bundle.
         </comment>
      </File>
      <Stream_Text>
         <name>readme_maven_sep_calibrated_1.12.txt</name>
```

```
         <local_identifier>Readme</local_identifier>
         <offset unit="byte">0</offset>
         <object_length unit="byte">7876</object_length>
         <parsing_standard_id>7-Bit                         ASCII
Text</parsing_standard_id>
         <description>
            This file contains a brief overview of the MAVEN SEP
Calibrated data bundle.
         </description>
         <record_delimiter>Carriage-Return                  Line-
Feed</record_delimiter>
      </Stream_Text>
   </File_Area_Text>
   <Bundle_Member_Entry>

<lidvid_reference>urn:nasa:pds:maven.sep.calibrated:data.anc::1.
11</lidvid_reference>
      <member_status>Primary</member_status>

<reference_type>bundle_has_data_collection</reference_type>
   </Bundle_Member_Entry>
   <Bundle_Member_Entry>

<lidvid_reference>urn:nasa:pds:maven.sep.calibrated:data.counts:
:1.12</lidvid_reference>
      <member_status>Primary</member_status>

<reference_type>bundle_has_data_collection</reference_type>
   </Bundle_Member_Entry>
   <Bundle_Member_Entry>

<lidvid_reference>urn:nasa:pds:maven.sep.calibrated:data.spec::1
.12</lidvid_reference>
      <member_status>Primary</member_status>

<reference_type>bundle_has_data_collection</reference_type>
   </Bundle_Member_Entry>
   <Bundle_Member_Entry>

