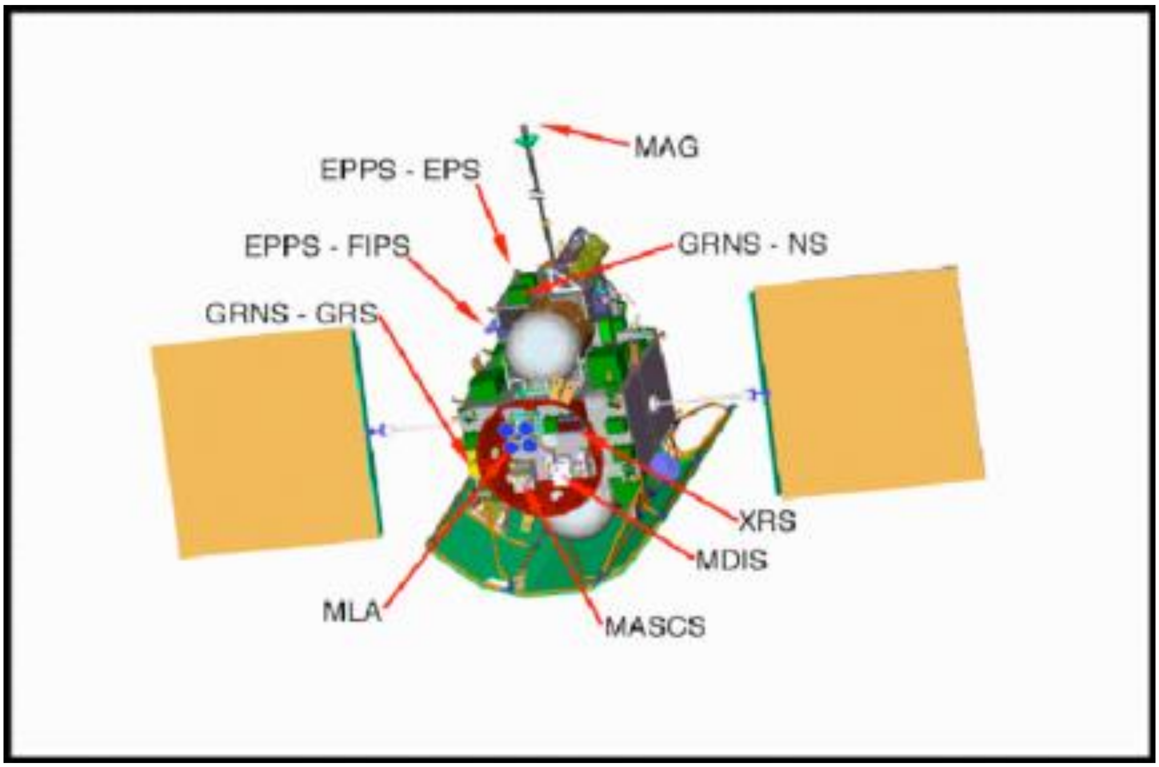
MESSENGER MASCS UVVS
Calibrated and Derived Data Record
Software Interface Specification

Version 5.2
February 22, 2016



Prepared by:

Noam Izenberg
Applied Physics Laboratory

Jennifer Ward
PDS Geosciences Node
Washington University

Document Review

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

William McClintock, MESSENGER Cognizant Co-Investigator/MASCS, has reviewed and approved this document.

Noam Izenberg, MESSENGER MASCS Instrument Scientist, has reviewed and approved this document.

Lyle Huber, PDS Atmospheres Node Representative, has reviewed and approved this document.

Susan Ensor, MESSENGER Science Operations Center Lead, has reviewed and approved this document.

Document Change History

Revision Number	Revision Date	Author	Section	Remarks
1.5	4/7/09			Start of revision history. Version submitted to PDS for Release 4.
1.6	1/8/10	J. Ward, GEO	5.3.4, Tables 3a & 3b, 6.3.2, Appendix B	1. Replaced sample PDS labels with new versions containing PRODUCT_VERSION_ID. 2. Added PRODUCT_VERSION_ID to UHCINDEX.TAB and USCINDEX.TAB column lists. 3. Updated UVVSSCIC.FMT columns to match file delivered in PDS Release 5.
1.7	9/15/10	J. Ward, GEO	5.2, 5.3.4.1, 5.3.4.2, 6.1.2, 6.1.3, 6.1.4, 6.3.2, Appendix B	1. Updated to describe new macro-based files. 2. Updated data product naming convention. 3. Added EXTRAS directory tables. 4. Removed <HHHH> subdirectories from CDR directory structure.
1.8	12/6/10	J. Ward, GEO	6.3.1, 6.3.2, Appendix A, Appendix B	1. Corrected formula for MIDSTEP_TIME. 2. Appended statement to PACKET_SUBSECONDS description.
1.9	5/5/11	J. Ward, GEO	6.1.3, 6.1.4	Updated to reflect new data directory structure.
2.0	6/10/11	J. Ward, GEO	6.1.4	Updated EXTRAS directory contents.
2.1	6/14/11	S. Ensor, SOC	Document Review	Replaced signature page with Document Review information.
2.2	6/17/11	J. Ward, GEO	6.1.4	Renamed SUPERTABLE.XLS TO MASTER_CRUISE_TABLE.XLS.
2.3	1/24/12	N. Izenberg, MASCS; J. Ward, GEO	2, Table 2, 6.1.4, 6.3.2, Appendix B	1. Added reference to calibration update document. 2. Temperature and solar scattering correction added to EDR to CDR processing steps table. 3. Added new documents to DOCUMENT and EXTRAS directory contents. 4. Spare column in UVVSSCIC.FMT converted to PMT temperature.
2.4	3/26/12	W. McClintock, MASCS; J. Ward, GEO	All	Converted to CDR/DDR Data Product SIS, adding new DDR data product. Draft version.
2.5	4/10/12	J. Ward, GEO	5.3.4.2, 6.3.1.2, Appendix B	Revised CDR sample label and format file.
2.6	4/13/12	W. McClintock, MASCS; J. Ward, GEO; R. Espiritu, ACT	Figures, Section 7	1. Added figures 2a-2c. 2. Deleted “UVVS position vectors in the inertial J2000 coordinate frame” figure. 3. Renumbered all figures. 4. Removed Section 7 Archive Release schedule. 5. Revised DDR index table columns.
2.7	4/20/12	N. Izenberg, MASCS; R.	5.2.2, 5.3.4, 6.1.2, 6.1.3,	1. Deleted DDR HDR file references (no DDR HDR file).

		Vervack, MASCS	6.1.4, 6.3.2, Appendix C	2. Revised DDR SCI file structure and description. 3. Renumbered sections/appendices. 4. Inserted new directory structure figure.
2.8	4/30/12	J. Ward, GEO	5.2.2, 5.3.4, 6.1.3, 6.1.4	Formatting and consistency edits.
2.9	5/3/12	J. Ward, GEO	Appendix C	Updated UVVSSCID.FMT.
3.0	5/11/12	A. Merkel, MASCS; J. Ward, GEO	5.3.4.3, 6.3.2.1, Appendix C	1. Format file edits. 2. Changed DDR file naming convention.
3.1	5/14/12	J. Ward, GEO	Appendix C	Fixed typo in UVVSSCID.FMT.
3.2	5/16/12	S. Ensor, SOC	2, 3, 4, 5.3.3, 5.5	Updated Applicable Document 4 name and references to it. Referenced Applicable Document 4 for delivery schedule.
3.3	5/18/12	J. Ward, GEO	6.1.4, Figure 4, Tables 3a-3c	1. Edited catalog directory contents. 2. Minor edits to directory structure. 3. Removed length column from index table contents table.
3.4	5/30/12	J. Ward, GEO	5.2.1, 5.3.4	Minor typo.
3.5	7/17/12	J. Ward, GEO	6.1.4	EXTRAS directory contents.
3.6	12/13/12	J. Ward, GEO	6.1.4	DOCUMENT and EXTRAS directory contents.
3.7	4/22/13	P. Bedini, SOC, J. Ward, GEO	All	Editorial changes.
3.8	4/25/13	J. Ward, GEO	All	Added new surface reflectance and atmosphere surface density data products. Draft version.
3.9	6/5/13	N. Izenberg, MASCS	All	Added Surface DDR information.
4.0	6/13/13	J. Ward, GEO	All	Additional edits.
4.1	6/19/13	R. Vervack, MASCS, J. Ward, GEO	5.2.2.3, 5.3.4, 6.1.2, 6.3.4	Added Atmospheric Model DDR information.
4.2	10/10/13	J. Ward, GEO	6.3.2.2, Table 3c	DDR-DAP peer review revisions.
4.3	12/4/13	J. Ward, GEO	2, 6.1.4	Added Applicable Document. Updated DOCUMENT and EXTRAS directory contents.
4.4	12/6/13	J. Ward, GEO	2, 6.1.4	Minor edit.
4.5	1/10/14	J. Ward, GEO	6.1.2, 6.1.4	Minor edits.
4.6	1/16/14	J. Ward, GEO	6.1.4	Minor typo.
4.7	2/18/14	J. Ward, GEO	5.2.2.3, 5.3.4.6, 6.1.4	1. Added Ca Chamberlain model document. 2. Updated Na atmospheric model sample label.
4.8	7/9/14	N. Izenberg	5.4.2, Various	MET/UT fixes, standardization between products, minor edits.

4.9	1/20/16	S. Ensor	All	Final mission edits. Reflect use of DEM in final surface pointing parameters.
5.0	1/21/16	J. Ward, GEO	All	Additional minor edits.
5.1	1/27/16	J. Ward, GEO	6.1.4	Additional minor edits.
5.2	2/22/16	R. Vervack, MASCS, J. Ward, GEO	All	Additional edits from Vervack for final release.

Table of Contents

1. Purpose and Scope of Document

1.1 Purpose

This document provides users of the MESSENGER Ultraviolet and Visible Spectrometer (UVVS) data products with a detailed description of the instrument (Figure 1), as well as Calibration Data Record (CDR) and Derived Data Record (DDR) generation and storage. The UVVS data products are deliverables to the Planetary Data System (PDS) and the scientific community that it supports. All data formats are compliant with PDS standards. In addition, this Software Interface Specification (SIS) documents the format and content of the MESSENGER MASCS CDR/DDR/DAP PDS archive volume. This document is both a CDR/DDR data product SIS and a CDR/DDR/DAP archive volume SIS.

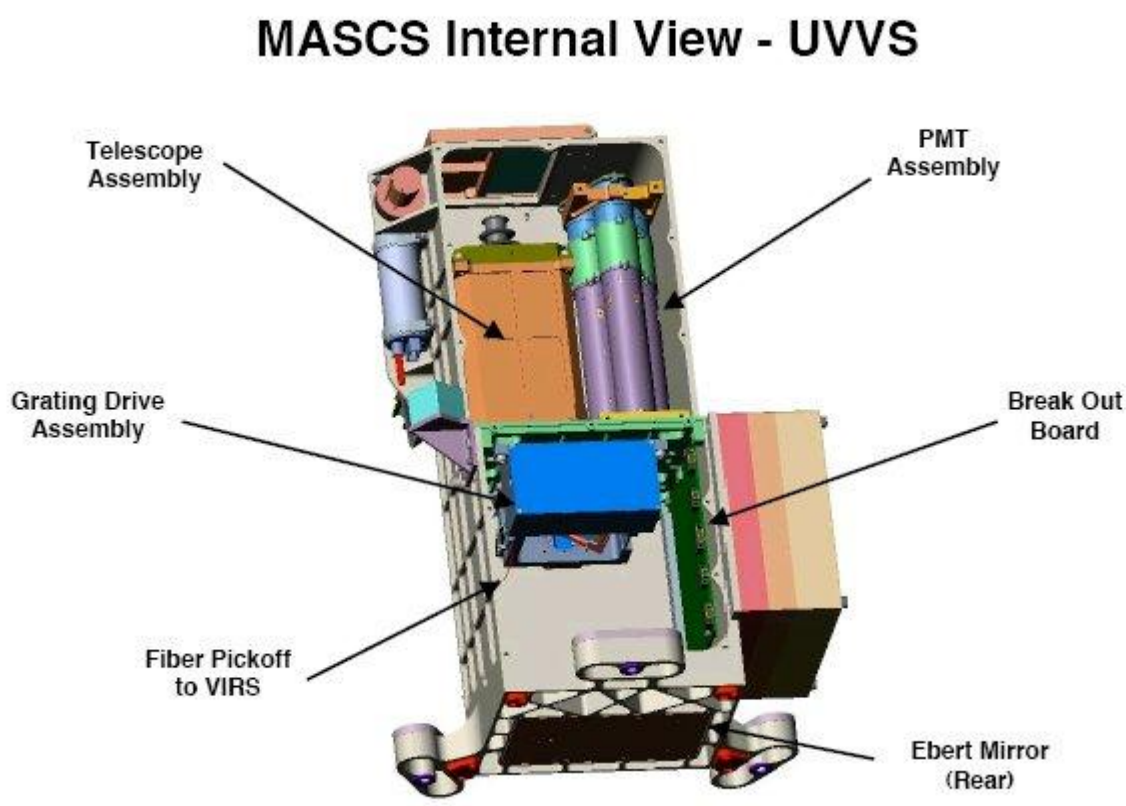


Figure 1: MASCS Instrument, UVVS Subsystem.

1.2 Scope

This specification is useful to those who wish to understand the format and content of the UVVS CDR and DDR data products. Typically, these individuals include software engineers, data analysts, and planetary scientists. The SIS applies to CDR/DDR data products produced during the course of MESSENGER mission operations. Experiment Data Records (EDRs), the raw, uncalibrated data from MASCS UVVS, are addressed in the UVVS EDR SIS (Applicable Document 8). EDR data products are archived in a separate PDS archive volume.

2. Applicable Documents

This SIS references the following documents:

1. MESSENGER Mercury: Surface, Space Environment, Geochemistry, Ranging; A mission to Orbit and Explore the Planet Mercury, Concept Study, March 1999. Document ID number FG632/ 99-0479.
2. Planetary Data System Archive Preparation Guide, NASA/JPL, August 29, 2006, Version 1.1, JPL D-31224.
3. Planetary Data System Standards Reference, NASA/JPL, March 20, 2006, Version 3.7, JPL D-7669, Part-2.
4. MESSENGER Data Management and Archiving Plan. The Johns Hopkins University, APL. Document ID number 7384-9019.
5. [PLR] Appendix 7 to the discovery program Plan; Program Level Requirement for the MESSENGER Discovery project; June 20, 2001.
6. MASCS Users Guide. Laboratory for Atmospheric and Space Physics, University of Colorado. Document ID number 20580-T5-5103.
7. Instrument Calibration Report. Mercury Atmospheric and Surface Composition Spectrometer (MASCS) on the Mercury: Surface, Space Environment, Geochemistry, Ranging (MESSENGER) Mission. LASP/CU Document Number 20580-T6-7915.
8. MESSENGER MASCS/UVVS EDR SIS: APL doc no. SIE-06-044 D.
9. MASCS Instrument Paper: W. E. McClintock and M. R. Lankton (2007) *Space Sci. Rev.* 131, 481-522.
10. MASCS Calibration Release Notes: W. E. McClintock and G. M. Holsclaw. APL document ID number: TSSD-19929.
11. UVVS Calibration Changes for PDS Delivery 7: Aimee Merkel, Ron Vervack, Noam Izenberg and the MASCS Team, APL Doc. No. SRE-02-12.
12. MESSENGER MASCS UVVS Calibration Update - PDS 11: Aimee Merkel and the MASCS Team, APL Doc. No. SRE-02-13, December 5, 2013.

3. Relationships with other Interfaces

The UVVS data products are stored on hard disk and in an SQL (Structured Query Language) relational database for rapid mission access during mission operations. The data products are electronically transferred to the PDS Geosciences and Atmospheres Nodes according to the delivery schedule in the MESSENGER Data Management and Archiving Plan [Applicable Document 4]. The UVVS and VIRS CDRs, DDRs, and DAPs contain some data that are useful in cross-comparison, therefore both the UVVS and VIRS CDRs/DDRs/DAPs are grouped together in the MASCS CDR/DDR/DAP archive volume stored at both PDS nodes.

4. Roles and Responsibilities

The roles and responsibilities of the instrument teams, Applied Physics Laboratory (APL), Applied Coherent Technology Corporation (ACT), and the PDS are defined in the MESSENGER Data Management and Archiving Plan [Applicable Document 4].

5. Data Product Characteristics and Environment

5.1 Instrument Overview

The Mercury Atmospheric and Surface Composition Spectrometer (MASCS) was comprised of a small Cassegrain telescope with a 257-mm effective focal length and a 50-mm aperture that simultaneously feeds both an UltraViolet and Visible Spectrometer (UVVS) and a Visible and InfraRed Spectrograph (VIRS). MASCS investigated Mercury's exosphere by measuring altitude profiles of known species as well as searching for previously undetected species. MASCS investigated the mineralogical composition of the surface of Mercury by obtaining maps of surface reflectance spectra on spatial scales of 5 km.

UVVS was a scanning grating, Ebert-Fastie monochromator with a focal length of 125 mm and equipped with three photomultiplier tube detectors (see Table 1). The three detectors covered the wavelength ranges of the far ultraviolet (115-180 nm), middle ultraviolet (160-320 nm), and visible (250-600 nm) with an average spectral resolution of 0.6 nm. The UVVS detector helped determine the global composition and spatial structure of Mercury's exosphere by measuring emission from known species (H, O, Na, K, and Ca) as well as previously undetected but predicted species (e.g. S, Si, Al, Mg, Fe, and OH). In addition to determining the composition and structure of the exosphere, these data provide the basis for determining exospheric processes, studying the relationship between surface and exospheric composition, and studying surface-exosphere-magnetosphere interactions.

VIRS was a fixed concave grating spectrograph with a 210-mm focal length (see Table 1). A beam splitter simultaneously dispersed the spectrum onto two solid-state array detectors: a 512-element silicon photodiode array, with a sensitivity to visible wavelengths (300-1050 nm), and a 256-element indium-gallium-arsenide photodiode array, to measure near infrared wavelengths (850-1450 nm). It was optimized to measure visible and near infrared surface reflectance, and VIRS obtained data with a resolution of 5 nm. Together, the VIRS and UVVS detectors measured surface reflectance at middle ultraviolet to visible to near infrared wavelengths to search for ferrous bearing minerals, Fe-Ti bearing phases, and ferrous iron. These measurements were made with a spatial resolution of 5 km or better. The VIRS data products are described in a separate VIRS data product SIS. The UVVS data products are described below.

		VIRS	UVVS
Focal length		210 mm	125 mm
Grating		120 g/mm blazed at 600 nm	1800 g/mm blazed at 300 nm
Spectral resolution	**FUV channel**	N/A	0.5 nm
	MUV channel	N/A	1.0 nm
	VIS channel	4 nm	1.0 nm
	IR channel	4 nm	N/A
Wavelength range	**FUV channel**	N/A	115 - 190 nm (2nd order)
	MUV channel	N/A	160 - 320 nm (1st order)
	VIS channel	300-1050 nm	250 - 600 nm (1st order)
	IR channel	850-1450 nm	N/A
Detector	**FUV channel**	N/A	Hamamatsu R 1081 PMT - CsI
	MUV channel	N/A	Hamamatsu R 759 PMT - CsTe
	VIS channel	Hamamatsu S3902-512 Si Diode Array	Hamamatsu R 647 PMT - Bi Alkali
	IR channel	Hamamatsu G8052-256 InGaAs Diode Array	N/A
Field of view	**Surface**	0.023° diameter	0.05° x 0.04°
	Atmosphere	N/A	1.0° x 0.04°

Table 1: MASCS Instrument Overview.

Please see Applicable Document 9 and Appendix I for additional details about the MASCS instrument.

5.2 Data Product Overview

5.2.1 Calibrated Data Records (CDRs)

The UVVS CDRs consist of calibrated data derived from MASCS UVVS EDRs. The Science EDRs are the raw data records used to derive emission and reflectance data used for scientific analysis. The Science EDRs contain raw counts of the UVVS photomultiplier tubes (PMT) at the commanded step of the UVVS grating, which correspond to a specific wavelength of light. Wavelength range and sensitivity of each PMT at each grating step vary, as documented in the MASCS Calibration Report, MASCS_CAL_RPT.PDF, provided in the DOCUMENT directory. Before the science data can be used for scientific analysis, the count rates in the EDRs must be converted to physical units and the data must be transformed into meaningful physical reference systems. This conversion yields calibrated data that are stored in CDRs.

Table 2a lists the processing steps from the EDR to the CDR level, along with the corresponding CDR table column names and numbers. The *.FMT files and their columns are fully described in section 6.3. The algorithms and tables used to convert raw, uncalibrated data to calibrated radiance at the sensor can be found in the CALIB and DOCUMENT directories of this archive volume.

Processing Step	**UVVSSCIC.FMT Column**
1. Determine wavelength and timing for each step of a given grating scan observation.	STEP_UTC_TIME (column 35) STEP_WAVELENGTH (column 38)
2. Account for zigzag scans if observation uses grating zigzag.	This is an operation on the way to FULLY_CORRECTED_COUNT_RATE (not preserved in CDR)
3. Correct for PMT nonlinearity.	DEAD_CORRECTED_COUNT_RATE (column 41)
4. Calculate empirical PMT temperature correction to dark counts.	DARK_RATE (column 42)
5. Calculate solar scattering where possible.	SCATTERED_LIGHT_RATE (column 43)
6. Row 3 – Row 4 – Row 5	FULLY_ CORRECTED_COUNT_RATE (column 44)
7. Apply PMT sensitivity for every step of every observation, convert counts to radiance at sensor.	STEP_RADIANCE_KR (column 46) STEP_RADIANCE_W (column 47)
8. Determine pointing parameters (geometry fields calculated from SPICE) for every step of every observation. Surface pointing parameters determined relative to Mercury DEM.	All geometry fields
9. Assign data quality flags and indicators.	DATA_QUALITY_INDEX (column 50)
Processing Step	**UVVSSCID_SUR.FMT Column**
10. Filter out non-surface observations	Use Macro number identifiers (Macros 48, 49)
11. Divide by solar spectrum for Reflectance, Bin steps to 1 nm bandwidths.	IOF_BIN_DATA (column 14) and IOF_BIN_NOISE_DATA (column 16)
12. Apply photometric correction	PHOTOM_IOF_BIN_DATA (column 15) and PHOTOM_IOF_BIN_NOISE_DATA (column 17)

Table 2a: UVVS EDR to CDR to Surface DDR Processing Steps.

The UVVS CDR data product contains all the data from one observation set. An observation set is defined in three ways. 1) Before adoption of macro-based commanding on the spacecraft, one observation set contains all the CCSDS (Consultative Committee for Space Data Systems) packets generated by one photomultiplier tube in a given hour of operation. UVVS produces one CCSDS packet per scan of the instrument grating (one scan may have repeated passes and/or a zigzag across a defined number of steps). 2) After macro-based commanding of the instrument commenced, an observation set consists of the all scans and packets produced by a single macro call. The exception to this is case 3) for very long executions of high-data rate macros that produce hundreds of megabytes of calibrated data. These “fat” macros are subdivided into several hour chunks. A variable number of CDR products are generated each day depending on the UVVS observation plan.

One observation set is associated with two CDR data products: a science header table (HDR), showing the instrument command parameters for a given observation, and a science data table (SCI), showing counts, derived science data, and pointing information for each step of an observation. The CDRs are in binary table format, and each is described by a detached PDS label. The label files define the start and end time of the observation, product creation time, etc. The label points to an associated format file that defines the fields of the binary table contained within the data file.

The UVVS macro-based science header (HDR) CDR (case 2) contains engineering data that does not change over the entire packet. It has N records, where N is the same number as in the corresponding EDR, and there is 1 record per packet. Thus, there is a 1-1 correspondence between the science header CDR and the corresponding EDR. The UVVS macro-based science (SCI) CDR contains per step data. 1 record = 1 step. The file contains N * f(N) records, where N is the number of records in the corresponding EDR and f(N) is a function of how many steps are extracted from a given packet in the EDR. Thus, the records f(N) in the macro science CDR correspond to record N in the macro science header CDR, which corresponds to record N in the EDR.

There are three EDR data products produced by the UVVS instrument, one for each detector (FUV, MUV, VIS). The detectors are also referred to as the Photomultiplier Tube detectors (FUV PMT, MUV PMT, VIS PMT). These are identified in the EDR PDS label as the “UVVSFUV,” “UVVSMUV,” and “UVVSVIS” standard data products, respectively. There is also a MASCS housekeeping EDR data product generated by the MASCS instrument. This is identified in the PDS label as the “MASCSHK” standard data product. The housekeeping EDR is defined in both the UVVS and the VIRS EDR SISs. UVVS EDR and associated housekeeping data are input into the UVVS calibration pipeline to derive Calibrated Data Records (CDRs).

The CDR archive consists of 6 standard data products, 2 for each detector (FUV, MUV, VIS). These are identified as “UVVSCFUVHDR,” “UVVSCFUVSCI,” “UVVSCMUVHDR,” “UVVSCMUVSCI,” “UVVSCVISHDR,” and “UVVSCVISSCI” CDRs.

There are three types of data stored in each data file: RAW_STEP_DATA (SCI table column 39), count rates (SCI table columns 40-44), and STEP_RADIANCE (_KR & _W, SCI table columns 46 & 47, respectively). Please see the table column definitions in section 6.3 for detailed descriptions of these columns.

5.2.2 Derived Data Records (DDRs)

5.2.2.1 Surface DDRs

For the UVVS surface DDR data products, one DDR contains all the derived reflectance data from one MUV surface observation. Not all surface CDRs are converted to DDRs; only targeted surface observations of the MUV PMT from Mercury orbit were processed to a DDR. Thus, there are only a few thousand total UVVS DDRs. CDRs were converted to DDRs by first filtering out non-planet-targeted observations, then converting to reflectance by dividing the solar irradiance spectrum out of the MASCS radiance data. A photometric correction was then applied to the reflectance data for corrected data. Bins of approximately 1 nm bandwidth (~5 UVVS steps) were created by coadding the signal in each step of the bin. In a 660 step scan of the standard UVVS surface observation, this results in a single UVVS spectrum of about 132 bins.

One observation set is associated with two surface DDR data products: a science header table, showing the instrument command parameters for a given observation, and a science data table, showing counts, derived science data, and pointing information for each bin of 5 steps of an observation. The surface DDRs are in binary table format, and each is described by a detached PDS label. The label points to an associated format file that defines the fields of the binary table contained within the data file.

There are four types of spectra stored in each surface DDR science data file: IOF_BIN_DATA (table column 14), PHOTOM_IOF_BIN_DATA (table column 15), IOF_ BIN_NOISE_DATA (table column 16), and PHOTOM_IOF_ BIN_NOISE_DATA (table column 17).

Table 2a lists the processing steps from the EDR to the CDR and DDR levels, along with the corresponding CDR and DDR table column names and numbers. The *.FMT files and their columns are fully described in section 6.3. The algorithms and tables used to convert EDRs to CDRs and DDRs can be found in the CALIB and DOCUMENT directories of this archive volume.

5.2.2.2 Atmosphere DDRs

The UVVS Atmosphere Derived Data Records consist of time ordered sequences of radiance values that are measured along lines of sight perpendicular to Mercury radius vectors. The viewing direction for each measurement is determined by specifying the latitude, longitude, and altitude of the spacecraft and the latitude, longitude, and altitude of the minimum ray (Figure 5a). Figures 2a-2c illustrate the three general geometry-based classifications of Atmosphere DDRs. These are dayside limb scans (LS), which are acquired as sets of limb altitude profiles at specific local times, dayside and nightside limb drift profiles (LD), which are acquired in a more random fashion, and nightside tail sweeps (NS), which are sets of back-and-forth sweeps of the UVVS line of sight across the nightside exosphere. Each of these products is generated for the three major exosphere species that were regularly observed by the UVVS: sodium (Na), magnesium (Mg), and calcium (Ca). The Mg data in the DDRs are observations of the emission line at 285.3 nm, the Ca data are observations of the emission line at 422.8 nm, and the Na data are observations of the doublet emission lines at 589.2 nm (D2) and 589.8 nm (D1). All wavelengths are specified in vacuum. The total radiance calculated for Na pertains to the sum of the D1 and D2 lines, which overlap to some extent at the spectral resolution of the UVVS.

A single Atmosphere DDR contains all of the observations for a given species and classification that were acquired during a single Mercury year. "Mercury year" is defined as the time to cover the full 360 degrees of Mercury's orbit around the Sun, with the starting point being at 0 degrees true anomaly. Because MESSENGER orbit insertion and the start of science data acquisition occurred at 73 degrees true anomaly, the first Mercury year only covered a range from 73 degrees to 360 degrees. The final Mercury year was also a partial year, covering true anomalies from 0 to 64 degrees at mission end.

Table 2b summarizes the processing of the Atmosphere DDR products. They were assembled from the CDRs by filtering each species to identify the particular geometry classification and eliminating observations of marginal to no use (e.g., saturated spectra, slit half-on/half-off the planet). Each Atmosphere DDR product consists of time-ordered sequences of spectra (wavelength versus radiance value), total radiance (total column emission rate), and pointing information for each minimum ray altitude within the given Mercury year.

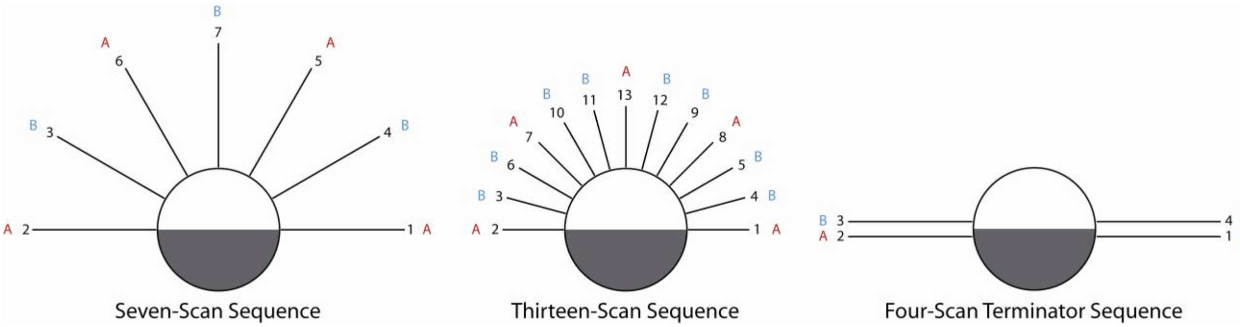


Figure 2a. Dayside limb scan implementation.

The nominal seven-scan scenario with full local-time coverage is shown at the left. The maximum altitude of each scan was fixed at 4000 km, or at whatever maximum altitude was achievable within spacecraft pointing constraints. The scans took 9 minutes each. The numbers indicate the order in which the scans occured, the back-and-forth step-like nature across the planet being necessary to keep the particular local times within the allowed pointing window as the spacecraft moved in its orbit. This nominal seven-scan scenario covers the majority of the limb scans.

The thirteen-scan scenario (middle panel) covers some cases from early in the orbital phase (mostly Mercury years 1-5) and occured when spacecraft pointing constraints did not allow for higher altitudes to be reached. To offset the lower altitude ranges (up to 2500 km maximum) the number of local times was increased. The time per scan in this case was reduced to 4 minutes per scan.

The four-scan scenario (right panel) occured when full local-time coverage was not possible within the spacecraft pointing constraints. Instead, four scans were conducted, two at dawn and two at dusk, to study the important dawn-dusk asymmetries. These scans could reach 4000 km altitude maximum and take 9 minutes each.

In all cases, A and B indicate a particular macro. A and B may be the same, but having different macros on the interleaved scans allows for multiple species to be observed in a given sequence. A and B may also indicate a change in the maximum altitude, with the A (or B) scans having a higher maximum altitude relative to the B (or A) scans. This option was employed in various ways throughout the orbital phase to provide a mix of spatial resolutions during any given sequence. The most common combination was A scans with maximum altitude of 4000 km and B scans with maximum altitude of 2500 km.

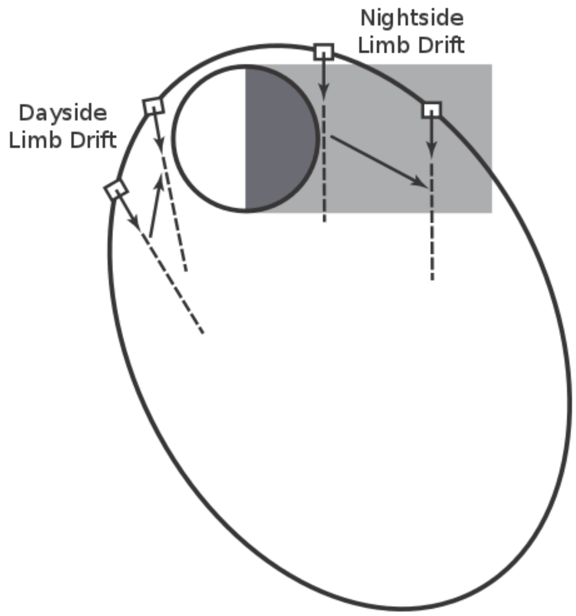


Figure 2b. Example limb drift observations.

These drift observations were serendipitous exospheric limb profile measurements during ride-alongs with other instruments. They occurred anywhere in the orbit as long as the UVVS line of sight observed off the planetary limb. As ride-along observations, the pointing was dictated by the other instruments; thus, the UVVS pointing may have varied during any given drift observation, and the altitudes covered ranged from as few as a hundred kilometers to as many as several thousand kilometers.

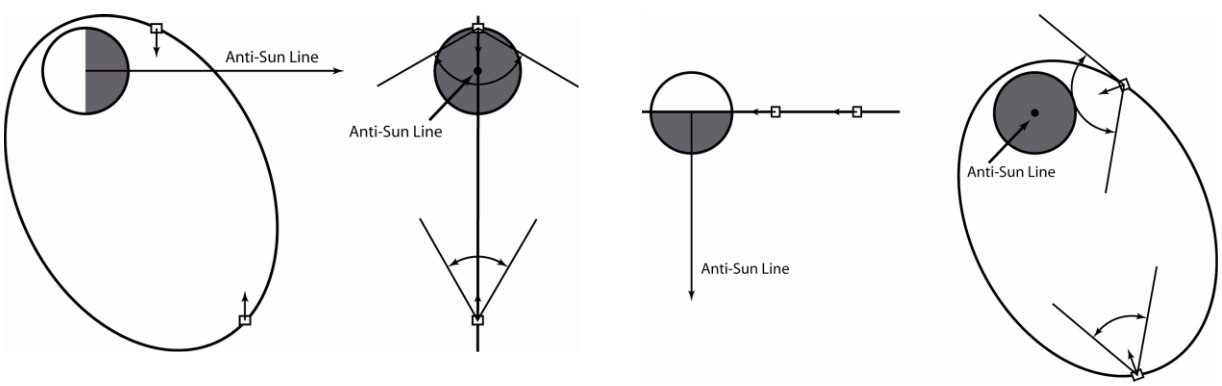


Figure 2c. Two end-member examples of the exosphere mapping scans (tail sweeps).

The left two illustrations show the noon-midnight/nightside apoapse case and the right two illustrations show the dawn-dusk/dawn side apoapse case. As indicated in the illustrations, the exosphere mapping scans proceeded by rocking the spacecraft back and forth about the line from the spacecraft to the Sun-Mercury line. The angle of the rocking was adjustable, generally smaller near apoapse, and the resulting observational sequence was a series of “fans” stacked one after the other.

The Atmosphere DDRs are in binary format and each is described by a detached PDS label. The label files define the start and end time, creation date, etc. The label points to an associated format file that defines the fields of the binary table contained within the data file. The UVVS Atmosphere DDR file contains pointing data and N records, where N is the number of sequential spectra recovered from the filtering process.

There are nine Atmosphere DDR standard data products produced from the CDRs, three for each species. These are identified as “UVVSDNALS,” “UVVSDNALD,” and “UVVSDNANS” for sodium. Names for Mg and Ca are produced by replacing ‘NA’ with ‘MG’ and ‘CA’, respectively. There are two types of data stored in each science file: RADIANCE versus WAVELENGTH (spectra, table column 23) and TOTAL_RADIANCE in each observed emission line (total radiance measured at each altitude (pointing), table column 25).

Data Product	Processing Step	Description
Dayside limb altitude profiles (LS)	1. Filter CDRs for a specified species and spacecraft orbit 2. Order as a time series, which keeps individual altitude profiles together	Dayside altitude limb scans for Na, Ca, and Mg each consisting of a sequential list of altitude scans with radiance values and spectra including appropriate geometry fields.
Dayside and nightside limb drift profiles (LD)	1. Filter CDRs for a specified species and spacecraft orbit 2. Order as a time series	Dayside and nightside limb drift profiles for Na, Ca, and Mg each consisting of a sequential list of altitude scans with radiance values and spectra including appropriate geometry fields.
Night side tail sweep profiles (NS)	1. Filter CDRs for a specified species and spacecraft orbit 2. Order as a time series	Night side sweep scans for Na, Ca, and Mg provides a sequential list of sweep scans with radiance values and spectra including appropriate geometry fields.

Table 2b: UVVS CDR to Atmosphere DDR Processing Steps.

5.2.2.3 Atmospheric Model DDRs

The UVVS Atmospheric Model Derived Data Records consist of a series of model fits to data averaged over specific Mercury true anomalies and local times. These model fits, and the parameters provided in the DDRs, are described below. The description is given for Na, but Ca and Mg are similarly fitted. For a full description of the Ca model, please see CALCIUM_CHAMBERLAIN_MODELS.PDF in the document directory.

It should be noted that these models are intended only as a first-order approximation of the average atmospheric state on the dayside using a well-known and accepted model (the Chamberlain model). However, such models lack some of the relevant physics that are pertinent to the Mercury exosphere. As such, they are excellent starting points for more detailed models but should not be interpreted as a true representation of the actual exosphere. More detailed models are too complicated to provide in any meaningful way.

The model employed is adapted from the model developed by Chamberlain (1963). The temperature and density of the dayside sodium exosphere were found by fitting the estimated column densities from individual limb scans. The fit applies only to the lower 700-1000 km of the exosphere, which is relatively cold and dense compared to the exosphere at higher altitudes. The DDRs give the averages of these fits as a function of true anomaly in 5 degree increments.

The column density N (cm^{-2}) is derived from radiance I (kR) using

$$N=I/(g\ 10^6) \qquad (1)$$

The g-value is the rate (s^{-1}) at which an atom scatters sodium D1 and D2 solar photons. It depends on distance from, and radial velocity relative to, the sun. The sodium atoms have a distribution of speeds, but because this distribution is relatively narrow for the low-altitude, low-temperature portion of the exosphere described in this data product, we use Mercury's radial velocity and distance from the sun to calculate g.

The exospheric column density is related to the density via

$$N=KHn \qquad (2)$$

where n is the density of the exosphere at the line-of-sight tangent point, H is the scale height of the exosphere, and K is the ratio between the line-of-sight column density and the vertical column density ($\sim Hn$) and given, approximately, by $[\pi r/(2H)]^{1/2}$. These formulas come from Chamberlain (1963).

The density is approximated by

$$n=n_0 e^{-U/kT} \qquad (3)$$

where U is the gravitational potential energy due to gravity and photon acceleration, T the temperature, and n_0 the surface density (see Feynman (1963) for a general discussion of this formula). The temperature and surface density are the free parameters of our fits to the limb scans and are provided in the DDR.

Photon acceleration (also called photon pressure or radiation pressure) is an antisunward acceleration due to the resonant scattering of sunlight. It is directly proportional to the g-value. At Mercury, for sodium, it can be nearly half as large as surface gravity (e.g., Wang and Ip, 2011). For that reason we included it along with the gravitational potential term in Eq. (1), so that the potential energy is written as

$$\mathrm{U}=GMm/r + mbr\cos(\theta) \qquad (4)$$

as described in Bishop (1985), where b is the photon acceleration, θ is the angle between the local radial vector and the Mercury-sun axis, G is the gravitational constant, M is the mass of Mercury, m is the mass of a sodium atom, and r is the distance from Mercury's center. For each limbscan, because they all have line-of-sight tangent points near the equator, θ is derived, approximately, by the angular distance from noon as measured by the local time provided in the DDR.

The scale height, used in the formulas above and provided in the data product, is defined by

$$H = n/(\mathrm{d}n/\mathrm{d}r) = kT/(\ GMm/r^2 + mb\cos(\theta)\ ). \qquad (5)$$

Note that in the absence of photon pressure and ignoring the radial variation in gravity, this definition reduces to the classic kT/ma, where a is gravitational acceleration. Alternately, we can write H as

$$kT/m(a + b\cos(\theta)\ ) \qquad (6)$$

where the parenthetical term in the denominator can be seen as a sum of two terms, the gravitational term and the radial component of the photon pressure. This scale height (measured in km) is also provided in the DDR.

Bishop, J., 1985. Geocoronal structure - The effects of solar radiation pressure and the plasmasphere interaction. Journal of Geophysical Research 90, 5235-5245.

Chamberlain, J. W., 1963. Planetary coronae and atmospheric evaporation. Planetary and Space Science 11, 901.

Feynman, R. P., 1963. Feynman lectures on physics - Volume 1, Chapter 40. Reading, Ma.: Addison-Wesley, 1963, edited by Feynman, Richard P.; Leighton, Robert B.; Sands, Matthew.

Wang, Y. C. and W. H. Ip, 2011. Source dependency of exospheric sodium on Mercury. Icarus 216, 387-402.

5.3 Data Processing

5.3.1 Data Processing Level

The CDR/DDR archive includes level 3 (CDR) and level 4 (DDR) data as defined by the Committee on Data Management and Computation (CODMAC, Appendix G). The archive also contains calibration information, a description of the SPICE kernels that are needed to generate viewing geometry, and documentation describing the characteristics and generation of the data products. Each product has a unique file name across all MASCS data products, see section 6.1.2.

5.3.2 Data Product Generation

The UVVS CDR/DDR files were produced by the MESSENGER Science Operations Center (SOC), operated jointly by APL and ACT. The 'PIPE-MASCS2CDR' and 'PIPE-MASCS2DDR' software, derived from MASCS-team produced calibration algorithms, converted the data to the proper PDS labeled format. These software were not supported products deliverable to the PDS; however the algorithms and tables are included in the archive.

The CDR/DDR data products were made available to the MESSENGER Science Team during the mission for initial evaluation and validation. At the end of the evaluation and validation period, the data were organized and stored in the directory structure described in section 6.1.3 for transmittal to the Geosciences and Atmospheres Nodes. The transmittal process is described in the following section, Data Flow. PDS provides public access to the data products through its online data distribution system. These products are used for engineering support, direct science analysis, and construction of other science products. Although there is enough information in the header to perform some processing, for more sophisticated processing, ancillary data are required. Examples of ancillary data include calibration files and viewing geometry files (SPICE kernels). Calibration files for UVVS are located in the CALIB directory. Calibration and data reduction details and tables are described in the UVVS_EDR2CDR.TXT, UVVS_CDR2DDR.TXT, UVVS_CDR2DDR_SUR.TXT, and MASCS_CAL_RPT.TXT documents, located in the DOCUMENT directory. The geometry.txt file located in the GEOMETRY directory (section 6.1.4) contains a listing of the SPICE kernel types that are needed by a user to generate viewing geometry. The SPICE kernel files are archived with the PDS NAIF Node.

5.3.3 Data Flow

The MESSENGER SOC operated under the auspices of the MESSENGER Project Scientist to plan data acquisition and generate and validate data archives. The SOC supported and worked with the Mission Operations Center (MOC), the Science Team, instrument scientists, and the PDS (Figure 3). The SOC was located at the Johns Hopkins University Applied Physics Lab (JHU/APL). During the mission operations phase, the SOC produced early versions of products to be used by the science and instrument teams.

The MESSENGER SOC delivered data to both the PDS Geosciences and Atmospheres Nodes in standard product packages according to the schedule outlined in the MESSENGER Data Management and Archiving Plan [Applicable Document 4]. The UVVS and VIRS data sets are archived at both Nodes. Each package comprises both data and ancillary data files, organized into directory structures consistent with the volume design described in Section 6.1.3.

In preparation for the delivery, the directory structure was copied onto hard disk and mailed to the Geosciences and Atmospheres PDS nodes. Also transferred was a checksum file created using the MD5 algorithm. This provided an independent method of verifying the integrity of the archive after it was transferred to disk. Within several days of delivery, the PDS Node acknowledged receipt of the archive and checksum file. If acknowledgement was not received, or if problems were reported, the MESSENGER SOC immediately took corrective action.

After receipt of the hard disk, the PDS Nodes transferred the archive files to their local archive staging areas and checked for data integrity using the checksum file. The Nodes performed any additional verification and validation of the data provided and reported any discrepancies or problems to the MESSENGER SOC. It was expected that the Nodes perform these checks in about two weeks. After inspection was completed to the satisfaction of the PDS Nodes, the Nodes issued to the MESSENGER SOC acknowledgement of successful receipt of the data.

Following receipt of a data delivery, each Node organized the data into PDS archive volume structure within its online data system. The Science Team generated all of the required files associated with a PDS archive volume (index file, readme files, etc.) as part of its routine processing of incoming MASCS data. Newly delivered data were made available publicly from PDS once accompanying labels and other documentation were validated.

Changes and/or updates in instrument calibration resulted in an incremented calibration version number and regeneration of CDRs/DDRs. Regenerated data were included in the next scheduled delivery, as appropriate.