<lidvid_reference>urn:nasa:pds:maven.sep.calibrated:document::1.
0</lidvid_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.

```
<?xml version="1.0" encoding="UTF-8"?>
<?xml-model
href="http://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1400.sch"
   schematypens="http://purl.oclc.org/dsdl/schematron"?>
<?xml-model
href="http://pds.nasa.gov/pds4/mission/mvn/v1/PDS4_MVN_1030.sch"
   schematypens="http://purl.oclc.org/dsdl/schematron"?>
<Product_Collection
   xmlns="http://pds.nasa.gov/pds4/pds/v1"
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xmlns:mvn="http://pds.nasa.gov/pds4/mission/mvn/v1"
   xsi:schemaLocation="
      http://pds.nasa.gov/pds4/pds/v1
      http://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1400.xsd

      http://pds.nasa.gov/pds4/mission/mvn/v1
      http://pds.nasa.gov/pds4/mission/mvn/v1/PDS4_MVN_1030.xsd
    ">
   <Identification_Area>

<logical_identifier>urn:nasa:pds:maven.sep.calibrated:data.spec<
/logical_identifier>
      <version_id>1.12</version_id>
      <title>MAVEN SEP Calibrated Ion and Electron Spectra Data
Collection</title>

<information_model_version>1.4.0.0</information_model_version>
      <product_class>Product_Collection</product_class>
      <Citation_Information>
         <author_list>Larson, D.</author_list>
         <publication_year>2018</publication_year>
         <description>
            Calibrated MAVEN SEP sensor ion and electron spectra
         </description>
      </Citation_Information>
      <Modification_History>
         <Modification_Detail>
            <modification_date>2018-08-14</modification_date>
            <version_id>1.12</version_id>
            <description>MAVEN Release 14</description>
         </Modification_Detail>
      </Modification_History>
   </Identification_Area>
   <Context_Area>
```

```
      <Time_Coordinates>
         <start_date_time>2014-09-
22T19:34:31.205Z</start_date_time>
         <stop_date_time>2018-05-
14T23:59:59.999Z</stop_date_time>
      </Time_Coordinates>
      <Primary_Result_Summary>
         <purpose>Science</purpose>
         <processing_level>Calibrated</processing_level>
         <Science_Facets>
            <domain>Magnetosphere</domain>
            <discipline_name>Particles</discipline_name>
            <facet1>Ions</facet1>
            <facet2>Solar Energetic</facet2>
         </Science_Facets>
         <Science_Facets>
            <domain>Magnetosphere</domain>
            <discipline_name>Particles</discipline_name>
            <facet1>Electrons</facet1>
            <facet2>Solar Energetic</facet2>
         </Science_Facets>
      </Primary_Result_Summary>
      <Investigation_Area>
         <name>Mars Atmosphere and Volatile EvolutioN
Mission</name>
         <type>Mission</type>
         <Internal_Reference>

<lid_reference>urn:nasa:pds:context:investigation:mission.maven<
/lid_reference>

<reference_type>collection_to_investigation</reference_type>
         </Internal_Reference>
      </Investigation_Area>
      <Observing_System>
         <Observing_System_Component>
            <name>MAVEN</name>
            <type>Spacecraft</type>
            <Internal_Reference>

<lid_reference>urn:nasa:pds:context:instrument_host:spacecraft.m
aven</lid_reference>

<reference_type>is_instrument_host</reference_type>
            </Internal_Reference>
         </Observing_System_Component>
         <Observing_System_Component>
```

```
            <name>Solar Energetic Particle Experiment</name>
            <type>Instrument</type>
            <Internal_Reference>

<lid_reference>urn:nasa:pds:context:instrument:sep.maven</lid_re
ference>
               <reference_type>is_instrument</reference_type>
            </Internal_Reference>
         </Observing_System_Component>
      </Observing_System>
      <Target_Identification>
         <name>Mars</name>
         <type>Planet</type>
         <Internal_Reference>

<lid_reference>urn:nasa:pds:context:target:planet.mars</lid_refe
rence>

<reference_type>collection_to_target</reference_type>
         </Internal_Reference>
      </Target_Identification>
      <Mission_Area>
         <MAVEN xmlns="http://pds.nasa.gov/pds4/mission/mvn/v1">
            <mission_phase_name>Mars Orbital
Insertion</mission_phase_name>
            <mission_phase_name>Transition</mission_phase_name>
            <mission_phase_name>Prime
Mission</mission_phase_name>
            <mission_phase_name>EM-1</mission_phase_name>
            <mission_phase_name>EM-2</mission_phase_name>
         </MAVEN>
      </Mission_Area>
   </Context_Area>
   <Reference_List>

   </Reference_List>
   <Collection>
      <collection_type>Data</collection_type>
      <description>
         Calibrated MAVEN SEP sensor ion and electron spectra
      </description>
   </Collection>
   <File_Area_Inventory>
      <File>
         <file_name>collection_data_l2_cal-svy-
full_1.12.csv</file_name>
```

```
         <creation_date_time>2018-08-
14T05:04:12</creation_date_time>
         <file_size unit="byte">230560</file_size>

<md5_checksum>9669dabd26643e54b6672842cea216a9</md5_checksum>
      </File>
      <Inventory>
         <offset unit="byte">0</offset>
         <parsing_standard_id>PDS DSV 1</parsing_standard_id>
         <records>2620</records>
         <record_delimiter>Carriage-Return Line-
Feed</record_delimiter>
         <field_delimiter>Comma</field_delimiter>
         <Record_Delimited>
            <fields>2</fields>
            <groups>0</groups>
            <maximum_record_length
unit="byte">257</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>
            </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">255</maximum_field_length>
            </Field_Delimited>
         </Record_Delimited>

<reference_type>inventory_has_member_product</reference_type>
      </Inventory>
   </File_Area_Inventory>
</Product_Collection>
```

Appendix E Sample Data Product Labels

Sample data product labesl are provided as a separate ASCII text document: maven_sep_sample_xml.txt (LID = urn:nasa:pds:maven.sep.calibrated:document:sample-xml).

Appendix F PDS Delivery Package Manifest File Record Structures

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.