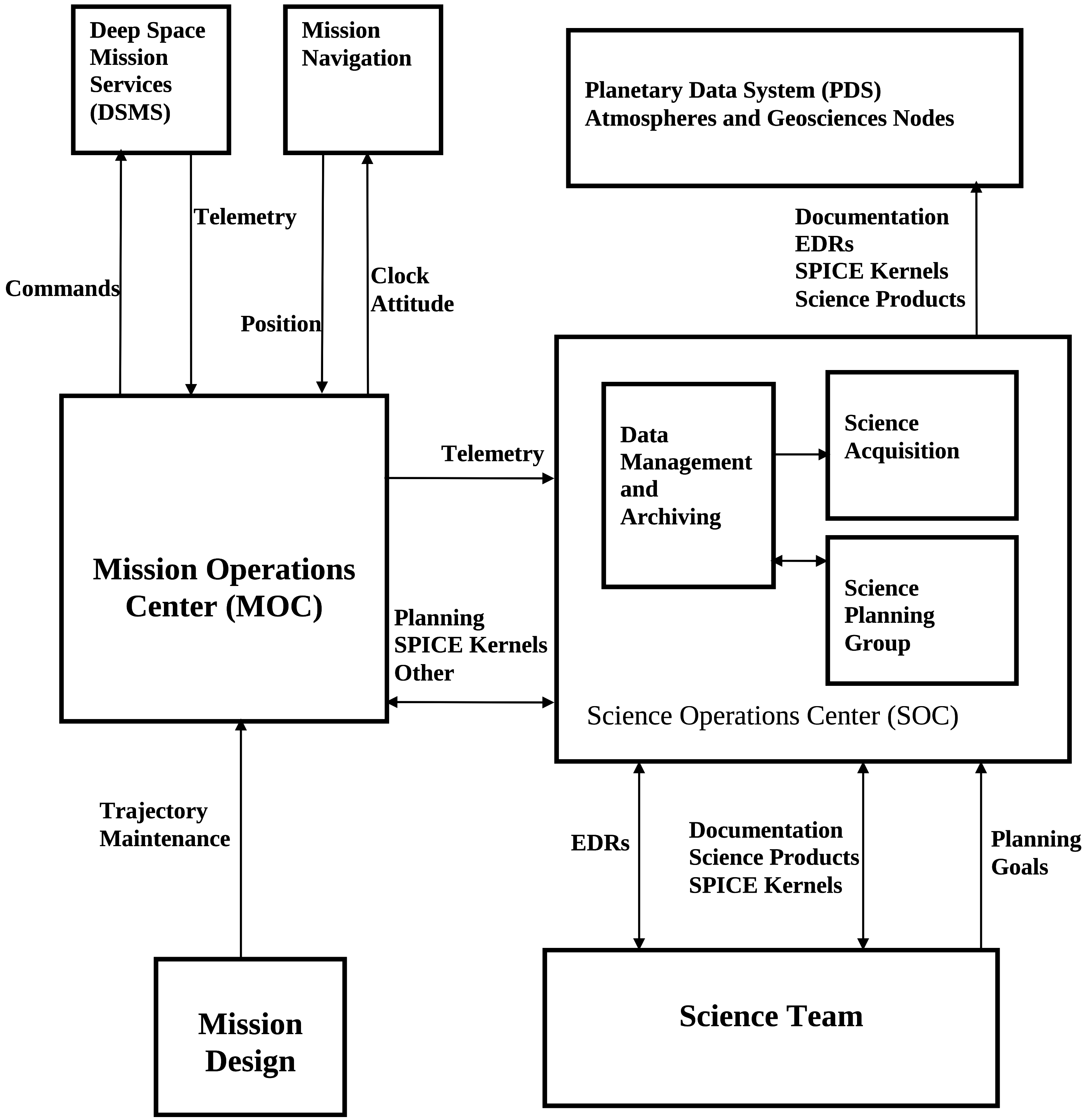


Figure 3: MESSENGER data flow.

5.3.4 Labeling and Identification

The PDS label conforms to the PDS version 3 standards. For more information on this standard consult the PDS Standards Reference JPL D-7669 Document [Applicable Document 3]. The purpose of the PDS label is to describe the data product and provide ancillary information about the data product.

One observation is associated with two CDR data products: a science header table (HDR), showing the instrument command parameters for a given observation, and a science data table (SCI), showing counts, derived science data, and pointing information for each step of an observation. The CDRs are in binary table format, and each is described by a detached PDS label. There are six standard data products, “UVVSCFUVHDR,” “UVVSCFUVSCI,” “UVVSCMUVHDR,” “UVVSCMUVSCI,” “UVVSCVISHDR,” and “UVVSCVISSCI” (Section 5.2).

UVVS Surface DDRs consist of individual surface scans of the MUV PMT on point targets to keep the FOV on the same spot during the entire grating scan. There is one pair of surface DDRs: “UVVSDMUVHDR" and “UVVSDMUVSCI".

The UVVS Atmosphere DDRs consist of time-ordered sequences of calibrated spectra and radiance values that are measured along lines of sight perpendicular to Mercury radius vectors. There are three defined geometry classifications: dayside limb scans, dayside and nightside limb drift profiles, and nightside tail sweeps. The Atmosphere DDRs are in binary format and each is described by a detached PDS label. Each file contains N records where N is the number of sequential steps recovered from the filtering process. There are nine standard Atmosphere DDRs produced from the CDRs. These are identified as “UVVSDNALS,” “UVVSDNALD,” and “UVVSDNANS” for sodium. Names for Mg and Ca are produced by replacing ‘NA’ with ‘MG’ and ‘CA’, respectively.

The UVVS Atmospheric Model DDRs consist of average fits to observations at a series of Mercury true anomaly and local times. The model parameters near-surface density, temperature, and scale height are provided. The data are provided in an ASCII table format. There are 3 atmospheric model DDRs, identified as “UVVSDNAMOD”, “UVVSDMGMOD”, and “UVVSDCAMOD” for the sodium, magnesium, and calcium models, respectively.

The following are examples of UVVS PDS labels for the “UVVSFUVHDR” and “UVVSFUVSCI” CDR data products and the "UVVSDMUVHDR", "UVVSDMUVSCI", “UVVSDNALS”, and "UVVSDNAMOD" DDR data products, respectively. Details about the label format are specified in section 6.3.

5.3.4.1 Example PDS Label for the UVVS Science Header CDR

```
PDS_VERSION_ID                    = "PDS3"

/*** FILE FORMAT ***/
```

```
RECORD_TYPE                    = FIXED_LENGTH
RECORD_BYTES                   = 50
FILE_RECORDS                   = 480

/*** GENERAL DATA DESCRIPTION PARAMETERS ***/
PRODUCT_ID                     = "UFC_MC4_07_09343_064005_HDR_DAT"
PRODUCT_VERSION_ID             = "V1 "
PRODUCT_CREATION_TIME          = 2010-07-28T19:53:37
PRODUCT_TYPE                   = "CDR"
SOFTWARE_NAME                  = "PIPE-MASCS2CDR"
SOFTWARE_VERSION_ID            = "2.0"
INSTRUMENT_HOST_NAME           = "MESSENGER"
INSTRUMENT_NAME                = "
 MERCURY ATMOSPHERIC AND SURFACE COMPOSITION SPECTROMETER"
INSTRUMENT_ID                  = "MASCS"
DETECTOR_ID                    = "UVVS"
DATA_SET_ID                    = "MESS-E/V/H-MASCS-3-UVVS-CDR-CALDATA-V1.0"
STANDARD_DATA_PRODUCT_ID       = "UVVSCFUVHDR"
MISSION_PHASE_NAME             = "MERCURY 4 CRUISE"
TARGET_NAME                    = "VENUS"
TARGET_DESC                    = "Venus-As-Star Cal"
START_TIME                     = 2009-12-09T06:40:05
STOP_TIME                      = 2009-12-09T10:08:02
SPACECRAFT_CLOCK_START_COUNT   = "168828279.009"
SPACECRAFT_CLOCK_STOP_COUNT    = "168840756.989"
^TABLE                         = "UFC_MC4_07_09343_064005_HDR.DAT"

OBJECT                         = TABLE
   COLUMNS                        = 23
   INTERCHANGE_FORMAT             = BINARY
   ROW_BYTES                      = 50
   ROWS                           = 480
   DESCRIPTION                    = "
       This table contains instrument engineering data collected by the
       FUV detector.

       Detailed descriptions for the parameters defined below are contained
       in the CDR SIS document.

       The complete column definitions are contained in an external file
      found in the LABEL directory of the archive volume.
   "
   ^STRUCTURE = "UVVSHDRC.FMT"
END_OBJECT                     = TABLE
END
```

5.3.4.2 Example PDS Label for the UVVS Science CDR

```
PDS_VERSION_ID                 = "PDS3"

/*** FILE FORMAT ***/
RECORD_TYPE                    = FIXED_LENGTH
RECORD_BYTES                   = 752
FILE_RECORDS                   = 1216
```

```
/*** GENERAL DATA DESCRIPTION PARAMETERS ***/
PRODUCT_ID                     = "UFC_ORB_29_12056_051641_SCI_DAT"
PRODUCT_VERSION_ID             = "V1 "
PRODUCT_CREATION_TIME          = 2012-03-26T18:13:40
PRODUCT_TYPE                   = "CDR"
SOFTWARE_NAME                  = "PIPE-MASCS2CDR"
SOFTWARE_VERSION_ID            = "9.0"
INSTRUMENT_HOST_NAME           = "MESSENGER"
INSTRUMENT_NAME                = "
 MERCURY ATMOSPHERIC AND SURFACE COMPOSITION SPECTROMETER"
INSTRUMENT_ID                  = "MASCS"
DETECTOR_ID                    = "UVVS"
DATA_SET_ID                    = "MESS-E/V/H-MASCS-3-UVVS-CDR-CALDATA-V1.0"
STANDARD_DATA_PRODUCT_ID       = "UVVSCFUVSCI"
MISSION_PHASE_NAME             = "MERCURY ORBIT"
TARGET_NAME                    = "MERCURY"
OBSERVATION_TYPE               = {"LimbOpp","ExoScan"}
START_TIME                     = 2012-02-25T05:16:41
STOP_TIME                      = 2012-02-25T05:22:26
SPACECRAFT_CLOCK_START_COUNT   = "238634468.125"
SPACECRAFT_CLOCK_STOP_COUNT    = "238634813.953"
^TABLE                         = "UFC_ORB_29_12056_051641_SCI.DAT"

OBJECT                         = TABLE
   COLUMNS                        = 63
   INTERCHANGE_FORMAT             = BINARY
   ROW_BYTES                      = 752
   ROWS                           = 1216
   DESCRIPTION                    = "
       This table contains MESSENGER UVVS spectra collected by the
       FUV detector and instrument engineering data.

       Detailed descriptions for the parameters defined below are contained
       in the CDR SIS document.

       The complete column definitions are contained in an external file
       found in the LABEL directory of the archive volume.
   "
   NOTE                           = "
     SPICE Kernels:
     msgr20120224.bc
     msgr20120225.bc
     msgr20120226.bc
     msgr_dyn_v600.tf
     msgr_v210.tf
     msgr_mascs_v100.ti
     naif0010.tls
     pck00009_MSGR_v10.tpc
     messenger_1444.tsc
     msgr_de405_de423s.bsp
     msgr_20040803_20140820_od259sc_0.bsp
   "

   ^STRUCTURE = "UVVSSCIC.FMT"
END_OBJECT                     = TABLE
END
```

5.3.4.3 *Example PDS Label for the UVVS Surface Header DDR*

```
PDS_VERSION_ID                  = "PDS3"

/*** FILE FORMAT ***/
RECORD_TYPE                     = FIXED_LENGTH
RECORD_BYTES                    = 36
FILE_RECORDS                    = 1

/*** GENERAL DATA DESCRIPTION PARAMETERS ***/
PRODUCT_ID                      = "UMD_ORB_48_11112_111324_HDR_DAT"
PRODUCT_VERSION_ID              = "V1 "
PRODUCT_CREATION_TIME           = 2013-05-31T19:53:37
PRODUCT_TYPE                    = "DDR"
SOFTWARE_NAME                   = "PIPE-MASCS2DDR"
SOFTWARE_VERSION_ID             = "1.0"
INSTRUMENT_HOST_NAME            = "MESSENGER"
INSTRUMENT_NAME                 = "
 MERCURY ATMOSPHERIC AND SURFACE COMPOSITION SPECTROMETER"
INSTRUMENT_ID                   = "MASCS"
DETECTOR_ID                     = "UVVS"
DATA_SET_ID                     = "MESS-E/V/H-MASCS-4-UVVS-DDR-V1.0"
STANDARD_DATA_PRODUCT_ID        = "UVVSDMUVHDR"
MISSION_PHASE_NAME              = "MERCURY ORBIT"
TARGET_NAME                     = "MERCURY"
TARGET_DESC                     = "UVVS SURFACE OBSERVATION"
START_TIME                      = 2011-04-22T11:13:26
STOP_TIME                       = 2011-04-22T11:13:31
SPACECRAFT_CLOCK_START_COUNT    = "1/211958275"
SPACECRAFT_CLOCK_STOP_COUNT     = "1/211958280"
^TABLE                          = "UMD_ORB_48_11112_111324_HDR.DAT"

OBJECT                          = TABLE
   COLUMNS                         = 16
   INTERCHANGE_FORMAT              = BINARY
   ROW_BYTES                       = 36
   ROWS                            = 1
   DESCRIPTION                     = "
       This table contains instrument engineering data collected by the
       MUV detector. Each record contains the values over a single UVVS
       observation. A UVVS observation is defined as all the scan data
       contained within one UVVS science packet.

       Detailed descriptions for the parameters defined below are contained
       in the CDR-DDR SIS document.

       The complete column definitions are contained in an external file
      found in the LABEL directory of the archive volume.
   "
   ^STRUCTURE = "UVVSHDRD_SUR.FMT"
END_OBJECT                      = TABLE
END
```

5.3.4.4 *Example PDS Label for the UVVS Surface Science DDR*

```
PDS_VERSION_ID                 = "PDS3"

/*** FILE FORMAT ***/
RECORD_TYPE                    = FIXED_LENGTH
RECORD_BYTES                   = 270
FILE_RECORDS                   = 46

/*** GENERAL DATA DESCRIPTION PARAMETERS ***/
PRODUCT_ID                     = "UMD_ORB_48_11112_111324_SCI_DAT"
PRODUCT_VERSION_ID             = "V1 "
PRODUCT_CREATION_TIME          = 2012-03-26T18:13:40
PRODUCT_TYPE                   = "DDR"
SOFTWARE_NAME                  = "PIPE-MASCS2DDR"
SOFTWARE_VERSION_ID            = "1.0"
INSTRUMENT_HOST_NAME           = "MESSENGER"
INSTRUMENT_NAME                = "
 MERCURY ATMOSPHERIC AND SURFACE COMPOSITION SPECTROMETER"
INSTRUMENT_ID                  = "MASCS"
DETECTOR_ID                    = "UVVS"
DATA_SET_ID                    = "MESS-E/V/H-MASCS-4-UVVS-DDR-V1.0"
STANDARD_DATA_PRODUCT_ID       = "UVVSDMUVSCI"
MISSION_PHASE_NAME             = "MERCURY ORBIT"
TARGET_NAME                    = "MERCURY"
OBSERVATION_TYPE               = "UVVSPhotometry"
START_TIME                     = 2011-04-22T11:13:26
STOP_TIME                      = 2011-04-22T11:13:31
SPACECRAFT_CLOCK_START_COUNT   = "1/211958275"
SPACECRAFT_CLOCK_STOP_COUNT    = "1/211958280"
^TABLE                         = "UMD_ORB_48_11112_111324_SCI.DAT"

OBJECT                         = TABLE
   COLUMNS                        = 25
   INTERCHANGE_FORMAT             = BINARY
   ROW_BYTES                      = 270
   ROWS                           = 46
   DESCRIPTION                    = "
       This table contains MESSENGER UVVS spectra collected by the
       MUV detector and instrument engineering data.

       Detailed descriptions for the parameters defined below are contained
       in the CDR-DDR SIS document.

       The complete column definitions are contained in an external file
       found in the LABEL directory of the archive volume.
   "
   NOTE                           = "
     SPICE Kernels:
     msgr20110421.bc
     msgr20110422.bc
     msgr20110423.bc
     msgr_dyn_v600.tf
     msgr_v220.tf
     msgr_mascs_v100.ti
     naif0010.tls
```

```
     pck00010_MSGR_v10.tpc
     messenger_1728.tsc
     msgr_de405_de423s.bsp
     msgr_20040803_20140822_od301sc_0.bsp
   "

   ^STRUCTURE = "UVVSSCID_SUR.FMT"
END_OBJECT                      = TABLE
END
```

5.3.4.5 Example PDS Label for the UVVS Atmosphere DDR

```
PDS_VERSION_ID                  = "PDS3"

/*** FILE FORMAT ***/
RECORD_TYPE                     = FIXED_LENGTH
RECORD_BYTES                    = 906
FILE_RECORDS                    = 1234

/*** GENERAL DATA DESCRIPTION PARAMETERS ***/
PRODUCT_ID                      = "UD_05_LS_NA_DAT"
PRODUCT_VERSION_ID              = "V1 "
PRODUCT_CREATION_TIME           = 2013-01-14T15:02:30
PRODUCT_TYPE                    = "DDR"
SOFTWARE_NAME                   = "PIPE-MASCS2DDR"
SOFTWARE_VERSION_ID             = "1.0"
INSTRUMENT_HOST_NAME            = "MESSENGER"
INSTRUMENT_NAME                 = "
 MERCURY ATMOSPHERIC AND SURFACE COMPOSITION SPECTROMETER"
INSTRUMENT_ID                   = "MASCS"
DETECTOR_ID                     = "UVVS"
DATA_SET_ID                     = "MESS-E/V/H-MASCS-4-UVVS-DDR-V1.0"
STANDARD_DATA_PRODUCT_ID        = "UVVSDNALS"
MISSION_PHASE_NAME              = "MERCURY ORBIT YEAR 2"
TARGET_NAME                     = "MERCURY"
OBSERVATION_TYPE                = "LimbScan"
START_TIME                      = 2013-12-09T06:40:05
STOP_TIME                       = 2013-12-09T10:08:02
SPACECRAFT_CLOCK_START_COUNT    = "268828279.009"
SPACECRAFT_CLOCK_STOP_COUNT     = "268840756.989"
^TABLE                          = "UD_05_LS_NA.DAT"

OBJECT                          = TABLE
   COLUMNS                         = 30
   INTERCHANGE_FORMAT              = BINARY
   ROW_BYTES                       = 906
   ROWS                            = 1234
   DESCRIPTION                     = "
       This table contains dayside limb scan data collected by the UVVS for a
       given Mercury year.

       Detailed descriptions for the parameters defined below are contained
       in the CDR/DDR SIS document.

       The complete column definitions are contained in an external file
       found in the LABEL directory of the archive volume.
```

```
   "
   ^STRUCTURE = "UVVSSCID.FMT"
END_OBJECT                      = TABLE
END
```

5.3.4.6 Example PDS Label for the UVVS Atmospheric Model DDR

```
PDS_VERSION_ID                  = "PDS3"

/*** FILE FORMAT ***/
RECORD_TYPE                     = FIXED_LENGTH
RECORD_BYTES                    = 128
FILE_RECORDS                    = 504

/*** GENERAL DATA DESCRIPTION PARAMETERS ***/
PRODUCT_ID                      = "UD_NA_MOD_TAB"
PRODUCT_VERSION_ID              = "V1"
PRODUCT_CREATION_TIME           = 2014-02-18T16:23:13
PRODUCT_TYPE                    = "DDR"
SOFTWARE_NAME                   = "PIPE-MASCS2DDR"
SOFTWARE_VERSION_ID             = "1.0"
INSTRUMENT_HOST_NAME            = "MESSENGER"
INSTRUMENT_NAME                 = "
 MERCURY ATMOSPHERIC AND SURFACE COMPOSITION SPECTROMETER"
INSTRUMENT_ID                   = "MASCS"
DETECTOR_ID                     = "UVVS"
DATA_SET_ID                     = "MESS-E/V/H-MASCS-4-UVVS-DDR-V1.0"
STANDARD_DATA_PRODUCT_ID        = "UVVSDNAMOD"
MISSION_PHASE_NAME              = "MERCURY ORBIT"
TARGET_NAME                     = "MERCURY"
START_TIME                      = 2011-04-04T21:02:28
STOP_TIME                       = 2013-03-17T23:51:20
SPACECRAFT_CLOCK_START_COUNT    = "1/210438416.311"
SPACECRAFT_CLOCK_STOP_COUNT     = "2/005888279.695"
^TABLE                          = "UD_NA_MOD.TAB"

OBJECT                          = TABLE
  COLUMNS                       = 9
  INTERCHANGE_FORMAT            = ASCII
  ROW_BYTES                     = 128
  ROWS                          = 504
  DESCRIPTION                   = "
   The table contains the series of model fits to data averaged over
   specific Mercury true anomalies and local times for Sodium.
   The table contains data processed from UVVS CDRs for the time period
   specified by START_TIME and END_TIME in the PDS label.
   "

  OBJECT                        = COLUMN
    NAME                        = TRUE_ANOMALY
    COLUMN_NUMBER               = 1
    START_BYTE                  = 1
    BYTES                       = 7
    DATA_TYPE                   = ASCII_REAL
    FORMAT                      = "F7.3"
    DESCRIPTION                 = "Mercury orbital position in degrees. Fit
```

```
    parameters are provided as averages over 5 degree increments, the middle
    of that 5 degree increment is listed in the file (e.g. 2.5 degrees for
    the 0-5 degree bin)."
  END_OBJECT = COLUMN

  OBJECT                         = COLUMN
    NAME                         = LOCAL_TIME
    COLUMN_NUMBER                = 2
    START_BYTE                   = 9
    BYTES                        = 6
    DATA_TYPE                    = ASCII_REAL
    FORMAT                       = "F6.3"
   DESCRIPTION                   = "Local time of the model fit. Only limb
   scans taken within half an hour of the given local time are included in
   the average."
  END_OBJECT = COLUMN

  OBJECT                         = COLUMN
    NAME                         = NEAR_SURFACE_DENSITY
    COLUMN_NUMBER                = 3
    START_BYTE                   = 16
    BYTES                        = 15
    DATA_TYPE                    = ASCII_REAL
    FORMAT                       = "F15.6"
    DESCRIPTION                  = "Average near-surface density from modified
    Chamberlain model fits. A value of -1 indicates no model fit for this
    combination of TRUE_ANOMALY and LOCAL_TIME. Units of cm-3."
  END_OBJECT = COLUMN

  OBJECT                         = COLUMN
    NAME                         = NEAR_SURFACE_DENSITY_UNCERTAINTY
    COLUMN_NUMBER                = 4
    START_BYTE                   = 32
    BYTES                        = 15
    DATA_TYPE                    = ASCII_REAL
    FORMAT                       = "F15.6"
    DESCRIPTION                  = "Average one-sigma standard deviation of the
    fit to near-surface density. A value of -1 indicates no model fit for
    this combination of TRUE_ANOMALY and LOCAL_TIME. Units of cm-3."
  END_OBJECT = COLUMN

  OBJECT                         = COLUMN
    NAME                         = TEMPERATURE
    COLUMN_NUMBER                = 5
    START_BYTE                   = 48
    BYTES                        = 15
    DATA_TYPE                    = ASCII_REAL
    FORMAT                       = "F15.6"
    DESCRIPTION                  = "Average temperature modified from
    Chamberlain model fits. A value of -1 indicates no model fit for this
    combination of TRUE_ANOMALY and LOCAL_TIME. Units of K."
  END_OBJECT = COLUMN

  OBJECT                         = COLUMN
    NAME                         = TEMPERATURE_UNCERTAINTY
    COLUMN_NUMBER                = 6
    START_BYTE                   = 64
```

```
    BYTES                       = 15
    DATA_TYPE                   = ASCII_REAL
    FORMAT                      = "F15.6"
    DESCRIPTION                 = "Average one-sigma standard deviation of the
    fit to temperature. A value of -1 indicates no model fit for this
    combination of TRUE_ANOMALY and LOCAL_TIME. Units of K."
  END_OBJECT = COLUMN

  OBJECT                        = COLUMN
    NAME                        = SCALE_HEIGHT
    COLUMN_NUMBER               = 7
    START_BYTE                  = 80
    BYTES                       = 15
    DATA_TYPE                   = ASCII_REAL
    FORMAT                      = "F15.6"
    DESCRIPTION                 = "Scale height corresponding to the model
    fit. A value of -1 indicates no model fit for this combination of
    TRUE_ANOMALY and LOCAL_TIME. Units of km."
  END_OBJECT = COLUMN

  OBJECT                        = COLUMN
    NAME                        = SPARE_1
    COLUMN_NUMBER               = 8
    START_BYTE                  = 96
    BYTES                       = 15
    DATA_TYPE                   = ASCII_REAL
    FORMAT                      = "F15.6"
    DESCRIPTION                 = "Spare column, placeholder for future
    parameter. Default to spare value of 0.000000."
  END_OBJECT = COLUMN

  OBJECT                        = COLUMN
    NAME                        = SPARE_2
    COLUMN_NUMBER               = 9
    START_BYTE                  = 112
    BYTES                       = 15
    DATA_TYPE                   = ASCII_REAL
    FORMAT                      = "F15.6"
    DESCRIPTION                 = "Spare column, placeholder for future
    parameter. Default to spare value of 0.000000."
  END_OBJECT = COLUMN

END_OBJECT                      = TABLE
END
```

5.4 Standards Used in Generating Data Products

5.4.1 PDS Standards

The UVVS CDR/DDR data products were constructed according to the data object concepts developed by the PDS. By adopting the PDS standards, the data products are consistent in content and organization with other planetary data collections. The UVVS CDR data are grouped into fours: a binary table of science data, a binary table of science header information, and detached PDS labels describing each of the binary tables. The UVVS Atmosphere and Surface DDR data are grouped into pairs: a table of binary data and a detached PDS label describing the data. The UVVS Atmospheric Model data are provided as ASCII tables (*.TAB) with detached PDS labels.

5.4.2 Time Standards

The SC_TIME field matches the spacecraft time in integer seconds that is transmitted to MESSENGER subsystems by the Integrated Electronics Module (IEM). It is intended to be the Mission Elapsed Time (MET). MET = 0 is August 3, 2004, at 05:59:16UTC, which is 1000 seconds prior to the MESSENGER launch. Relativistic effects and circumstances occurring during the mission would result in MET not being a true account of seconds since launch. Following a planned spacecraft clock reset in early 2013, partition numbers (1/, or 2/) were added to product labels to disambiguate MET seconds after the spacecraft clock reset (if partition number is not present, SPICE defaults to partition 1/). The SPICE spacecraft clock coefficients file (see Appendix F) should be used to calculate the conversion between MET and UTC. Product label files express MET in <met_partition>/<met_seconds>.<met_milliseconds> format (note: MET milliseconds are only used in CDR and DDR product labels). UTC times in some products had a 1-second quantization issue before PDS Delivery 12 that has been solved (and the affected products redelivered).

5.4.3 Coordinate Systems

The computational assumptions for the geometric and viewing data provided in the PDS label are listed below. There are two coordinate systems in use: 1) the celestial reference system used for target and spacecraft position and velocity vectors; and 2) the planetary coordinate system for geometry vectors and target location. The celestial coordinate system is J2000 (Mean of Earth equator and equinox of J2000). The planetary coordinate system is planetocentric.

- For individual spectra in VIRS and individual steps in UVVS, the midpoint of the observation is used for determination of most geometric elements (such as center of observation, subspacecraft latitude/longitude/altitude, etc.). For VIRS, the "leading" and "trailing" point of the footprint smear use interpolation of the start and end time of the observation.

- Label parameters reflect observed, not true, geometry. Therefore, light-time and stellar aberration corrections are used as appropriate.

- The inertial reference frame is J2000 (also called EME2000).

- Latitudes and longitudes are planetocentric.

- The "sub-point" of a body on a target is defined by the surface intercept of the body-to-target-center vector. This is not the closest point on the body to the observer.

- Distances are in km, speeds in km/sec, angles in degrees, angular rates in degrees/sec, unless otherwise noted.

- Angle ranges are 0 to 360 degrees for azimuths and local hour angle. Longitudes range from 0 to 360 degrees (positive to the East). Latitudes range from -90 to 90 degrees.

- `SPICE kernel files used in the geometric parameters are outlined in APPENDIX F– SPICE Kernel Files Used in MESSENGER Data Products.`

5.4.4 Data Storage Conventions

The data are organized following PDS standards and stored on hard disk and an SQL (Structured Query Language) relational database for rapid access during mission operations. The MESSENGER SOC transfers data to PDS via electronic transfer and delivery methods as detailed in section 5.3.3. After verification of the data transfer, PDS provides public access to MESSENGER science data products through its online data distribution system. Data are stored under a unique file name as defined in section 6.1.2.

5.5 Data Validation

The UVVS CDR/DDR data products are validated by the UVVS Instrument Scientist for science content and for compliance with PDS archive standards and the MESSENGER Data Management and Archiving Plan [Applicable Document 4].

6. Detailed Data Product Specifications

6.1 Data Archive Structure and Organization

The UVVS EDR data set is a static dataset. Static data sets, once produced and validated, are not subject to update or modification. The UVVS CDR/DDR data set is a dynamic dataset. Dynamic data sets have the inherent property that they continue to evolve and improve as the knowledge of the mission parameters improve. These data sets are periodically updated or replaced with new versions, and are likely to be updated by post-mission data analysis programs. As an example, the calibration files continue to evolve as knowledge of the MASCS sensor, as well as of the pointing accuracy of the MESSENGER spacecraft improves.

6.1.1 Handling Errors

It is inevitable that errors are introduced into the archive even with data validation procedures applied to the volumes. As errors were discovered, they are reported to the MESSENGER SOC. An errata report file (ERRATA.TXT), located in the ROOT directory, was maintained to track and document all discovered errors during the mission, including any CDRs/DDRs that were revised during the course of the mission. Revised CDRs/DDRs or CDRs/DDRs that were missing from a previous PDS delivery were provided at the next scheduled PDS delivery or at the final PDS delivery as needed. PDS replaces the outdated files with the revised files when provided in the data directories of the archive volume.

MASCS followed similar procedures as other instruments have historically. The CONFIDENCE_LEVEL_NOTE in the uvvs_cdr/ddr_ds.cat files located in the CATALOG directory was updated with each regeneration, and CDR/DDR regenerations were delivered at normal periodic delivery times. Redeliveries followed the same pattern as standard deliveries. As SPICE kernels were updated periodically, updated pointing information flowed down to

CDR/DDR geometry fields of all CDRs/DDRs. File delivery manifests were provided with deliveries, including MD5 checksums.

6.1.2 File Naming Conventions

The file names developed for PDS data volumes are restricted to a 36-character file name and a 3-character extension name with a period separating the file and extension names.

The general form of the UVVS CDR and Surface DDR file name is "UdL_mmm_XX_YYDDD_HHMMSS_xxx" where:

```
     U: UVVS
     d: detector. F = FUV, M = MUV, V = VIS
     L: data-level. E = EDR, C = CDR, D = DDR
   mmm: mission phase
        EAC = Earth cruise to Earth flyby
        EAF = Earth flyby
        VC1 = cruise, post Earth flyby to pre-Venus 1 flyby
        VF1 = Venus 1 flyby
        VC2 = cruise, post Venus 1 to pre-Venus 2 flyby
        VF2 = Venus 2 flyby
        MC1 = cruise, post Venus 2 to pre-Mercury 1 flyby
        MF1 = Mercury 1 flyby
        MC1 = cruise, post Mercury 1 to pre-Mercury 2 flyby
        MF2 = Mercury 2 flyby
        MC3 = cruise, post Mercury 2 to pre-Mercury 3 flyby
        MF3 = Mercury 3 flyby
        MC4 = cruise, post Mercury 3 to pre-orbit insertion
        ORB = Orbit insertion until end of nominal orbit mission
        OB2 = Extended mission (orbit year 2)
        OB3 = Extended mission (orbit year 3)
        OB4 = Extended mission (orbit year 4)
        OB5 = Extended mission (orbit year 5)
    XX: two digit macro id. Valuebe 00 for data created prior to the
        existence of UVVS macros or when PIPE cannot determine the macro
        id used. Value 48 or 49 for surface observations.
    YY: The last two digits of the year in which the data were acquired.
   DDD: The three digit day of year in which the data were acquired.
HHMMSS: The 6 digit hour, minute, second of the start of the observation.
   xxx: data-type. HDR = per observation (science header) data, SCI = per
        step (science CDR) or per bin (surface science DDR) data.
```

The general form of the UVVS Atmosphere DDR file name is "UL_mm_XX_ss" where:

```
     U: UVVS
     L: data-level. D = DDR
    mm: mercury year
        01-04 = Primary mission
        05-09 = Extended mission (orbit year 2)
        10-13 = Extended mission (orbit year 3)
        14-17 = Extended mission (orbit year 4)
        18    = Extended mission (orbit year 5)
    XX: the record category
```

```
        LS = Dayside Limb Scan
        LD = Dayside and Nightside Limb Drift
        NS = Nightside Sweep
    ss: species. NA = sodium, MG = magnesium, CA = calcium
```

The general form of the UVVS Atmospheric Model DDR file name is “UL_ss_XXX” where:

```
     U: UVVS
     L: data-level. D = DDR
    ss: species. NA = sodium, MG = magnesium, CA = calcium
   XXX: MOD = model
```

6.1.3 Directory Structure and Contents for MASCS CDR/DDR/DAP Archive Volume

The following illustrations (Figures 4a-4c) show the directory structure overview for the MASCS CDR/DDR/DAP archive volume. A detailed description of the directory tree is provided in section 6.1.4. Empty directories are not included on the volume.

Note that the volume contains both UVVS and VIRS CDRs/DDRs/DAPs. Details for the VIRS CDRs/DDRs/DAPs are contained in a separate VIRS SIS document. This archive volume is stored at both the Atmospheres and Geosciences PDS Nodes.

Figure 4a: Directory Structure Overview.

```
                                      <ROOT>
_________________________________________|___________________________
    |          |        |        |       |       |       |       |
<DOCUMENT> <CATALOG> <INDEX> <GEOMETRY>  |   <CALIB> <LABEL> <EXTRAS>
                                      <DATA>
                                         |
                             ____________|____________
                                  |           |          |
                                <CDR>      <DDR>      <DAP>
                                  |           |          |
                              [Fig. 4b]  [Fig. 4c]    <VIRS>
```

Figure 4b: CDR Directory Structure.

```
               <CDR>
                 |
                 |
          <mission phase>
                 |
                 |
          <MASCSYYYYMMDD>
                 |
          _______|_______
          |              |
       <UVVS>         <VIRS>
          |              |
 _________|___        ___|___
 |    |      |        |     |
FUV  MUV    VIS      VIS   NIR
```

Figure 4c: DDR Directory Structure.

```
                              <DDR>
                                |
                                |
                         <mission phase>
                                |
       _________________________|__________________
        |                       |                 |
<UVVS_ATMOSPHERE>         <UVVS_SURFACE>       <VIRS>
        |                       |                 |
    ____|_________              |                 |
    |            |              |                 |
<models>  <mercury year>  <MASCSYYYYMMDD>  <MASCSYYYYMMDD>
                                                  |
                                               ___|___
                                               |     |
                                              VIS   NIR
```

6.1.4 Directory Contents

<ROOT> Directory

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

AAREADME.TXT - General information file. Provides users with information about the MESSENGER MASCS data products. Directs user to other documents on the volume containing more detailed information.

VOLDESC.CAT - PDS file containing the VOLUME object. This gives a high-level description of the contents of the volume. Information includes: production date, producer name and institution, volume ID, etc.

ERRATA.TXT - Text file for identifying and describing errors and/or anomalies found in the current volume, and possibly previous volumes of a set. Any known errors for the associated volume are documented in this file. This includes revised data products meant to replace data products in a previous PDS delivery.

<DOCUMENT> Directory

This subdirectory contains the documentation that is needed in order to understand and analyze the data products. The documentation files exist in several formats in order to facilitate access to the documents. Updated documents include incrementing version numbers.

DOCINFO.TXT - Identifies and describes the function of each file in the DOCUMENT directory.

VIRS_CDR_DDR_DAP_SIS.PDF - The MASCS VIRS CDR/DDR/DAP SIS: "MESSENGER MASCS VIRS Calibrated Data Record, Derived Data Record, and Derived Analysis Product Software Interface Specification" in Adobe Acrobat format. Note that, in contrast to the .TXT version, the illustrations, tables, etc. display appropriately in this format.

VIRS_CDR_DDR_DAP_SIS.TXT - The MASCS VIRS CDR/DDR/DAP SIS: "MESSENGER MASCS VIRS Calibrated Data Record, Derived Data Record, and Derived Analysis Product Software Interface Specification" in ASCII text format. Only the text is provided; for illustrations, tables, etc. the PDF should be consulted.

VIRS_CDR_DDR_DAP_SIS.LBL - A detached PDS label that describes the text and PDF files.

UVVS_CDR_DDR_SIS.PDF - The MASCS UVVS CDR/DDR SIS: "MESSENGER MASCS UVVS Calibrated and Derived Data Record Software Interface Specification" in Adobe Acrobat format. Note that, in contrast to the .TXT version, the illustrations, tables, etc. display appropriately in this format.

UVVS_CDR_DDR_SIS.TXT - The MASCS UVVS CDR/DDR SIS: "MESSENGER MASCS UVVS Calibrated and Derived Data Record Software Interface Specification" in ASCII text format. Only the text is provided; for illustrations, tables, etc. the PDF should be consulted.

UVVS_CDR_DDR_SIS.LBL - A detached PDS label that describes the text and PDF files.

VIRS_EDR2CDR.TXT - Detailed procedures and tables for EDR to CDR calibration.

VIRS_EDR2CDR.LBL - The detached label for the calibration document.

UVVS_EDR2CDR.TXT - Detailed procedures and tables for EDR to CDR calibration.

UVVS_EDR2CDR.LBL - The detached label for the calibration document.

VIRS_CDR2DDR.TXT - Detailed procedures and tables for CDR to DDR data reduction.

VIRS_CDR2DDR.LBL - The detached label for the CDR to DDR document.

UVVS_CDR2DDR.TXT - Detailed procedures and tables for CDR to Atmosphere DDR data reduction.

UVVS_CDR2DDR.LBL - The detached label for the CDR to Atmosphere DDR document.

UVVS_CDR2DDR_SUR.TXT - Detailed procedures and tables for CDR to Surface DDR data reduction.

UVVS_CDR2DDR_SUR.LBL - The detached label for the CDR to Surface DDR document.

MASCS_CAL_RPT.PDF - The MESSENGER instrument calibration report for MASCS, in Adobe Acrobat format. Note that, in contrast to the .TXT version, the illustrations, tables, etc. display appropriately in this format.

MASCS_CAL_RPT.TXT - The MESSENGER instrument calibration report for MASCS, in ASCII text format. Only the text is provided; for illustrations, tables, etc. one of the other formats should be consulted.

MASCS_CAL_RPT.LBL - A detached PDS label that describes the text and PDF file.

VIRS_DARK_ANALYSIS_REPORT_1.PDF - "VIRS IR Dark Analysis Report 1: Operational Changes" in Adobe Acrobat format. Details the evolving understanding of MASCS dark current during Mercury orbit, describing temperature dependence and effects on the NIR data in particular. Note that, in contrast to the .TXT version, the illustrations, tables, etc. display appropriately in this format.

VIRS_DARK_ANALYSIS_REPORT_1.TXT - "VIRS IR Dark Analysis Report 1: Operational Changes" in ASCII text format. Details the evolving understanding of MASCS dark current during Mercury orbit, describing temperature dependence and effects on the NIR data in particular. Only the text is provided; for illustrations, tables, etc. the PDF should be consulted.

VIRS_DARK_ANALYSIS_REPORT_1.LBL - A detached PDS label that describes the text and PDF file.

VIRS_DARK_ANALYSIS_REPORT_2.PDF - "VIRS IR Dark Analysis Report 2: Calibration Changes" in Adobe Acrobat format. Describes the adjustments to MASCS calibration to improve dark subtraction and account for pixels saturated due to temperature. Note that, in contrast to the .TXT version, the illustrations, tables, etc. display appropriately in this format.

VIRS_DARK_ANALYSIS_REPORT_2.TXT - "VIRS IR Dark Analysis Report 2: Calibration Changes" in ASCII text format. Describes the adjustments to MASCS calibration to improve dark subtraction and account for pixels saturated due to temperature. Only the text is provided; for illustrations, tables, etc. the PDF should be consulted.

VIRS_DARK_ANALYSIS_REPORT_2.LBL - A detached PDS label that describes the text and PDF file.

VIRS_CALIBRATION CHANGES_PDS9.PDF - "VIRS Calibration changes for PDS delivery 9" in Adobe Acrobat format. Describes the calibration changes implemented to simplify the handling of dark subtractions for VIRS, and an adjustment to the DATA_QUALITY_INDEX provided in the data records.

VIRS_CALIBRATION CHANGES_PDS9.TXT - "VIRS Calibration changes for PDS delivery 9" in Adobe Acrobat format. Describes the calibration changes implemented to simplify the handling of dark subtractions for VIRS, and an adjustment to the DATA_QUALITY_INDEX provided in the data records.

VIRS_CALIBRATION CHANGES_PDS9.LBL - A detached PDS label that describes the text and PDF file.

UVVS_CALIBRATION_CHANGES_PDS7.PDF - "UVVS Calibration Changes for PDS Delivery 7" in Adobe Acrobat format. Describes the need for and method of removing solar background signal in several emission wavelength regions.

UVVS_CALIBRATION_CHANGES_PDS7.TXT - "UVVS Calibration Changes for PDS Delivery 7" in ASCII text format. Describes the need for and method of removing solar background signal in several emission wavelength regions.

UVVS_CALIBRATION_CHANGES_PDS7.LBL - A detached PDS label that describes the text and PDF file.

VIRS_CALIBRATION_CHANGES_PDS11.PDF - "VIRS Calibration Changes for PDS Delivery 11" in Adobe Acrobat format. Describes changes to the calibration procedure that have been implemented to remedy an observed shift in the wavelength scale of the VIRS visible channel.

VIRS_CALIBRATION_CHANGES_PDS11.TXT - "VIRS Calibration Changes for PDS Delivery 11" in ASCII text format. Describes changes to the calibration procedure that have been implemented to remedy an observed shift in the wavelength scale of the VIRS visible channel.

VIRS_CALIBRATION_CHANGES_PDS11.LBL - A detached PDS label that describes the text and PDF file.

UVVS_CALIBRATION_CHANGES_PDS11.PDF - "MESSENGER MASCS UVVS Calibration Update - PDS 11" in Adobe Acrobat format. Describes the UVVS FUV CDR calibration sensitivity update.

UVVS_CALIBRATION_CHANGES_PDS11.TXT - "MESSENGER MASCS UVVS Calibration Update - PDS 11" in ASCII text format. Describes the UVVS FUV CDR calibration sensitivity update.

UVVS_CALIBRATION_CHANGES_PDS11.LBL - A detached PDS label that describes the text and PDF file.

CALCIUM_CHAMBERLAIN_MODELS.PDF - Description of the calcium Chamberlain models in Adobe Acrobat format.

CALCIUM_CHAMBERLAIN_MODELS.TXT - Description of the calcium Chamberlain models in ASCII text format. Only the text is provided; for equations, tables, etc. the PDF should be consulted.

CALCIUM_CHAMBERLAIN_MODELS.LBL - A detached PDS label that describes the text and PDF file.

<CATALOG> Directory

This subdirectory contains the catalog object files for the entire volume. The following files are included in the catalog subdirectory.

CATINFO.TXT - Identifies and describes the function of each file in the catalog directory.

MISSION.CAT - Describes the scientific goals and objectives of the MESSENGER mission.

INSTHOST.CAT - Describes the MESSENGER spacecraft.

INST.CAT - Describes physical attributes of the MASCS instrument and provides relevant references to published literature.

UVVS_CDR_DS.CAT, VIRS_CDR_DS.CAT - Describes the general content of the MASCS UVVS and MASCS VIRS CDR datasets, and includes information about the duration of the mission and the person or group responsible for producing the data.

UVVS_DDR_DS.CAT, VIRS_DDR_DS.CAT - Describes the general content of the MASCS UVVS DDR and MASCS VIRS DDR datasets, and includes information about the duration of the mission and the person or group responsible for producing the data.

VIRS_DAP_DS.CAT - Describes the general content of the MASCS VIRS DAP dataset, and includes information about the duration of the mission and the person or group responsible for producing the data.

DAP_MAP.CAT – Describes the DAP dataset equirectangular map projection.

PERSON.CAT - Lists and provides contact information for the people involved with the MASCS instrument on the MESSENGER mission.

REF.CAT - Contains the complete citations of references mentioned in the above catalog files, along with citations of additional documents that may be useful to the person using the MASCS data.

<INDEX> Directory

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

INDXINFO.TXT – Identifies and describes the function of each file in the index subdirectory.

MD5.TAB - Provides the MD5 checksum (message digest) for each file in the archive, with the exception of the MD5.TAB file itself.

MD5.LBL - Detached PDS label for MD5.TAB.

VICINDEX.TAB - The VIRS CDR index file is organized as a table: there is one entry for each of the data files included in the VIRS data set; the columns contain parameters that describe the observation, instrument, and spacecraft parameters.