F.1 Transfer Package Directory Structure

Zip file directory structure will follow the structure used by the MAVEN SDC.

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.).

Appendix G PDS4 Labels for SEP CDF Data Files

This appendix describes the way that the metadata provided in the SEP PDS4 label files may be used to understand the internal physical and logical structure of the SEP data files, and how those labels may be used to access the data directly.

G.1 CDF Formatted Data Files

Common Data Format (CDF) is a self-describing data format for the storage of scalar and multidimensional data in a platform- and discipline-independent way. It has both library and toolkit support for the most commonly used platforms and programming languages. For the PDS archive, CDF files are required meet CDF-A specification with the PDS extensions [CDF-A]. In addition, the MAVEN mission includes other attributes in the CDF file as defined in the MAVEN archive CDF document [MAVEN CDF].

G.2 CDF and PDS4 Metadata

The PDS4 product label is an XML file that accompanies the CDF file. The PDS4 labels are designed to enable data users to read the CDF files without the use of a CDF reader or any awareness that the data are stored in a CDF file. Since the data consist of multiple data parameters (arrays) which have very specific relationships, the label describes both the physical structure of the data file, as well as the logical relationships between data parameters. This section describes the approach used to document both the physical structure and logical relationships.

G.2.1 PDS4 Label Structure

The PDS label is subdivided into a series of separate sections or "areas". Metadata describing the data parameters and their relationships are located in different areas of the label. Data parameters in the label are assigned a "local_identifier" and this identifier is referenced in the descriptions of the logical structure. A complete PDS4 label contains many areas. In this section we concentrate only on the areas which describe the physical structure and the logical relationships.

G.2.1.1. PDS Label Physical Structure Description

The physical structure of the data files are described in the "File_Area_Observational" portion of the label. Each data parameter is described using an "Array" object. The Array object contains location, data type, size, and descriptive information for each parameter. An "Axis_Array" object is provided for each axis of an array. Axis_Array includes an "axis_name" which is either set to the name of the CDF value associated with the axis or to the value "index" if the parameter is itself an independent variable. For each Array the "name" is the name assigned to the parameter ("variable" in CDF terms) in the CDF file. This is also assigned to "local_identifier" since a variable name is unique within a CDF. *Figure 17* contains sample Array objects.

```
<Array>
   <name>epoch</name>
   <local_identifier>epoch</local_identifier>
   <offset unit="byte">120576</offset>
   <axes>1</axes>
   <axis_index_order>Last Index Fastest</axis_index_order>
   <description>
      Time, middle of sample, in TT2000 time base
   </description>
   <Element_Array>
      <data_type>SignedMSB8</data_type>
      <unit>ns</unit>
   </Element_Array>
   <Axis_Array>
      <axis_name>time</axis_name>
      <elements>12220</elements>
      <sequence_number>1</sequence_number>
   </Axis_Array>
</Array>
   .
   .
   .
<Array>
   <name>f_ion_flux</name>
   <local_identifier>f_ion_flux</local_identifier>
   <offset unit="byte">521529</offset>
   <axes>2</axes>
   <axis_index_order>Last Index Fastest</axis_index_order>
   <description>
      Ion Flux in Forward look direction (#/cm^2/sec/ster/keV)
   </description>
   <Element_Array>
      <data_type>IEEE754MSBSingle</data_type>
   </Element_Array>
     <Axis_Array>
      <axis_name>time</axis_name>
      <elements>12220</elements>
      <sequence_number>1</sequence_number>
   </Axis_Array>
     <Axis_Array>
      <axis_name>energy</axis_name>
      <elements>28</elements>
      <sequence_number>2</sequence_number>
   </Axis_Array>
</Array>
```

Figure 17. Sample PDS4 Array objects.

G.2.1.1. Parameter Logical Relationships

The Discipline_Area may contain objects which are specific to a discipline. The logical relationships of parameters is often specific to the types of observations, so is described in the Discipline_Area.