VICINDEX.LBL - Detached PDS label for VICINDEX.TAB.

VIDINDEX.TAB - The VIRS DDR index file is organized as a table: there is one entry for each of the data files included in the VIRS DDR data set; the columns contain parameters that describe the observation, instrument, and spacecraft parameters.

VIDINDEX.LBL - Detached PDS label for VIDINDEX.TAB.

VDAPINDEX.TAB - The VIRS DAP index file is organized as a table: there is one entry for each of the data files included in the VIRS DAP data set; the columns contain parameters that describe the observation, instrument, and spacecraft parameters.

VDAPINDEX.LBL - Detached PDS label for VDAPINDEX.TAB.

UHCINDEX.TAB - The UVVS CDR header index file is organized as a table: there is one entry for each of the data files included in the UVVS data set; the columns contain parameters that describe the observation, instrument, and spacecraft parameters.

UHCINDEX.LBL - Detached PDS label for UVCINDEX.TAB.

USCINDEX.TAB - The UVVS CDR science index file is organized as a table: there is one entry for each of the data files included in the UVVS data set; the columns contain parameters that describe the observation, instrument, and spacecraft parameters.

USCINDEX.LBL - Detached PDS label for UVCINDEX.TAB.

USDINDEX.TAB - The UVVS DDR science index file is organized as a table: there is one entry for each of the data files included in the UVVS DDR data set; the columns contain parameters that describe the observation, instrument, and spacecraft parameters.

USDINDEX.LBL - Detached PDS label for USDINDEX.TAB.

Tables 3a-3c below list the columns in the UHCINDEX.TAB, USCINDEX.TAB, and USDINDEX.TAB files, respectively. They are the most significant keywords pulled from the labels of the various products. For any given data product, some of the fields are inapplicable and are set to N/A.

Column	Format	Example
VOLUME_ID	CHARACTER	“MESSMAS_2001”
FILE_SPECIFICATION_NAME	CHARACTER	“DATA/CDR/MF1/MASCS20080114/UVVS/VIS/UVC_MF1_00_08014_162537_HDR.DAT”
MISSION_PHASE_NAME	CHARACTER	"MERCURY 1 FLYBY"
TARGET_NAME	CHARACTER	“MERCURY”
PRODUCT_ID	CHARACTER	“UVC_MF1_00_08014_162537_HDR_DAT”
PRODUCT_VERSION_ID	CHARACTER	"V1 "
PRODUCT_CREATION_TIME	TIME	2008-06-25T21:54:32
DATA_SET_ID	CHARACTER	“MESS-E/V/H-MASCS-3-UVVS-CDR-CALDATA-V1.0”
STANDARD_DATA_PRODUCT_ID	CHARACTER	UVVSCVISHDR
START_TIME	TIME	2008-01-14T16:25:37
STOP_TIME	TIME	2008-01-14T16:25:54
START_MET_PARTITION	ASCII_INTEGER	1
SPACECRAFT_CLOCK_START_COUNT	CHARACTER	“1/108815318.5”
SPACECRAFT_CLOCK_STOP_COUNT	CHARACTER	“1/108815335.5”
START_POS	ASCII_INTEGER	2266
STEP_COUNT	ASCII_INTEGER	18
INT_TIME	ASCII_INTEGER	3000
SCAN_CYCLES	ASCII_INTEGER	0
ZIGZAG	ASCII_INTEGER	0
SLIT_MASK_POS	ASCII_INTEGER	1
NUM_SCAN_VALUES	ASCII_INTEGER	18
COADD	ASCII_INTEGER	1

Table 3a: UHCINDEX.TAB Columns.

Column	Format	Example
VOLUME_ID	CHARACTER	“MESSMAS_2001”
FILE_SPECIFICATION_NAME	CHARACTER	“DATA/CDR/MF1/MASCS20080114/UVVS/VIS/UVC_MF1_00_08014_162537_SCI.DAT”
MISSION_PHASE_NAME	CHARACTER	"MERCURY 1 FLYBY"
TARGET_NAME	CHARACTER	“MERCURY”
PRODUCT_ID	CHARACTER	“UVC_MF1_00_08014_162537_SCI_DAT”
PRODUCT_VERSION_ID	CHARACTER	"V1 "
PRODUCT_CREATION_TIME	TIME	2009-02-08T00:26:29

Column	Format	Example
DATA_SET_ID	CHARACTER	“MESS-E/V/H-MASCS-3-UVVS-CDR-CALDATA-V1.0”
STANDARD_DATA_PRODUCT_ID	CHARACTER	UVVSCVISSCI
START_TIME	TIME	2008-01-14T16:25:37
STOP_TIME	TIME	2008-01-14T16:25:54
START_MET_PARTITION	ASCII_INTEGER	1
SPACECRAFT_CLOCK_START_COUNT	CHARACTER	“1/108815318.5”
SPACECRAFT_CLOCK_STOP_COUNT	CHARACTER	“1/108815335.5”
CENTER_TARGET_LATITUDE	ASCII_REAL	0.290
CENTER_TARGET_LONGITUDE	ASCII_REAL	4.991
CENTER_TANGENT_ALTITUDE	ASCII_REAL	-1E32
SURFACE_OR_EXOSPHERE	ASCII_INTEGER	2
CENTER_RA	ASCII_REAL	92.340
CENTER_DEC	ASCII_REAL	25.404
TRUE_ANOMALY	ASCII_REAL	284.751
START_WAVELENGTH	ASCII_REAL	586.915
END_WAVELENGTH	ASCII_REAL	589.744
AVERAGE_RAD_KR	ASCII_REAL	0.61600
AVERAGE_RAD_W	ASCII_REAL	0.00022
SUMMARY_DQI	CHARACTER	0-11111-0000-000-2000

Table 3b: USCINDEX.TAB Columns.

Column	Format	Example
VOLUME_ID	CHARACTER	“MESSMAS_2001”
FILE_SPECIFICATION_NAME	CHARACTER	“DATA/DDR/OB2/UVVS_ATMOSPHERE/05/UD_05_LS_NA.LBL”
MISSION_PHASE_NAME	CHARACTER	"MERCURY ORBIT YEAR 2"
MERCURY_YEAR	ASCII_INTEGER	05
TARGET_NAME	CHARACTER	“MERCURY”
PRODUCT_ID	CHARACTER	“UNAD_05_LS_DAT”
PRODUCT_VERSION_ID	CHARACTER	"V1 "
PRODUCT_CREATION_TIME	TIME	2013-01-14T15:02:30
DATA_SET_ID	CHARACTER	“MESS-E/V/H-MASCS-4-UVVS-DDR -V1.0”
STANDARD_DATA_PRODUCT_ID	CHARACTER	UVVSDNALS
START_TIME	TIME	2009-12-09T06:40:05
STOP_TIME	TIME	2009-12-09T10:08:02
START_MET_PARTITION	ASCII_INTEGER	1
SPACECRAFT_CLOCK_START_COUNT	CHARACTER	“1/168828279.009”
SPACECRAFT_CLOCK_STOP_COUNT	CHARACTER	“1/168840756.989”

Table 3c: USDINDEX.TAB Columns.

<GEOMETRY> Directory

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

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

<CALIB> Directory

This subdirectory contains a look up table for calibration.

CALINFO.TXT – Describes the contents of this directory.

UVVS_GRATING_OFFSET.TAB - Time tag table of UVVS grating offsets to feed into the GRATING_OFFSET parameter. Currently, this table is not implemented correctly.

UVVS_GRATING_OFFSET.LBL - Detached PDS label for UVVS_GRATING_OFFSET.TAB.

<LABEL> Directory

This subdirectory contains format files (label fragments) that are referenced in the PDS labels for data files. These format files define the structure and contents of the binary data tables. Software that interprets PDS labels automatically include these files to determine how to read the data.

LABINFO.TXT – Describes the contents of this directory.

VIRSVC.FMT - Format of the VIRS VIS (visible wavelength) CDR data table.

VIRSNC.FMT - Format of the VIRS NIR (near infrared wavelength) CDR data table.

VIRSVD.FMT - Format of the VIRS VIS (visible wavelength) DDR data table.

VIRSND.FMT - Format of the VIRS NIR (near infrared wavelength) DDR data table.

UVVSHDRC.FMT - Format of the UVVS CDR science header table file.

UVVSSCIC.FMT - Format of the UVVS CDR science data table file.

UVVSSCID.FMT - Format of the UVVS atmosphere science DDR data table file.

UVVSHDRD_SUR.FMT - Format of the UVVS surface header DDR data table file.

UVVSSCID_SUR.FMT - Format of the UVVS surface science DDR data table file.

<EXTRAS> Directory

This subdirectory contains ancillary material that may be useful but is not required for the understanding of the archive.

VIRS_MISSING_PACKETS_R6.TXT - This file describes the investigation and resolution of the missing packet error described in the "Data Coverage and Quality" section of VIRS_CDR_DS.CAT. Included is a list of the EDRs (and thus also CDRs) missing packets for PDS release 6.

VIRS_VIS_EDR_MISSING_PACKET_ANALYSIS_R6.XLS - This is a companion spreadsheet to the file above. It shows a detailed breakdown of the EDRs and exactly which packets are missing.

VIRS_VIS_MISSING_PACKETS_R*.TXT - These files list the incomplete VIRS VIS EDRs/CDRs for PDS releases, where '*' is the release #. The errors are described in the "Data Coverage and Quality" section of VIRS_CDR_DS.CAT.

VIRS_NIR_MISSING_PACKETS_R*.TXT - These files list the incomplete VIRS NIR EDRs/CDRs for PDS releases, where '*' is the release #. The errors are described in the "Data Coverage and Quality" section of VIRS_CDR_DS.CAT.

MASTER_CRUISE_TABLE.XLS - This is an extended instrument operation table used during cruise and flyby operations of MASCS, showing details of VIRS and UVVS observations, times, and other information useful for quick reference. In orbit, the mission planning software SCIBOX takes over the function of this table. This file can be viewed using Microsoft Excel.

VIRS_CDR_EXCLUDED.TXT - This is a list of VIRS CDRs that are excluded from PDS delivery due to bad dark solutions. See VIRS_CDR_DS.CAT for more information.

VIRS_DDR_EXCLUDED.TXT - This is a list of VIRS DDRs that are excluded from PDS delivery due to:
1) all footprints have shutter closed
2) all footprints are off planet
3) all footprints are in nightside shadow
4) bad dark solutions
See VIRS_DDR_DS.CAT for more information.

<DATA> Directory

This is the top level directory for the data products (see Figure 3a). Directly underneath the <DATA> directory are the <CDR>, <DDR>, and <DAP> directories. Below the <DAP> directory is the <VIRS> subdirectory, wherein lies the VIRS DAP image (*.IMG) and associated PDS label (*.LBL). Below the <CDR> and <DDR> directories are the three-letter "mission phase" subdirectories, detailed in section 6.1.2 above.

For the CDRs, below the mission phase directories are the <MASCSYYYYMMDD> directories, where the "YYYYMMDD" characters define the four-digit year, 2-digit month, 2-digit day which is common to all the MET times for the CDRs stored in that directory. The <MASCSYYYYMMDD> directories are further subdivided into two subdirectories, <UVVS> and <VIRS>. The <UVVS> subdirectory is divided into the detector subdirectories <FUV>, <MUV>, and <VIS> and the <VIRS> subdirectory into <VIS> and <NIR>. Within the detector subdirectories are the CDR data files themselves (*.DAT) and, for each CDR data file, a detached label file (*.LBL). Subdirectories only exist if that particular type of data exists for that day. If there are no data of a particular type for a particular day, no subdirectory is included for that type.

For the DDRs, below the mission phase directories are the <UVVS_ATMOSPHERE>, <UVVS_SURFACE>, and <VIRS> directories. Each of the <UVVS_ATMOSPHERE> directories is further subdivided into directories based on the Mercury year of data acquisition (01-04 for primary mission, 05+ for extended mission). Each of the <UVVS_SURFACE> and <VIRS> directories is subdivided into <MASCSYYYYMMDD> date directories, and the VIRS directories are further subdivided into <VIS> and <NIR> detector subdirectories following the structure of the VIRS CDRs. Within the Mercury year (UVVS_ATMOSPHERE), date (UVVS_SURFACE), and detector (VIRS) subdirectories are the UVVS and VIRS DDR data files themselves (*.DAT), and, for each DDR data file, a detached label file (*.LBL). The atmospheric model data (*.TAB) and associated PDS labels (*.LBL) are located in the <models> directory beneath <UVVS_ATMOSPHERE>.

6.2 Data Format Description

Data are stored in binary and ASCII table format. Detached PDS labels provide detailed descriptions of the structure of the tables.

6.3 Label and Header Descriptions

6.3.1 CDR Column Descriptions

Each UVVS observation (contiguous time period of data acquisition with a given sequence) is associated with two CDR data products: a science header table (HDR), showing the instrument command parameters for a given observation, and a science data table (SCI), showing counts, derived science data, and pointing information for each step of an observation. The table columns are described by the format files UVVSHDRC.FMT and UVVSSCIC.FMT, respectively. The following are detailed descriptions of the columns in the UVVS CDR binary table objects. “OBSERVATION” columns have the same value for the whole CDR - these are parameters such as integration time set during the UVVS setup command. “PER STEP” columns have different values for each step in the observation. Times associated with individual steps refer to the middle of the integration period for that step. Replicas of the UVVSHDRC.FMT and UVVSSCIC.FMT format files can be found in Appendices A and B, respectively.

6.3.1.1 Fields in Science Header CDR Format File (UVVSHDRC.FMT)

1. SEQ_COUNTER
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

CCSDS packet sequence counter. PER OBSERVATION column.

2. SC_TIME
`Bytes: 4        Type: MSB_UNSIGNED_INTEGER`

Spacecraft time in integer seconds that is transmitted to the MESSENGER subsystems by the Integrated Electronics Module. This is assigned as the start time of the UVVS observation. A UVVS observation is defined as all the scan data contained within one UVVS science packet. This is due to the highly configurable nature of the instrument, i.e. it can be commanded to take multiple scans over multiple wavelengths. Unit is in mission elapsed time which is the number of seconds since launch. PER OBSERVATION column.

3. PACKET_SUBSECONDS
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

The subsecond time in milliseconds that the telemetry packet was initiated. SC_TIME plus PACKET_SUBSECONDS is the spacecraft time of the first integration. Values of this field are in units of 5 milliseconds. For example, a value of 10 refers to a time of 50 milliseconds. PER OBSERVATION column.

4. START_POS
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Start position where grating drive begins a scan. Grating drive step position corresponds to a given wavelength being observed by an instrument. PER OBSERVATION column.

5. STEP_COUNT
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Number of steps the grating drive took in a scan. This directly corresponds to the range of wavelengths that were observed in one UVVS observation. PER OBSERVATION column.

6. INT_TIME
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Integration time in grating drive loop control interrupt periods (nominally 3000 Hz). For example, the actual integration time in seconds is INT_TIME/3000. PER OBSERVATION column.

7. STEP_TIME
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Step time in grating drive loop control interrupt periods (nominally 3000 Hz). For example, the actual step time in seconds is STEP_TIME/3000. PER OBSERVATION column.

8. PHASE_OFFSET
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Phase offset in grating drive loop control interrupt periods. Phase offset between the beginning of grating drive step and the start of a PMT integration in units of 0.3 milliseconds. Default value is 0 (no phase offset). Setting the phase offset to a non-zero value (reserved for contingency operations), instructed the software to initiate a step before the end of an integration, accounting for latencies in the motor controller. PER OBSERVATION column.

9. SCAN_CYCLES
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Number of times to repeat scan. PER OBSERVATION column.

10. ZIGZAG
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Indicates whether grating drive moves in a 'triangle' (stepping up, then stepping down), or 'sawtooth' (stepping up, then 'flying' down) motion. A 'triangle' observation takes one grating scan stepping up the grating, then reverses direction and takes the next grating scan stepping back down the grating. A 'sawtooth' observation takes one grating scan stepping up the grating, then 'flies' the grating back to the START_POSITION to take the next observation. =0 disable, =1 enable. PER OBSERVATION column.

11. COMPRESSION
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Selectable data size, =0 16 bit data, =1 9 bit data. Used to help determine the total number of data points contained in the observation. PER OBSERVATION column.

12. SLIT_MASK_POS
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Indicates whether slit mask is in atmospheric (open) or surface (closed) position. Atmospheric slit results in a 1 deg. by 0.04 deg. instantaneous field of view (iFOV). Surface slit results in a 0.05 deg. by 0.04 deg. iFOV. =0 closed, =1 open. PER OBSERVATION column.

13. FUV_ON
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Indicates whether FUV PMT power is on. =0 off, =1 on. PER OBSERVATION column.

14. MUV_ON
```
Bytes: 2        Type: MSB_UNSIGNED_INTEGER
```

Indicates whether MUV PMT power is on. A more complete description of this field can be found in the MASCS User's Guide (Applicable Document 6 in UVVS_CDR_DDR_SIS.PDF). =0 off, =1 on. PER OBSERVATION column.

15. VIS_ON
```
Bytes: 2        Type: MSB_UNSIGNED_INTEGER
```

Indicates whether VIS PMT power is on, =0 off, =1 on. PER OBSERVATION column.

16. BUFFER_OVERFLOW
```
Bytes: 2        Type: MSB_UNSIGNED_INTEGER
```

Indicates whether scan programmed overflowed data buffer and was therefore truncated. =0 false, =1 true. PER OBSERVATION column.

17. SPARE_BITS
```
Bytes: 2        Type: MSB_UNSIGNED_INTEGER
```

A two-byte spare location.

18. GD_SETTLE_CTR
```
Bytes: 2        Type: MSB_UNSIGNED_INTEGER
```

Number of times during integration that the grating drive wandered outside target range. This can happen very rarely with an encoder misread, or motor misstep, and would result in an offset of step-number to wavelength correlations for subsequent observations in a given scan. PER OBSERVATION column.

19. NUM_SCAN_VALUES
```
Bytes: 2        Type: MSB_UNSIGNED_INTEGER
```

Total number of values or data points in the entire scan observation. Used to determine the number of valid data points in the SCAN_DATA column. Maximum value is 3626. PER OBSERVATION column.

20. STEP_SIZE
```
Bytes: 2        Type: MSB_UNSIGNED_INTEGER
```

Step size in arcmin units. PER OBSERVATION column.

21. PAD_BYTE
```
Bytes: 2        Type: MSB_UNSIGNED_INTEGER
```

A two-byte spare location. PER OBSERVATION column.

22. COADD
```
Bytes: 2        Type: MSB_UNSIGNED_INTEGER
```

Number of steps coadded to make a single observation. Default = 1, i.e. one step per observation. PER OBSERVATION column.

23. CALIBRATION_SOFTWARE_VERSION
```
Bytes: 4        Type: IEEE_REAL
```

Indicates version of calibration software used. Increments with reprocessing of CDRs. PER OBSERVATION column.

6.3.1.2 Fields in Science Data CDR Format File (UVVSSCIC.FMT)

UVVS “corners” are the corners of the instantaneous field of view rectangle described by the atmospheric or surface slit. They are denoted throughout the geometry fields as c1, c2, c3, and c4, and shown schematically in Figures 5a and 5b. Relative to spacecraft axes, corner 1 (c1) is in the +y, +x corner of the field of view; c2 is –y, +x; c3 is –y, -x, and c4 is +y, -x. Figure 5c illustrates spacecraft position vectors in the planetocentric reference frame.

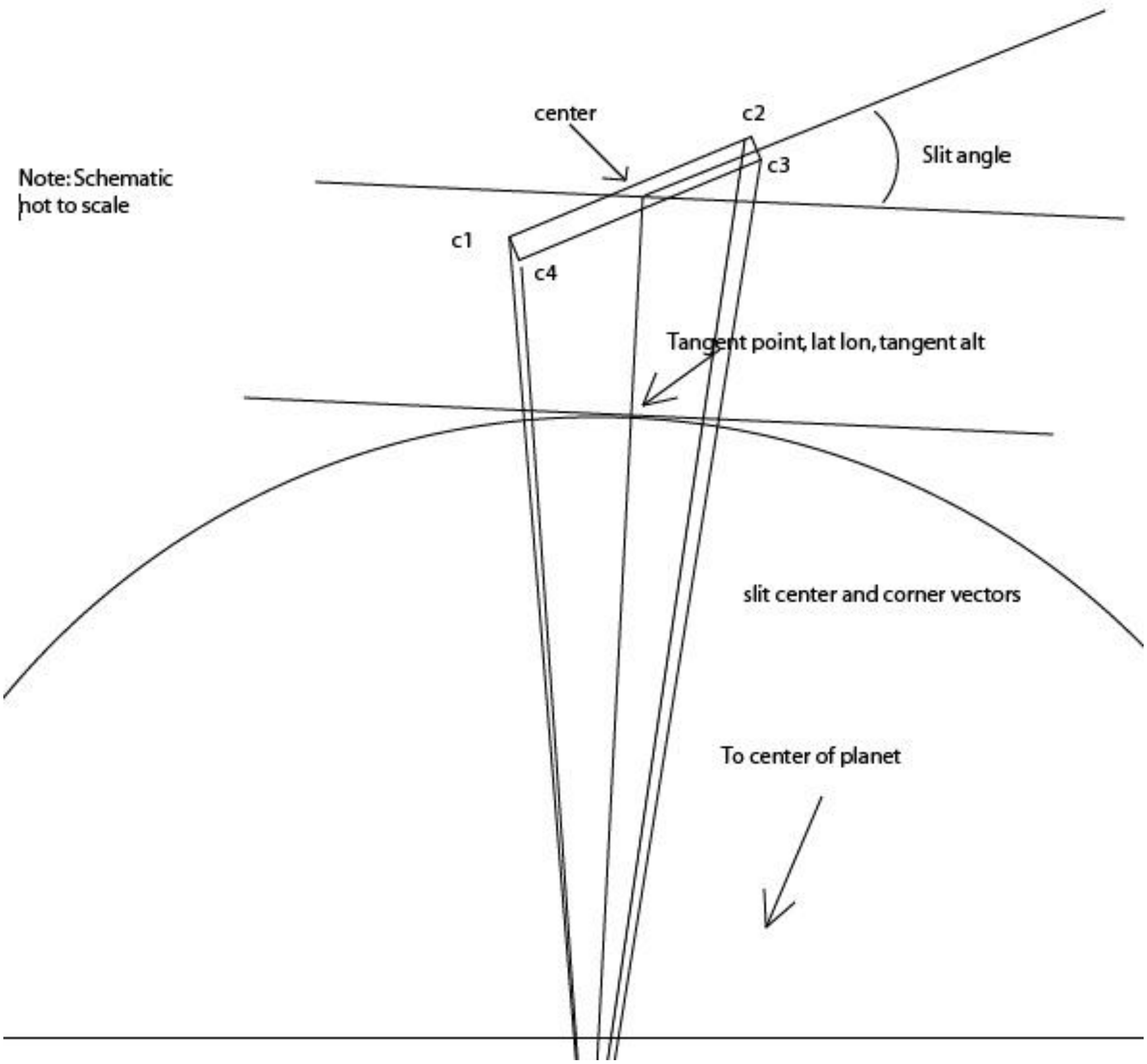


Figure 5a: UVVS Geometry Illustration. Exosphere Observations.

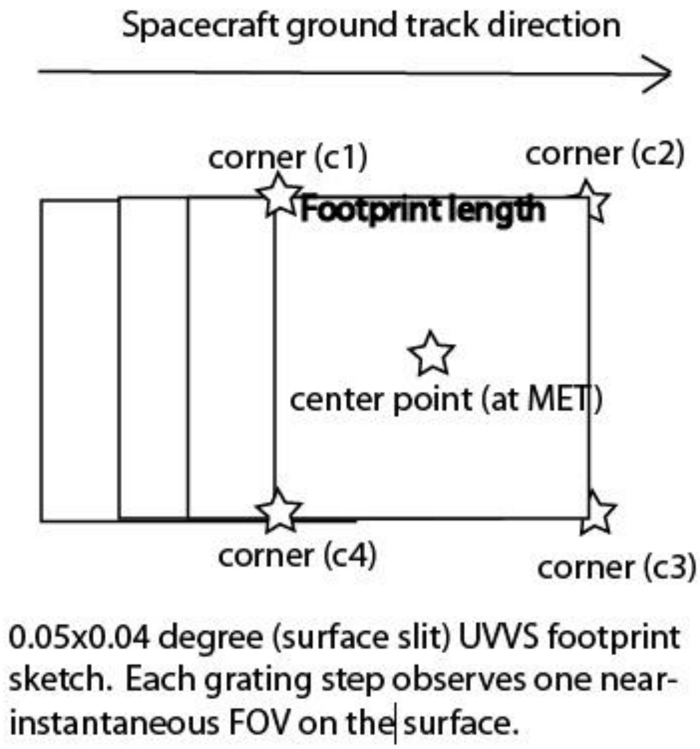


Figure 5b: UVVS Geometry Illustration. Surface (Ground) Observations.

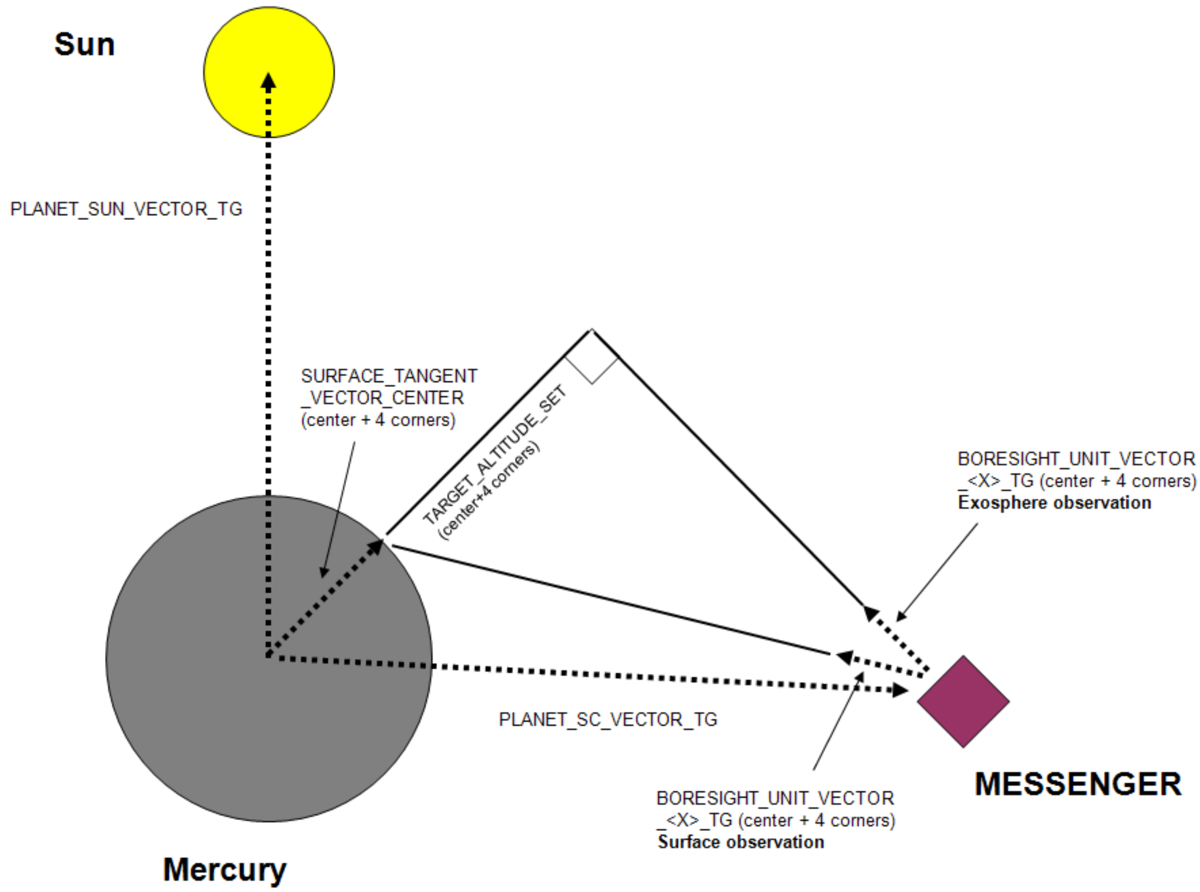


Fig. 5c: UVVS Position vectors in the planet-fixed coordinate frame. Two different types of observations are shown here on one figure. For an exosphere scan, the boresight makes a right angle with a vector pointed radially from the center of the planet. As defined here, the 'tangent' vector lies on this radial line and has a length equal to the radius of the planet, while the altitudes of the actual tangent points are given as a set of fixed values. For a surface scan, the instrument boresight intersects the planet surface and the 'tangent' vector points to this location. For other flybys, Earth, Moon, or Venus is substituted for Mercury.

1. STEP_NUMBER
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Step in the observation. PER STEP column.

2. PLANET_SUN_VECTOR_TG
```
Bytes: 24       Type: IEEE_REAL
Items: 3        Item Bytes: 8
```

Derived (x,y,z) vector giving center-to-center planet- sun position in target body-fixed coordinate system. Unit = kilometers. PER STEP column.

3. PLANET_SC_VECTOR_ TG
```
Bytes: 24       Type: IEEE_REAL
Items: 3        Item Bytes: 8
```

Derived (x,y,z) vector giving center-to-center planet- spacecraft position in target body-fixed coordinate system. Unit = kilometers. PER STEP column.

4. BORESIGHT_UNIT_VECTOR_CENTER_ TG
```
Bytes: 24       Type: IEEE_REAL
Items: 3        Item Bytes: 8
```

Derived (x,y,z) vector giving look direction of MASCS UVVS center in target body-fixed coordinate system. Unit = N/A. PER STEP column.

5. BORESIGHT_UNIT_VECTOR_C1_ TG
```
Bytes: 24       Type: IEEE_REAL
Items: 3        Item Bytes: 8
```

Derived (x,y,z) vector giving look direction of MASCS UVVS corner 1 in target body-fixed coordinate system. Unit = N/A. PER STEP column.

6. BORESIGHT_UNIT_VECTOR_C2_ TG
```
Bytes: 24       Type: IEEE_REAL
Items: 3        Item Bytes: 8
```

Derived (x,y,z) vector giving look direction of MASCS UVVS corner 2 in target body-fixed coordinate system. Unit = N/A. PER STEP column.

7. BORESIGHT_UNIT_VECTOR_C3_ TG
```
Bytes: 24       Type: IEEE_REAL
Items: 3        Item Bytes: 8
```

Derived (x,y,z) vector giving look direction of MASCS UVVS corner 3 in target body-fixed coordinate system. Unit = N/A. PER STEP column.

8. BORESIGHT_UNIT_VECTOR_C4_ TG
```
Bytes: 24       Type: IEEE_REAL
Items: 3        Item Bytes: 8
```

Derived (x,y,z) vector giving look direction of MASCS UVVS corner 4 in target body-fixed coordinate system. Unit = N/A. PER STEP column.

9. SURFACE_TANGENT_VECTOR_CENTER
`Bytes: 24       Type: IEEE_REAL`

```
Items: 3        Item Bytes: 8
```

Vector from center of target planet through tangent line (a radial line which intersects the boresight look direction at a 90 deg. angle) to the planet surface, with a magnitude equal to the planet radius, UVVS Center. In target body-fixed coordinate system. Unit = kilometers. PER STEP column.

*Note: Value = NAN when pointing vector is >50 planetary radii from planet.

10. SURFACE_TANGENT_VECTOR_C1

```
Bytes: 24       Type: IEEE_REAL
Items: 3        Item Bytes: 8
```

Vector from center of target planet through tangent line (a radial line which intersects the boresight look direction at a 90 deg. angle) to the planet surface, with a magnitude equal to the planet radius, UVVS Corner 1. In target body-fixed coordinate system. Unit = kilometers. PER STEP column.

*Note: Value = NAN when pointing vector is >50 planetary radii from planet.

11. SURFACE_TANGENT_VECTOR_C2

```
Bytes: 24       Type: IEEE_REAL
Items: 3        Item Bytes: 8
```

Vector from center of target planet through tangent line (a radial line which intersects the boresight look direction at a 90 deg. angle) to the planet surface, with a magnitude equal to the planet radius, UVVS Corner 2. In target body-fixed coordinate system. Unit = kilometers. PER STEP column.

*Note: Value = NAN when pointing vector is >50 planetary radii from planet.

12. SURFACE_TANGENT_VECTOR_C3

```
Bytes: 24       Type: IEEE_REAL
Items: 3        Item Bytes: 8
```

Vector from center of target planet through tangent line (a radial line which intersects the boresight look direction at a 90 deg. angle) to the planet surface, with a magnitude equal to the planet radius, UVVS Corner 3. In target body-fixed coordinate system. Unit = kilometers. PER STEP column.

*Note: Value = NAN when pointing vector is >50 planetary radii from planet.

13. SURFACE_TANGENT_VECTOR_C4

```
Bytes: 24       Type: IEEE_REAL
Items: 3        Item Bytes: 8
```

Vector from center of target planet through tangent line (a radial line which intersects the boresight look direction at a 90 deg. angle) to the planet surface, with a magnitude equal to the planet radius, UVVS Corner 4. In target body-fixed coordinate system. Unit = kilometers. PER STEP column.

*Note: Value = NAN when pointing vector is >50 planetary radii from planet.

14. RA_SET

```
Bytes: 40       Type: IEEE_REAL
Items: 5        Item Bytes: 8
```

Right ascension of UVVS footprint center, and 4 corners - 5 total values. Format: (center, corner 1, corner 2, corner 3, corner 4). Unit = degrees. PER STEP column.

15. DEC_SET

```
Bytes: 40       Type: IEEE_REAL
Items: 5        Item Bytes: 8
```

Declination of UVVS footprint center, and 4 corners - 5 total values. Format: (center, corner 1, corner 2, corner 3, corner 4). Unit =degrees. PER STEP column.

16. TARGET_LATITUDE_SET

```
Bytes: 40       Type: IEEE_REAL
Items: 5        Item Bytes: 8
```

For exosphere observations, this indicates the latitudes below the tangent points of the UVVS field-of-view center and corners. For surface observations, this indicates the latitudes at the locations where the field-of-view center and corners intersect the planet surface. Format: (center, corner 1, corner 2, corner 3, corner 4). Unit = degrees. PER STEP column.

17. TARGET_LONGITUDE_SET

```
Bytes: 40       Type: IEEE_REAL
Items: 5        Item Bytes: 8
```

For exosphere observations, this indicates the longitudes below the tangent points of the UVVS field-of-view center and corners. For surface observations, this indicates the longitudes at the locations where the field-of-view center and corners intersect the planet surface. Format: (center, corner 1, corner 2, corner 3, corner 4). Unit = degrees. PER STEP column.

18. TARGET_ALTITUDE_SET

```
Bytes: 40       Type: IEEE_REAL
Items: 5        Item Bytes: 8
```

For exosphere observations, this indicates the altitudes of the actual field-of-view center and corner tangent points above the surface along a radial line. For surface observations, these altitudes have a value of 0. Format: (center, corner 1, corner 2, corner 3, corner 4). Unit = kilometers. PER STEP column.

19. SLIT_ROTATION_ANGLE

```
Bytes: 8        Type: IEEE_REAL
```

Angle of long dimension of the slit with the surface tangent line. Unit = degrees. PER STEP column.

20. ALONG_TRACK_FOOTPRINT_SIZE

```
Bytes: 8        Type: IEEE_REAL
```

Derived length of UVVS footprint along track, accounting for smear across surface. Unit = meters. PER STEP column.

21. ACROSS_TRACK_FOOTPRINT_SIZE

```
Bytes: 8        Type: IEEE_REAL
```

Derived width of UVVS footprint across track, accounting for jitter across surface. Unit = meters. PER STEP column.

22. FOOTPRINT_AZIMUTH

```
Bytes: 8        Type: IEEE_REAL
```

Derived angle of footprint smear relative to a N-S line. 0 is North, plus/minus 180 is South, sign denotes east (clockwise) or west rotation of azimuth from North. Unit = degrees. PER STEP column.

23. INCIDENCE_ANGLE

```
Bytes: 8        Type: IEEE_REAL
```

Derived solar incidence angle of footprint center. Unit = degrees. PER STEP column.

24. EMISSION_ANGLE
```
Bytes: 8        Type: IEEE_REAL
```

Derived emission angle of footprint center. Unit = degrees. PER STEP column.

25. PHASE_ANGLE
```
Bytes: 8        Type: IEEE_REAL
```

Derived phase angle of footprint center. Unit = degrees. PER STEP column.

26. SLANT_RANGE_TO_CENTER
```
Bytes: 8        Type: IEEE_REAL
```

Derived slant range from s/c to footprint center (equal to s/c NADIR_ALTITUDE in nadir pointing case). Unit = kilometers. PER STEP column.

27. SUBSPACECRAFT_LATITUDE
```
Bytes: 8        Type: IEEE_REAL
```

Derived subspacecraft latitude on planet surface. Unit = degrees. PER STEP column.

28. SUBSPACECRAFT_LONGITUDE
```
Bytes: 8        Type: IEEE_REAL
```

Derived subspacecraft longitude on planet surface. Unit = degrees. PER STEP column.

29. NADIR_ALTITUDE
```
Bytes: 8        Type: IEEE_REAL
```

Derived spacecraft altitude above nadir point. Unit = kilometers. PER STEP column.

30. SUBSOLAR_LATITUDE
```
Bytes: 8        Type: IEEE_REAL
```

Derived subsolar latitude on planet surface. Unit = degrees. PER STEP column.

31. SUBSOLAR_LONGITUDE
```
Bytes: 8        Type: IEEE_REAL
```

Derived subsolar longitude on planet surface. Unit = degrees. PER STEP column.

32. SOLAR_DISTANCE
```
Bytes: 8        Type: IEEE_REAL
```

Derived subsolar distance to footprint center on planet surface. Unit = kilometers. PER STEP column.

33. PLANET_TRUE_ANOMALY
```
Bytes: 8        Type: IEEE_REAL
```

Derived true anomaly of planet. Unit = degrees. PER STEP column.

34. MIDSTEP_TIME

```
Bytes: 8        Type: IEEE_REAL
```

A calculated value indicating the mission elapsed time since launch at the middle of an individual UVVS step. Unit = seconds. This is a double precision value.

The formula used is:
MIDSTEP_TIME = (N-1)*(INT_TIME+STEP_TIME)/3000 + SC_TIME + PACKET_SUBSECONDS*5/1000 + (INT_TIME/3000)/2,

where N is the Nth step in an observation sequence, and the other values are contained in the UVVS Science Header CDR. PER STEP column.

35. STEP_UTC_TIME
```
Bytes: 17       Type: CHARACTER
```

UTC time in YYDOYTHH:MM:SS.00 format derived from the MIDSTEP_TIME using SPICE kernels. PER STEP column.

36. GRATING_OFFSET
```
Bytes: 4        Type: IEEE_REAL
```

From lookup table located in the CALIB directory of the archive volume. PER STEP column. Currently, the grating offset table is not implemented correctly.

37. STEP_POSITION
```
Bytes: 4        Type: MSB_INTEGER
```

Actual grating position calculated by start position + (step number * step size) + offset. PER STEP column.

38. STEP_WAVELENGTH
```
Bytes: 4        Type: IEEE_REAL
```

From wavelength equation (Eq. 6.2 in calibration report):

$\lambda = 403.079 \bullet \sin(12.652 + 0.016665 \bullet n)$ nm (FUV)

$\lambda = 814.105 \bullet \sin(10.312 + 0.016665 \bullet n)$ nm (MUV)

$\lambda = 820.679 \bullet \sin(7.977 + 0.016665 \bullet n)$ nm (VIS)

where n is grating step number. Unit = nanometers. PER STEP column.

39. RAW_STEP_DATA
```
Bytes: 2        Type: MSB_UNSIGNED_INTEGER
```

Column of uncompressed raw data. Unit = counts. PER STEP column.

40. COUNT_RATE
```
Bytes: 4        Type: IEEE_REAL
```

Count rate of step. Unit = counts/second. PER STEP column.

41. DEAD_CORRECTED_COUNT_RATE
```
Bytes: 4        Type: IEEE_REAL
```

Count rate corrected for nonlinearity due to dead-time. Unit = counts/second. PER STEP column.

42. DARK_RATE
```
Bytes: 4        Type: IEEE_REAL
```

Dark count rate at step from model/module. Unit = counts/second. PER STEP column.

43. SCATTERED_LIGHT_RATE
```
Bytes: 4        Type: IEEE_REAL
```

Scattered light at step from model/module. Unit = counts/second. PER STEP column.

44. FULLY_CORRECTED_COUNT_RATE
```
Bytes: 4        Type: IEEE_REAL
```

Count rate corrected for dark, scattered light, dead time, etc. Unit = counts/second. PER STEP column.

45. FULLY_CORRECTED_COUNT_RATE_UNCERTAINTY
```
Bytes: 4        Type: IEEE_REAL
```

Uncertainty for count rate, equivalent to instrument shot noise. Unit = counts/second. PER STEP column.

46. STEP_RADIANCE_KR
```
Bytes: 4        Type: IEEE_REAL
```

Calibrated radiance value at step. Unit = kiloRayleighs/nanometer. PER STEP column.

47. STEP_RADIANCE_W
```
Bytes: 4        Type: IEEE_REAL
```

Calibrated radiance value at step. Unit = W/(m^2 steradian micron). PER STEP column.

48. STEP_ RADIANCE_SIGNAL_TO_NOISE
```
Bytes: 4        Type: IEEE_REAL
```

Derived signal to noise in fully calibrated radiance, propagated from fully corrected count rate uncertainty and sensitivity uncertainty. Unitless ratio, applied to radiance. PER STEP column.

49. PMT_TEMPERATURE
```
Bytes: 4        Type: IEEE_REAL
```

Photomultiplier tube (PMT) temperature in degrees C.

50. DATA_QUALITY_INDEX
```
Bytes: 21       Type: CHARACTER
```

21 character index of data quality. Each digit signifies quality factor of measurements. PER STEP column.
Format: A-BCDEF-GHIJ-KLM-NOPQ
A: SBOS trip
 0 = no trip
 1 = trip
 9 = Unknown. No information found from MASCS HK EDR for the time period START_TIME to STOP TIME.
B: Footprint center on planet
 0 = not on planet
 1 = on planet
C: Footprint C1 on planet
 0 = not on planet

1 = on planet
D: Footprint C2 on planet
0 = not on planet
1 = on planet
E: Footprint C3 on planet
0 = not on planet
1 = on planet
F: Footprint C4 on planet
0 = not on planet
1 = on planet
G: Partial scan (macro cutoff)
0 = No partial scan.
1 = Partial scan.
H: Temperature 1 flag for this UVVS detector
0 = Temperature does not exceed 25 deg C threshold.
1 = Temperature exceeds 25 deg C threshold but less than 45 deg C threshold.
2 = Temperature exceeds 45 deg C threshold.
9 = Unknown. No information found from MASCS HK EDR for the time period START_TIME to STOP TIME.
I: UVVS noise spike flag
0 = No noise spike detected.
1 = Noise spike detected.
J: VIRS operating flag
0 = VIRS is not scanning during readout.
1 = VIRS is scanning during readout.
9 = Unknown. No information found from MASCS HK EDR for the time period START_TIME to STOP TIME.
K: Buffer overflow flag
0 = No buffer overflow.
1 = Buffer overflow.
L: Background subtraction method
= Method used
M: Background quality flag (not yet implemented)
0 = Not yet implemented.
1 = Inside TBD threshold.
N: SPICE Version Epoch. Indicates what SPICE is used to determine pointing fields in CDR. ‘Predict’ SPICE may change one or more times before settling on ‘Final’ pointing solutions about 2 weeks from data acquisition.
0 = No SPICE
1 = Predict
2 = Actual
O-Q: Spares

51. SC_TIME
`Bytes: 4        Type: MSB_UNSIGNED_INTEGER`

Spacecraft time in integer seconds that is transmitted to the MESSENGER subsystems by the Integrated Electronics Module. This is assigned as the start time of the UVVS observation. A UVVS observation is defined as all the scan data contained within one UVVS science packet. This is due to the highly configurable nature of the instrument, i.e. it can be commanded to take multiple scans over multiple wavelengths. Unit is in mission elapsed time which is the number of seconds since launch. PER STEP column.

52. OBSERVATION_TYPE
`Bytes: 30       Type: CHARACTER`

Describes the type of observation being executed at this MIDSTEP time. PER STEP column..

53. SPARE_2
`Bytes: 8        Type: IEEE_REAL`

SPARE column.

6.3.2 Surface DDR Column Descriptions

Each UVVS surface observation (contiguous time period of data acquisition with a given sequence) is associated with two DDR data products: a science header table (HDR), showing the instrument command parameters for a given observation, and a science data table (SCI), showing counts, derived science data, and pointing information for each bin of 5 steps of an observation. The table columns are described by the format files UVVSHDRD_SUR.FMT and UVVSSCID_SUR.FMT, respectively. The following are detailed descriptions of the columns in the UVVS DDR binary table objects. "OBSERVATION" columns have the same value for the whole DDR - these are parameters such as integration time set during the UVVS setup command. "PER BIN" columns have different values for each bin of 5 steps in the observation. Times associated with individual bins refer to the middle of the integration period for that bin. Replicas of the UVVSHDRD_SUR.FMT and UVVSSCID_SUR.FMT format files can be found in Appendices C and D, respectively.