The Alternate_Values object is used to indicate arrays which are functionally interchangeable. Note that this does not mean that the arrays are equivalent, only that they serve the same function. For example, this object may be used to associate multiple time arrays included in a data file. An Alternate_Values object contains a series of Data_Values objects which reference arrays by Local_Internal_Reference. Each of the Data_Values array within a single Alternate_Values must have the same dimensions. Figure 18contains a sample Alternate_Values object. The Alternate_Values object is defined in the “alt” discipline schema (LID = urn:nasa:pds:system_bundle:xml_schema:alt-xml_schema).

```
<Alternate_Values xmlns="http://pds.nasa.gov/pds4/alt/v1">
   <name>Time Values</name>
   <Data_Values>
      <Local_Internal_Reference>
         <local_identifier_reference>epoch</local_identifier_reference>
         <local_reference_type>data_values_to_data_values</local_reference_type>
      </Local_Internal_Reference>
   </Data_Values>
   <Data_Values>
      <Local_Internal_Reference>
         <local_identifier_reference>time_unix</local_identifier_reference>
         <local_reference_type>data_values_to_data_values</local_reference_type>
      </Local_Internal_Reference>
   </Data_Values>
   <Data_Values>
      <Local_Internal_Reference>
         <local_identifier_reference>time_met</local_identifier_reference>
         <local_reference_type>data_values_to_data_values</local_reference_type>
      </Local_Internal_Reference>
   </Data_Values>
   <Data_Values>
      <Local_Internal_Reference>
         <local_identifier_reference>time_ephemeris</local_identifier_reference>
         <local_reference_type>data_values_to_data_values</local_reference_type>
      </Local_Internal_Reference>
   </Data_Values>
</Alternate_Values>
```

Figure 18. Sample Alternate_Values object.

The Particle_Observation class describes the relationship between (typically multi-dimensional) data arrays and other arrays that are associated with an axis or axes of the data array. The Primary_Values object identifies the primary data array. The Axis_Values object associates an array with a single axes of the primary data array. The Aligned_Values object associates two arrays of the same dimensionality and axis definitions. Each “primary”, “axis”, and “aligned” array is referenced using the local_identifier attribute of a Local_Internal_Reference. Figure 19 contains a sample Particle_Observation object. The schema for the Particle_Observation object is defined in the “particle” discipline schema (LID = urn:nasa:pds:system_bundle:xml_schema:particle-xml_schema).

```
<Particle_Observation xmlns="http://pds.nasa.gov/pds4/particle/v1">
   <name>f_ion_flux</name>
   <description>Ion Flux in Forward look direction
(#/cm^2/sec/ster/keV)</description>
   <Primary_Values>
      <Local_Internal_Reference>
         <local_identifier_reference>f_ion_flux</local_identifier_reference>

<local_reference_type>particle_observation_to_observation_values</local_reference_ty
pe>
      </Local_Internal_Reference>
   </Primary_Values>
   <Axis_Values>
      <Local_Internal_Reference>
         <local_identifier_reference>epoch</local_identifier_reference>

<local_reference_type>particle_observation_to_axis_values</local_reference_type>
      </Local_Internal_Reference>
      <axis_number>1</axis_number>
   </Axis_Values>
   <Aligned_Values>
      <Local_Internal_Reference>
         <local_identifier_reference>f_ion_energy</local_identifier_reference>

<local_reference_type>particle_observation_to_aligned_values</local_reference_type>
      </Local_Internal_Reference>
   </Aligned_Values>
   <Aligned_Values>
      <Local_Internal_Reference>
         <local_identifier_reference>f_ion_flux_unc</local_identifier_reference>

<local_reference_type>particle_observation_to_aligned_values</local_reference_type>
      </Local_Internal_Reference>
   </Aligned_Values>
</Particle_Observation>
```

Figure 19. Sample Particle_Observation object