6.3.2.1 Fields in Surface HDR DDR Format File (UVVSHDRD_SUR.FMT)

1. SC_TIME
`Bytes: 4        Type: MSB_UNSIGNED_INTEGER`

Spacecraft time in integer seconds that is transmitted to the MESSENGER subsystems by the Integrated Electronics Module. This is assigned as the start time of the UVVS observation. A UVVS observation is defined as all the scan data contained within one UVVS science packet. This is due to the highly configurable nature of the instrument, i.e. it can be commanded to take multiple scans over multiple wavelengths. Unit is in mission elapsed time which is the number of seconds since launch. PER OBSERVATION column.

2. PACKET_SUBSECONDS
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

The subsecond time in milliseconds that the telemetry packet was initiated. SC_TIME plus PACKET_SUBSECONDS is the spacecraft time of the first integration. Values of this field are in units of 5 milliseconds. For example, a value of 10 refers to a time of 50 milliseconds. PER OBSERVATION column.

3. START_POS
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Start position where grating drive begins a scan. Grating drive step position corresponds to a given wavelength being observed by an instrument. PER OBSERVATION column.

4. STEP_COUNT
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Number of steps the grating drive took in a scan. This directly corresponds to the range of wavelengths that were observed in one UVVS observation. PER OBSERVATION column.

5. INT_TIME
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Integration time in grating drive loop control interrupt periods (nominally 3000 Hz). For example, the actual integration time in seconds is INT_TIME/3000. PER OBSERVATION column.

6. STEP_TIME
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Step time in grating drive loop control interrupt periods (nominally 3000 Hz). For example, the actual step time in seconds is STEP_TIME/3000. PER OBSERVATION column.

7. PHASE_OFFSET
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Phase offset in grating drive loop control interrupt periods. Phase offset between the beginning of grating drive step and the start of a PMT integration in units of 0.3 milliseconds. Default value is 0 (no phase offset). Setting the phase offset to a non-zero value (reserved for contingency operations), instructed the software to initiate a step before the end of an integration, accounting for latencies in the motor controller. PER OBSERVATION column.

8. SCAN_CYCLES
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Number of times to repeat scan. PER OBSERVATION column.

9. ZIGZAG
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Indicates whether grating drive moves in a 'triangle' (stepping up, then stepping down), or 'sawtooth' (stepping up, then 'flying' down) motion. A 'triangle' observation takes one grating scan stepping up the grating, then reverses direction and takes the next grating scan stepping back down the grating. A 'sawtooth' observation takes one grating scan stepping up the grating, then 'flies' the grating back to the START_POSITION to take the next observation. =0 disable, =1 enable. PER OBSERVATION column.

10. COMPRESSION
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Selectable data size, =0 16 bit data, =1 9 bit data. Used to help determine the total number of data points contained in the observation. PER OBSERVATION column.

11. SLIT_MASK_POS
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Indicates whether slit mask is in atmospheric (open) or surface (closed) position. Atmospheric slit results in a 1 deg. by 0.04 deg. instantaneous field of view (iFOV). Surface slit results in a 0.05 deg. by 0.04 deg. iFOV. =0 closed, =1 open. PER OBSERVATION column.

12. GD_SETTLE_CTR
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Number of times during integration that the grating drive wandered outside target range. This can happen very rarely with an encoder misread, or motor misstep, and would result in an offset of step-number to wavelength correlations for subsequent observations in a given scan. PER OBSERVATION column.

13. NUM_SCAN_VALUES
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Total number of values or data points in the entire scan observation. Used to determine the number of valid data points in the SCAN_DATA column. Maximum value is 3626. PER OBSERVATION column.

14. STEP_SIZE
```
Bytes: 2        Type: MSB_UNSIGNED_INTEGER
```

Step size in arcmin units. PER OBSERVATION column.

15. COADD
```
Bytes: 2        Type: MSB_UNSIGNED_INTEGER
```

Number of steps coadded to make a single observation. Default = 1, i.e. one step per observation. PER OBSERVATION column.

16. CALIBRATION_SOFTWARE_VERSION
```
Bytes: 4        Type: IEEE_REAL
```

Indicates version of calibration software used. Increments with reprocessing of CDRs. PER OBSERVATION column.

6.3.2.2 Fields in Surface SCI DDR Format File (UVVSSCID_SUR.FMT)

As a single UVVS surface spectrum is acquired by holding the FOV on the surface for the duration of a grating scan, Footprint center stability is noted in DQI column "O" to denote how much smear across the ground occurs during any single observation.

1. BIN_NUMBER
```
Bytes: 2        Type: MSB_UNSIGNED_INTEGER
```

BIN of steps in the observation.

2. TARGET_LATITUDE_SET
```
Bytes: 40       Type: IEEE_REAL
Items: 5        Item Bytes: 8
```

This indicates the BIN-average latitudes at the locations where the field-of-view center and corners intersect the planet surface. Format: (center, corner 1, corner 2, corner 3, corner 4). Unit = degrees.

3. TARGET_LONGITUDE_SET
```
Bytes: 40       Type: IEEE_REAL
Items: 5        Item Bytes: 8
```

This indicates the BIN-average longitudes at the locations where the field-of-view center and corners intersect the planet surface. Format: (center, corner 1, corner 2, corner 3, corner 4). Unit = degrees.

4. SLIT_ROTATION_ANGLE
```
Bytes: 8        Type: IEEE_REAL
```

BIN average angle of long dimension of the slit with the surface tangent line. Unit = degrees.

5. ALONG_TRACK_FOOTPRINT_SIZE
```
Bytes: 8        Type: IEEE_REAL
```

Derived BIN average length of UVVS footprints along track, accounting for smear across surface. Unit = meters.

6. ACROSS_TRACK_FOOTPRINT_SIZE
```
Bytes: 8        Type: IEEE_REAL
```

Derived BIN average length of UVVS footprints across track, accounting for smear across surface. Unit = meters.

7. INCIDENCE_ANGLE
```
Bytes: 8        Type: IEEE_REAL
```

Derived BIN average solar incidence angle of footprint center. Unit = degrees.

8. EMISSION_ANGLE
```
Bytes: 8        Type: IEEE_REAL
```

Derived BIN average solar emission angle of footprint center. Unit = degrees.

9. PHASE_ANGLE
```
Bytes: 8        Type: IEEE_REAL
```

Derived BIN average solar phase angle of footprint center. Unit = degrees.

10. SOLAR_DISTANCE
```
Bytes: 8        Type: IEEE_REAL
```

Derived BIN average subsolar distance to footprint center on planet surface. Unit = kilometers.

11. MIDBIN_TIME
```
Bytes: 8        Type: IEEE_REAL
```

A calculated value indicating the average mission elapsed time since launch of the BIN of steps. Unit = seconds. This is a double precision value. The formula used is: MIDBIN_TIME = average(MIDSTEP_TIME for each step). MIDSTEP_TIME values are taken from the source UVVS Science CDR steps that were incorporated into the BIN.

12. BIN_UTC_TIME
```
Bytes: 17       Type: CHARACTER
```

UTC time in YYDOYTHH:MM:SS.00 format in the middle of the BIN of steps.

13. BIN_WAVELENGTH
```
Bytes: 4        Type: IEEE_REAL
```

Center wavelength of BIN, Derived from average step wavelengths from wavelength equation. Unit = nanometers..

14. IOF_BIN_DATA
```
Bytes: 4        Type: IEEE_REAL
```

Derived column of BIN photometrically corrected reflectance at sensor.

15. PHOTOM_IOF_BIN_DATA
```
Bytes: 4        Type: IEEE_REAL
```

Derived column of BIN reflectance at sensor.

16. IOF_BIN_NOISE_DATA
```
Bytes: 4        Type: IEEE_REAL
```

Derived column of BIN reflectance noise/error propagated through post-calibration procedure. PER BIN column.

17. PHOTOM_IOF_BIN_NOISE_DATA
```
Bytes: 4        Type: IEEE_REAL
```

Derived column of BIN photometrically corrected reflectance noise/error propagated through post-calibration procedure.

18. FULLY_CORRECTED_COUNT_RATE
```
Bytes: 4        Type: IEEE_REAL
```

Count rate of BIN. Unit = counts/second.

19. STEP_RADIANCE_W
```
Bytes: 4        Type: IEEE_REAL
```

BIN average calibrated radiance value . Unit = W/(m^2 steradian micron).

20. PMT_TEMPERATURE
```
Bytes: 4        Type: IEEE_REAL
```

BIN average PMT temperature in degrees C.

21. DATA_QUALITY_INDEX
```
Bytes: 21       Type: CHARACTER
```

21 character index of data quality taken from the middle of the BIN of steps. Each digit signifies quality factor of measurements. Format: A-BCDEF-GHIJ-KLM-NOPQ

A: SBOS trip
 0 = no trip
 1 = trip
 9 = Unknown. No information found from MASCS HK EDR for the time period START_TIME to STOP TIME.

B: Footprint center on planet
 0 = not on planet
 1 = on planet

C: Footprint C1 on planet
 0 = not on planet
 1 = on planet

D: Footprint C2 on planet
 0 = not on planet
 1 = on planet

E: Footprint C3 on planet
 0 = not on planet
 1 = on planet

F: Footprint C4 on planet
 0 = not on planet
 1 = on planet

G: Partial scan (macro cutoff)
 0 = No partial scan.
 1 = Partial scan.

H: Temperature 1 flag for this UVVS detector
 0 = Temperature does not exceed 25 deg C threshold.
 1 = Temperature exceeds 25 deg C threshold but less than 45 deg C threshold.
 2 = Temperature exceeds 45 deg C threshold.
 9 = Unknown. No information found from MASCS HK EDR for the time period START_TIME to STOP TIME.

I: UVVS noise spike flag
 0 = No noise spike detected.
 1 = Noise spike detected.

J: VIRS operating flag
  0 = VIRS is not scanning during readout.
  1 = VIRS is scanning during readout.
  9 = Unknown. No information found from MASCS HK EDR for the time period START_TIME to STOP TIME.
K: Buffer overflow flag
  0 = No buffer overflow.
  1 = Buffer overflow.
L: Background subtraction method
  # = Method used
M: Background quality flag (not yet implemented)
  0 = Not yet implemented.
  1 = Inside TBD threshold.
N: SPICE Version Epoch. Indicates what SPICE is used to determine pointing fields in CDR. 'Predict' SPICE may change one or more times before settling on 'Final' pointing solutions about 2 weeks from data acquisition.
  0 = No SPICE
  1 = Predict
  2 = Actual
O: Footprint center stability. Fraction of FOV smear during the BIN observation. 0-9 = 0.0 to 0.9 FOVs movement while obtaining the steps that comprise the BIN. A= 1.0 FOVs, B=1.1, C=1.2, etc. each letter representing 0.1 FOV increments. Z=2.6 or greater FOV's smear.
P-Q: Spares.

22. OBSERVATION_TYPE

```
Bytes: 30       Type: CHARACTER
```

Describes the type of observation being executed at this MIDSTEP time. PER STEP column.

23. SPARE

```
Bytes: 8        Type: IEEE_REAL
```

24. SPARE

```
Bytes: 8        Type: IEEE_REAL
```

25. SPARE

```
Bytes: 8        Type: IEEE_REAL
```

6.3.3 Atmosphere DDR Column Descriptions

The UVVS observations (contiguous time period of data acquisition with a given sequence) are associated with a single Atmosphere DDR data product: a science data table (SCI), showing calibrated spectra, total radiance integrated over the emission lines, and pointing information for each altitude step of a given observational sequence. The table columns are described by the format file UVVSSCID.FMT. The following are detailed descriptions of the columns in the UVVS Atmosphere DDR binary table objects. Each of N time-ordered records in the file represents the observed spectrum and radiance at a single altitude. Times and geometry associated with each individual record refer to the midpoint of the spectral scan (middle wavelength), where the given emission line is centered. A replica of the UVVSSCID.FMT format file can be found in Appendix E.

6.3.2.1 Fields in Atmosphere DDR Format File (UVVSSCID.FMT)

All "PER SPECTRAL SCAN" geometry and time columns are defined at the midpoint (middle wavelength) of the observed spectral scan.

1. OBSERVATION_TYPE
```
Bytes: 30            Type: CHARACTER
```

Name of the observation type. PER SPECTRAL SCAN.

2. CDR_NAME
```
Bytes: 27            Type: CHARACTER
```

Name of the CDR from which the data were extracted. PER SPECTRAL SCAN.

3. OBS_SEQUENCE_INDEX
```
Bytes: 2       Type: MSB_UNSIGNED_INTEGER
```

Counting index for a given observational sequence. Sequences are arranged consecutively in time, so this index allows the points within a given sequence to be identified. Resets to 1 with each new sequence. PER SPECTRAL SCAN.

4. PLANET_SUN_VECTOR_TG
```
Bytes: 24      Type: IEEE_REAL
Items: 3       Item Bytes: 8
```

Derived (x,y,z) vector giving center-to-center planet-sun position in target body-fixed coordinate system at midpoint of spectral scan. Unit = kilometers. PER SPECTRAL SCAN.

5. PLANET_SC_VECTOR_ TG
```
Bytes: 24      Type: IEEE_REAL
Items: 3       Item Bytes: 8
```

Derived (x,y,z) vector giving center-to-center planet-spacecraft position in target body-fixed coordinate system at midpoint of spectral scan. Unit = kilometers. PER SPECTRAL SCAN.

6. BORESIGHT_UNIT_VECTOR_CENTER_ TG
```
Bytes: 24      Type: IEEE_REAL
Items: 3       Item Bytes: 8
```

Derived (x,y,z) vector giving look direction of MASCS UVVS center in target body-fixed coordinate system at midpoint of spectral scan. Unit = N/A. PER SPECTRAL SCAN.

7. TARGET_LATITUDE
```
Bytes: 8       Type: IEEE_REAL
```

Latitude below the tangent point of the UVVS field-of-view center. Measured at midpoint of spectral scan. Unit = degrees. PER SPECTRAL SCAN.

8. TARGET_LONGITUDE
```
Bytes: 8       Type: IEEE_REAL
```

Longitude below the tangent point of the UVVS field-of-view center. Measured at midpoint of spectral scan. Unit = degrees. PER SPECTRAL SCAN.

9. TARGET_ALTITUDE
```
Bytes: 24      Type: IEEE_REAL
Items: 3       Item Bytes: 8
```

Altitude (center, min, max) of the actual field-of-view slit projection. Measured at midpoint of spectral scan. Unit = kilometers. PER SPECTRAL SCAN.

10. TARGET_LOCAL_TIME
`Bytes: 4        Type: IEEE_REAL`

Local time of the tangent point of the UVVS field-of-view center. Local time is defined as 0 at midnight, 6 at dawn, and 12 at noon. Measured at midpoint of spectral scan. Unit= hour plus fraction of hour. (e.g. 1.5 = 90 minutes). PER SPECTRAL SCAN.

11. SUBSPACECRAFT_LATITUDE
`Bytes: 8        Type: IEEE_REAL`

Derived subspacecraft latitude on planet surface. Measured at midpoint of spectral scan. Unit = degrees. PER SPECTRAL SCAN.

12. SUBSPACECRAFT_LONGITUDE
`Bytes: 8        Type: IEEE_REAL`

Derived subspacecraft longitude on planet surface. Measured at midpoint of spectral scan. Unit = degrees. PER SPECTRAL SCAN.

13. SPACECRAFT_ALTITUDE
`Bytes: 8        Type: IEEE_REAL`

Derived spacecraft altitude above nadir point. Unit = kilometers. PER SPECTRAL SCAN.

14. SPACECRAFT_LOCAL_TIME
`Bytes: 4        Type: IEEE_REAL`

Local time of the subspacecraft point. Local time is defined as 0 at midnight, 6 at dawn, and 12 at noon. Measured at midpoint of spectral scan. Unit=hour plus fraction of hour. (e.g. 1.5 = 90 minutes). PER SPECTRAL SCAN.

15. SUBSOLAR_LATITUDE
`Bytes: 8        Type: IEEE_REAL`

Derived subsolar latitude on planet surface. Measured at midpoint of spectral scan. Unit = degrees. PER SPECTRAL SCAN.

16. SUBSOLAR_LONGITUDE
`Bytes: 8        Type: IEEE_REAL`

Derived subsolar longitude on planet surface. Measured at midpoint of spectral scan. Unit = degrees. PER SPECTRAL SCAN.

17. PLANET_TRUE_ANOMALY
`Bytes: 8        Type: IEEE_REAL`

Derived true anomaly of planet. Measured at midpoint of spectral scan. Unit = degrees. PER SPECTRAL SCAN.

18. ORBIT_NUMBER
`Bytes: 4 Type: MSB_UNSIGNED_INTEGER`

Mercury orbit number. PER SPECTRAL SCAN.

19. MID_SPECTRUM_TIME
```
Bytes: 8       Type: IEEE_REAL
```

A calculated value indicating the mission elapsed time since launch at the middle of an individual UVVS spectral scan. Unit = seconds. PER SPECTRAL SCAN.

20. UTC_TIME
```
Bytes: 17      Type: CHARACTER
```

UTC time in YYDOYTHH:MM:SS.00 format derived from the MID_SPECTRUM_TIME using SPICE kernels. PER SPECTRAL SCAN.

21. WAVELENGTH
```
Bytes: 200           Type: IEEE_REAL
Items: 25            Item Bytes: 8
```

Wavelength vector of the spectral scan, which can be up to 25 elements. Shorter scans are padded with zeros. PER SPECTRAL SCAN.

22. RADIANCE_KR
```
Bytes: 200           Type: IEEE_REAL
Items: 25            Item Bytes: 8
```

Vector of calibrated radiances matched with scan WAVELENGTH; up to 25 elements. Shorter scans are padded with zeros. Unit = kiloRayleighs/nanometer. PER SPECTRAL SCAN.

23. RADIANCE_SNR
```
Bytes: 200           Type: IEEE_REAL
Items: 25            Item Bytes: 8
```

Vector of calibrated radiance SNR matched with scan WAVELENGTH; up to 25 elements. Shorter scans are padded with zeros. Derived signal-to-noise in fully calibrated radiance, propagated from fully corrected count rate uncertainty and sensitivity uncertainty. Unitless fraction, applied to radiance. PER SPECTRAL SCAN.

24. TOTAL_RADIANCE_KR
```
Bytes: 8 Type: IEEE_REAL
```

Total radiance integrated over the specified emission line(s) in the given calibrated spectrum. Unit = kiloRayleighs. PER SPECTRAL SCAN.

25. TOTAL_RADIANCE_SNR
```
Bytes: 8 Type: IEEE_REAL
```

Derived SNR in the total radiance, propagated from radiance SNR. Unitless fraction, applied to total radiance. PER SPECTRAL SCAN.

26. SLIT_POS
```
Bytes: 2 Type: MSB_UNSIGNED_INTEGER
```

Indicates whether slit mask is in atmospheric or surface position. Atmospheric slit results in a 1 deg. by 0.04 deg. instantaneous field of view (iFOV). Surface slit results in a 0.05 deg. by 0.04 deg. iFOV. Surface=0, Atmosphere=1. Unitless, PER SPECTRAL SCAN.

27. SPARE_1
```
Bytes: 8       Type: IEEE_REAL
```

SPARE column.

28. SPARE_2
`Bytes: 8        Type: IEEE_REAL`

SPARE column.

29. SPARE_3
`Bytes: 8        Type: IEEE_REAL`

SPARE column.

30. SPARE_4
`Bytes: 8        Type: IEEE_REAL`

SPARE column.

6.3.4 Atmospheric Model DDR Column Descriptions

1. TRUE_ANOMALY
`Bytes: 7              Type: ASCII_REAL`

Mercury's orbital position in degrees. Fit parameters are provided as averages over 5 degree increments, the middle of that 5 degree increment is listed in the file (e.g., 2.5 degrees for the 0-5 degree bin).

2. LOCAL_TIME
`Bytes: 6              Type: ASCII_REAL`

The local time of the model fit. Only limb scans taken within half an hour of the given local time are included in the average.

3. NEAR_SURFACE_DENSITY
`Bytes: 15             Type: ASCII_REAL`

Average near-surface density from modified Chamberlain model fits. A value of -1 indicates no model fit for this combination of TRUE_ANOMALY and LOCAL_TIME. Units of cm^{-3}.

4. NEAR_SURFACE_DENSITY_UNCERTAINTY
`Bytes: 15             Type: ASCII_REAL`

Average one-sigma standard deviation of the fit to near-surface density. A value of -1 indicates no model fit for this combination of TRUE_ANOMALY and LOCAL_TIME. Units of cm^{-3}.

5. TEMPERATURE
`Bytes: 15             Type: ASCII_REAL`

Average temperature modified from Chamberlain model fits. A value of -1 indicates no model fit for this combination of TRUE_ANOMALY and LOCAL_TIME. Units of K.

6. TEMPERATURE_UNCERTAINTY
`Bytes: 15             Type: ASCII_REAL`

Average one-sigma standard deviation of the fit to temperature. A value of -1 indicates no model fit for this combination of TRUE_ANOMALY and LOCAL_TIME. Units of K.

7. SCALE_HEIGHT
`Bytes: 15            Type: ASCII_REAL`

Scale height corresponding to the model fit. A value of -1 indicates no model fit for this combination of TRUE_ANOMALY and LOCAL_TIME. Units of km.

8. SPARE_1
`Bytes: 15            Type: ASCII_REAL`

Spare column, placeholder for future parameter. Default to spare value of 0.000000.

9. SPARE_2
`Bytes: 15            Type: ASCII_REAL`

Spare column, placeholder for future parameter. Default to spare value of 0.000000.

7. Appendices

APPENDIX A- UVVSHDRC.FMT FILE

```
/* FIELDS OBTAINED FROM EXPERIMENT DATA RECORD (EDR) */

OBJECT        = COLUMN
   NAME           = SEQ_COUNTER
   COLUMN_NUMBER  = 1
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 1
   DESCRIPTION    = "CCSDS packet sequence counter. PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SC_TIME
   COLUMN_NUMBER  = 2
   BYTES          = 4
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 3
   DESCRIPTION    = "Spacecraft time in integer seconds that is transmitted
   to the MESSENGER subsystems by the Integrated Electronics Module. This is
   assigned as the start time of the UVVS observation. A UVVS observation is
   defined as all the scan data contained within one UVVS science packet.
   This is due to the highly configurable nature of the instrument, i.e. it
   can be commanded to take multiple scans over multiple wavelengths. Unit is
   in mission elapsed time which is the number of seconds since launch. PER
   OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = PACKET_SUBSECONDS
   COLUMN_NUMBER  = 3
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 7
   DESCRIPTION    = "The subsecond time in milliseconds that the telemetry
   packet was initiated. SC_TIME plus PACKET_SUBSECONDS is the spacecraft
   time of the first integration. Values of this field are in units of 5
   milliseconds. For example, a value of 10 refers to a time of 50
   milliseconds. PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = START_POS
   COLUMN_NUMBER  = 4
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 9
   DESCRIPTION    = "Start position where grating drive begins a scan.
   Grating drive step position corresponds to a given wavelength being
   observed by an instrument. PER OBSERVATION column."
END_OBJECT    = COLUMN
```

```
OBJECT        = COLUMN
   NAME           = STEP_COUNT
   COLUMN_NUMBER  = 5
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 11
   DESCRIPTION    = "Number of steps the grating drive will take in a scan.
   This directly corresponds to the range of wavelengths that will be
   observed in one UVVS observation. PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = INT_TIME
   COLUMN_NUMBER  = 6
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 13
   DESCRIPTION    = "Integration time in grating drive loop control
   interrupt periods (nominally 3000 Hz). For example, the actual
   integration time in seconds is INT_TIME/3000. PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = STEP_TIME
   COLUMN_NUMBER  = 7
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 15
   DESCRIPTION    = "Step time in grating drive loop control interrupt
   periods (nominally 3000 Hz). For example, the actual step time in
   seconds is STEP_TIME/3000. PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = PHASE_OFFSET
   COLUMN_NUMBER  = 8
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 17
   DESCRIPTION    = "Phase offset in grating drive loop control interrupt
   periods. Phase offset between the beginning of grating drive step and
   the start of a PMT integration in units of 0.3 milliseconds. Default
   value is 0 (no phase offset).  By setting the phase offset to a
   non-zero value (reserved for contingency operations), the user will
   tell the software to initiate a step before the end of an integration,
   accounting for latencies in the motor controller. PER OBSERVATION
   column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SCAN_CYCLES
   COLUMN_NUMBER  = 9
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 19
   DESCRIPTION    = "Number of times to repeat scan. PER OBSERVATION column."
END_OBJECT    = COLUMN
```

```
OBJECT        = COLUMN
   NAME           = ZIGZAG
   COLUMN_NUMBER  = 10
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 21
   DESCRIPTION    = "Indicates whether grating drive moves in a 'triangle'
   (stepping up, then stepping down), or 'sawtooth' (stepping up, then
   'flying' down) motion. A 'triangle' observation takes one grating scan
   stepping up the grating, then reverses direction and takes the next
   grating scan stepping back down the grating. A 'sawtooth' observation
   takes one grating scan stepping up the grating, then 'flies' the grating
   back to the START_POSITION to take the next observation. =0 disable,
   =1 enable. PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = COMPRESSION
   COLUMN_NUMBER  = 11
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 23
   DESCRIPTION    = "Selectable data size, =0 16 bit data, =1 9 bit data.
   Used to help determine the total number of data points contained
   in the observation. PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SLIT_MASK_POS
   COLUMN_NUMBER  = 12
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 25
   DESCRIPTION    = "Indicates whether slit mask is in atmospheric (open)
   or surface (closed) position. Atmospheric slit results in a 1 deg. by
   0.04 deg. instantaneous field of view (iFOV). Surface slit results in a
   0.05 deg. by 0.04 deg. iFOV. =0 closed, =1 open. PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = FUV_ON
   COLUMN_NUMBER  = 13
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 27
   DESCRIPTION    = "Indicates whether FUV PMT power is on. =0 off, =1 on.
   PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = MUV_ON
   COLUMN_NUMBER  = 14
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 29
   DESCRIPTION    = "Indicates whether MUV PMT power is on. A more complete
```

```
   description of this field can be found in the MASCS User's Guide
   (Applicable Document 6 in UVVS_CDR_DDR_SIS.PDF). =0 off, =1 on. PER
   OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = VIS_ON
   COLUMN_NUMBER  = 15
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 31
   DESCRIPTION    = "Indicates whether VIS PMT power is on, =0 off, =1 on.
   PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = BUFFER_OVERFLOW
   COLUMN_NUMBER  = 16
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 33
   DESCRIPTION    = "Indicates whether scan programmed overflowed data buffer
   and was therefore truncated. =0 false, =1 true. PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPARE_BITS
   COLUMN_NUMBER  = 17
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 35
   DESCRIPTION    = "A two-byte spare location."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = GD_SETTLE_CTR
   COLUMN_NUMBER  = 18
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 37
   DESCRIPTION    = "Number of times during integration that the grating
   drive wandered outside target range. This can happen very rarely with an
   encoder misread, or motor misstep, and would result in an offset of
   step-number to wavelength correlations for subsequent observations in a
   given scan. PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = NUM_SCAN_VALUES
   COLUMN_NUMBER  = 19
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 39
   DESCRIPTION    = "Total number of values or data points in the entire scan
   observation. Used to determine the number of valid data points in the
   SCAN_DATA column. Maximum value is 3626. PER OBSERVATION column."
END_OBJECT    = COLUMN
```

```
OBJECT        = COLUMN
   NAME           = STEP_SIZE
   COLUMN_NUMBER  = 20
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 41
   DESCRIPTION    = "Step size in arcmin units. PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = PAD_BYTE
   COLUMN_NUMBER  = 21
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 43
   DESCRIPTION    = "A two-byte spare location. PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = COADD
   COLUMN_NUMBER  = 22
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 45
   DESCRIPTION    = "Number of steps coadded to make a single observation.
   Default = 1, i.e. one step per observation. PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CALIBRATION_SOFTWARE_VERSION
   COLUMN_NUMBER  = 23
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 47
   DESCRIPTION    = "Indicates version of calibration software used.
   Increments with reprocessing of CDRs. PER OBSERVATION column."
END_OBJECT    = COLUMN
```

APPENDIX B- UVVSSCIC.FMT FILE

```
OBJECT        = COLUMN
   NAME             = STEP_NUMBER
   COLUMN_NUMBER    = 1
   BYTES            = 2
   DATA_TYPE        = MSB_UNSIGNED_INTEGER
   START_BYTE       = 1
   DESCRIPTION    = "Step in the observation. PER STEP column."
END_OBJECT    = COLUMN

/* SPICE DERIVED GEOMETRY VALUES */

OBJECT        = COLUMN
   NAME             = PLANET_SUN_VECTOR_TG
   COLUMN_NUMBER    = 2
   BYTES            = 24
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 3
   ITEMS            = 3
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Derived (x,y,z) vector giving center-to-center planet-
   sun position in target body-fixed coordinate system. Unit = kilometers.
   PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = PLANET_SC_VECTOR_TG
   COLUMN_NUMBER    = 3
   BYTES            = 24
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 27
   ITEMS            = 3
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Derived (x,y,z) vector giving center-to-center planet-
   spacecraft position in target body-fixed coordinate system.
   Unit = kilometers. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = BORESIGHT_UNIT_VECTOR_CENTER_TG
   COLUMN_NUMBER    = 4
   BYTES            = 24
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 51
   ITEMS            = 3
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Derived (x,y,z) vector giving look direction of MASCS
   UVVS center in target body-fixed coordinate system. Unit = N/A. PER STEP
   column."
END_OBJECT    = COLUMN
```

```
OBJECT         = COLUMN
   NAME              = BORESIGHT_UNIT_VECTOR_C1_TG
   COLUMN_NUMBER     = 5
   BYTES             = 24
   DATA_TYPE         = IEEE_REAL
   START_BYTE        = 75
   ITEMS             = 3
   ITEM_BYTES        = 8
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Derived (x,y,z) vector giving look direction of MASCS
   UVVS corner 1 in target body-fixed coordinate system. Unit = N/A. PER
   STEP column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME              = BORESIGHT_UNIT_VECTOR_C2_TG
   COLUMN_NUMBER     = 6
   BYTES             = 24
   DATA_TYPE         = IEEE_REAL
   START_BYTE        = 99
   ITEMS             = 3
   ITEM_BYTES        = 8
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Derived (x,y,z) vector giving look direction of MASCS
   UVVS corner 2 in target body-fixed coordinate system. Unit = N/A. PER
   STEP column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME              = BORESIGHT_UNIT_VECTOR_C3_TG
   COLUMN_NUMBER     = 7
   BYTES             = 24
   DATA_TYPE         = IEEE_REAL
   START_BYTE        = 123
   ITEMS             = 3
   ITEM_BYTES        = 8
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Derived (x,y,z) vector giving look direction of MASCS
   UVVS corner 3 in target body-fixed coordinate system. Unit = N/A. PER
   STEP column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME              = BORESIGHT_UNIT_VECTOR_C4_TG
   COLUMN_NUMBER     = 8
   BYTES             = 24
   DATA_TYPE         = IEEE_REAL
   START_BYTE        = 147
   ITEMS             = 3
   ITEM_BYTES        = 8
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Derived (x,y,z) vector giving look direction of MASCS
   UVVS corner 4 in target body-fixed coordinate system. Unit = N/A. PER
   STEP column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
```

```
   NAME             = SURFACE_TANGENT_VECTOR_CENTER
   COLUMN_NUMBER    = 9
   BYTES            = 24
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 171
   ITEMS            = 3
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Vector from center of target planet through tangent
   line (a radial line which intersects the boresight look direction at a 90
   deg. angle) to the planet surface, with a magnitude equal to the planet
   radius, UVVS Center. In target body-fixed coordinate system.
   Unit = kilometers. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SURFACE_TANGENT_VECTOR_C1
   COLUMN_NUMBER    = 10
   BYTES            = 24
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 195
   ITEMS            = 3
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Vector from center of target planet through tangent
   line (a radial line which intersects the boresight look direction at a 90
   deg. angle) to the planet surface, with a magnitude equal to the planet
   radius, UVVS Corner 1. In target body-fixed coordinate system.
   Unit = kilometers. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SURFACE_TANGENT_VECTOR_C2
   COLUMN_NUMBER    = 11
   BYTES            = 24
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 219
   ITEMS            = 3
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Vector from center of target planet through tangent
   line (a radial line which intersects the boresight look direction at a 90
   deg. angle) to the planet surface, with a magnitude equal to the planet
   radius, UVVS Corner 2. In target body-fixed coordinate system.
   Unit = kilometers. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SURFACE_TANGENT_VECTOR_C3
   COLUMN_NUMBER    = 12
   BYTES            = 24
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 243
   ITEMS            = 3
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Vector from center of target planet through tangent
```

```
   line (a radial line which intersects the boresight look direction at a 90
   deg. angle) to the planet surface, with a magnitude equal to the planet
   radius, UVVS Corner 3. In target body-fixed coordinate system.
   Unit = kilometers. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SURFACE_TANGENT_VECTOR_C4
   COLUMN_NUMBER    = 13
   BYTES            = 24
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 267
   ITEMS            = 3
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Vector from center of target planet through tangent
   line (a radial line which intersects the boresight look direction at a 90
   deg. angle) to the planet surface, with a magnitude equal to the planet
   radius, UVVS Corner 4. In target body-fixed coordinate system.
   Unit = kilometers. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = RA_SET
   COLUMN_NUMBER    = 14
   BYTES            = 40
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 291
   ITEMS            = 5
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Right ascension of UVVS footprint center, and 4
   corners - 5 total values. Format: (center, corner 1, corner 2, corner 3,
   corner 4). Unit = degrees. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = DEC_SET
   COLUMN_NUMBER    = 15
   BYTES            = 40
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 331
   ITEMS            = 5
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Declination of UVVS footprint center, and 4
   corners - 5 total values. Format: (center, corner 1, corner 2, corner 3,
   corner 4). Unit = degrees. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = TARGET_LATITUDE_SET
   COLUMN_NUMBER    = 16
   BYTES            = 40
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 371
   ITEMS            = 5
```

```
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "For exosphere observations, this indicates the
   latitudes below the tangent points of the UVVS field-of-view center and
   corners. For surface observations, this indicates the latitudes at the
   locations where the field-of-view center and corners intersect the planet
   surface. Format: (center, corner 1, corner 2, corner 3, corner 4).
   Unit = degrees. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = TARGET_LONGITUDE_SET
   COLUMN_NUMBER    = 17
   BYTES            = 40
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 411
   ITEMS            = 5
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "For exosphere observations, this indicates the
   longitudes below the tangent points of the UVVS field-of-view center and
   corners. For surface observations, this indicates the longitudes at the
   locations where the field-of-view center and corners intersect the planet
   surface. Format: (center, corner 1, corner 2, corner 3, corner 4).
   Unit = degrees. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = TARGET_ALTITUDE_SET
   COLUMN_NUMBER    = 18
   BYTES            = 40
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 451
   ITEMS            = 5
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "For exosphere observations, this indicates the
   altitudes of the actual field-of-view center and corner tangent points
   above the surface along a radial line.  For surface observations, these
   altitudes have a value of 0. Format: (center, corner 1, corner 2,
   corner 3, corner 4). Unit = kilometers. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SLIT_ROTATION_ANGLE
   COLUMN_NUMBER    = 19
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 491
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Angle of long dimension of the slit with the surface
   tangent line. Unit = degrees. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = ALONG_TRACK_FOOTPRINT_SIZE
   COLUMN_NUMBER    = 20
```

```
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 499
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Derived length of UVVS footprint along track,
   accounting for smear across surface. Unit = meters. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = ACROSS_TRACK_FOOTPRINT_SIZE
   COLUMN_NUMBER    = 21
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 507
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Derived width of UVVS footprint across track,
   accounting for jitter across surface. Unit = meters. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = FOOTPRINT_AZIMUTH
   COLUMN_NUMBER    = 22
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 515
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Derived angle of footprint smear relative to a N-S
   line. 0 is North, plus/minus 180 is South, sign denotes east (clockwise)
   or west rotation of azimuth from North. Unit = degrees. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = INCIDENCE_ANGLE
   COLUMN_NUMBER    = 23
   BYTES          = 8
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 523
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Derived solar incidence angle of footprint center.
   Unit = degrees. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = EMISSION_ANGLE
   COLUMN_NUMBER    = 24
   BYTES          = 8
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 531
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Derived emission angle of footprint center.
   Unit = degrees. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = PHASE_ANGLE
   COLUMN_NUMBER    = 25
   BYTES          = 8
```

```
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 539
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Derived phase angle of footprint center.
   Unit = degrees. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SLANT_RANGE_TO_CENTER
   COLUMN_NUMBER    = 26
   BYTES          = 8
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 547
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Derived slant range from s/c to footprint center (equal
   to s/c NADIR_ALTITUDE in nadir pointing case). Unit = kilometers. PER
   STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SUBSPACECRAFT_LATITUDE
   COLUMN_NUMBER    = 27
   BYTES          = 8
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 555
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Derived subspacecraft latitude on planet surface.
   Unit = degrees. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SUBSPACECRAFT_LONGITUDE
   COLUMN_NUMBER    = 28
   BYTES          = 8
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 563
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Derived subspacecraft longitude on planet surface.
   Unit = degrees. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = NADIR_ALTITUDE
   COLUMN_NUMBER    = 29
   BYTES          = 8
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 571
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Derived spacecraft altitude above nadir point.
   Unit = kilometers. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SUBSOLAR_LATITUDE
   COLUMN_NUMBER    = 30
   BYTES          = 8
   DATA_TYPE      = IEEE_REAL
```

```
   START_BYTE     = 579
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Derived subsolar latitude on planet surface.
   Unit = degrees. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SUBSOLAR_LONGITUDE
   COLUMN_NUMBER    = 31
   BYTES          = 8
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 587
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Derived subsolar longitude on planet surface.
   Unit = degrees. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SOLAR_DISTANCE
   COLUMN_NUMBER    = 32
   BYTES          = 8
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 595
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Derived subsolar distance to footprint center on planet
   surface. Unit = kilometers. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = PLANET_TRUE_ANOMALY
   COLUMN_NUMBER    = 33
   BYTES          = 8
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 603
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Derived true anomaly of planet. Unit = degrees.
   PER STEP column."
END_OBJECT    = COLUMN

/* CALIBRATED ITEMS AND ADDITIONAL METADATA */

OBJECT        = COLUMN
   NAME           = MIDSTEP_TIME
   COLUMN_NUMBER  = 34
   BYTES          = 8
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 611
   DESCRIPTION    = "A calculated value indicating the mission elapsed
   time since launch at the middle of an individual UVVS step.
   Unit = seconds. This is a double precision value. The formula used is:
   MIDSTEP_TIME = (N-1)*(INT_TIME+STEP_TIME)/3000 + SC_TIME +
                   PACKET_SUBSECONDS*5/1000 + (INT_TIME/3000)/2
   where N is the Nth step in an observation sequence, and the other values
   are contained in the UVVS Science Header CDR. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
```

```
   NAME           = STEP_UTC_TIME
   COLUMN_NUMBER  = 35
   BYTES          = 17
   DATA_TYPE      = CHARACTER
   START_BYTE     = 619
   DESCRIPTION    = "UTC time in YYDOYTHH:MM:SS.00 format derived from the
   MIDSTEP_TIME using SPICE kernels. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = GRATING_OFFSET
   COLUMN_NUMBER  = 36
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 636
   DESCRIPTION    = "From lookup table; however, currently, the grating
   offset table is not implemented correctly. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = STEP_POSITION
   COLUMN_NUMBER  = 37
   BYTES          = 4
   DATA_TYPE      = MSB_INTEGER
   START_BYTE     = 640
   DESCRIPTION    = "Actual grating position calculated by start position +
   (step number * step size) + offset. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = STEP_WAVELENGTH
   COLUMN_NUMBER  = 38
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 644
   DESCRIPTION    = "From wavelength equation. Unit = nanometers. PER STEP
   column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = RAW_STEP_DATA
   COLUMN_NUMBER  = 39
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 648
   DESCRIPTION    = "Column of uncompressed raw data. Unit = counts. PER STEP
   column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = COUNT_RATE
   COLUMN_NUMBER  = 40
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 650
   DESCRIPTION    = "Count rate of step. Unit = counts/second. PER STEP
   column."
```

```
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DEAD_CORRECTED_COUNT_RATE
   COLUMN_NUMBER  = 41
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 654
   DESCRIPTION    = "Count rate corrected for nonlinearity due to dead-time.
   Unit = counts/second. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DARK_RATE
   COLUMN_NUMBER  = 42
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 658
   DESCRIPTION    = "Dark count rate at step from model/module.
   Unit = counts/second. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SCATTERED_LIGHT_RATE
   COLUMN_NUMBER  = 43
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 662
   DESCRIPTION    = "Scattered light at step from model/module.
   Unit = counts/second. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = FULLY_CORRECTED_COUNT_RATE
   COLUMN_NUMBER  = 44
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 666
   DESCRIPTION    = "Count rate corrected for dark, scattered light, dead
   time, etc. Unit = counts/second. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = FULLY_CORRECTED_COUNT_RATE_UNCERTAINTY
   COLUMN_NUMBER  = 45
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 670
   DESCRIPTION    = "Uncertainty for count rate, equivalent to instrument
   shot noise. Unit = counts/second. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = STEP_RADIANCE_KR
   COLUMN_NUMBER  = 46
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
```

```
   START_BYTE      = 674
   DESCRIPTION     = "Calibrated radiance value at step.
   Unit = kiloRayleighs/nanometer. PER STEP column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = STEP_RADIANCE_W
   COLUMN_NUMBER   = 47
   BYTES           = 4
   DATA_TYPE       = IEEE_REAL
   START_BYTE      = 678
   DESCRIPTION     = "Calibrated radiance value at step.
   Unit = W/(m^2 steradian micron). PER STEP column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = STEP_RADIANCE_SIGNAL_TO_NOISE
   COLUMN_NUMBER   = 48
   BYTES           = 4
   DATA_TYPE       = IEEE_REAL
   START_BYTE      = 682
   DESCRIPTION     = "Signal to noise ratio for the step radiance values."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = PMT_TEMPERATURE
   COLUMN_NUMBER   = 49
   BYTES           = 4
   DATA_TYPE       = IEEE_REAL
   START_BYTE      = 686
   DESCRIPTION     = "PMT temperature in degrees C."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = DATA_QUALITY_INDEX
   COLUMN_NUMBER   = 50
   BYTES           = 21
   DATA_TYPE       = CHARACTER
   START_BYTE      = 690
   DESCRIPTION     = "21 character index of data quality. Each digit signifies
   quality factor of measurements. PER STEP column.
   Format: A-BCDEF-GHIJ-KLM-NOPQ
   A: SBOS trip
     0 = no trip
     1 = trip
     9 = Unknown. No information found from MASCS HK EDR for the time period
         START_TIME to STOP TIME.
   B: Footprint center on planet
     0 = not on planet
     1 = on planet
   C: Footprint C1 on planet
     0 = not on planet
     1 = on planet
   D: Footprint C2 on planet
     0 = not on planet
     1 = on planet
   E: Footprint C3 on planet
```

```
     0 = not on planet
     1 = on planet
   F: Footprint C4 on planet
     0 = not on planet
     1 = on planet
   G: Partial scan (macro cutoff)
     0 = No partial scan.
     1 = Partial scan.
   H: Temperature 1 flag for this UVVS detector
     0 = Temperature does not exceed 25 deg C threshold.
     1 = Temperature exceeds 25 deg C threshold but less than 45 deg C
     threshold.
     2 = Temperature exceeds 45 deg C threshold.
     9 = Unknown. No information found from MASCS HK EDR for the time period
         START_TIME to STOP TIME.
   I: UVVS noise spike flag
     0 = No noise spike detected.
     1 = Noise spike detected.
   J: VIRS operating flag
     0 = VIRS is not scanning during readout.
     1 = VIRS is scanning during readout.
     9 = Unknown. No information found from MASCS HK EDR for the time period
         START_TIME to STOP TIME.
   K: Buffer overflow flag
     0 = No buffer overflow.
     1 = Buffer overflow.
   L: Background subtraction method
     # = Method used
   M: Background quality flag (not yet implemented)
     0 = Not yet implemented.
     1 = Inside TBD threshold.
   N: SPICE Version Epoch. Indicates what SPICE is used to determine pointing
     fields in CDR. 'Predict' SPICE may change one or more times before
     settling on 'Final' pointing solutions about 2 weeks from data
     acquisition.
     0 = No SPICE
     1 = Predict
     2 = Actual
   O-Q: Spares"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SC_TIME
   COLUMN_NUMBER  = 51
   BYTES          = 4
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 711
   DESCRIPTION    = "Spacecraft time in integer seconds that is transmitted
   to the MESSENGER subsystems by the Integrated Electronics Module. This is
   assigned as the start time of the UVVS observation. A UVVS observation is
   defined as all the scan data contained within one UVVS science packet.
   This is due to the highly configurable nature of the instrument, i.e. it
   can be commanded to take multiple scans over multiple wavelengths. Unit is
   in mission elapsed time which is the number of seconds since launch. PER
   OBSERVATION column."
END_OBJECT    = COLUMN
```

```
OBJECT        = COLUMN
   NAME            = OBSERVATION_TYPE
   COLUMN_NUMBER  = 52
   BYTES           = 30
   DATA_TYPE       = CHARACTER
   START_BYTE      = 715
   DESCRIPTION     = "Describes the type of observation being executed at this
   MIDSTEP time. PER STEP column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME            = SPARE_2
   COLUMN_NUMBER  = 53
   BYTES           = 8
   DATA_TYPE       = IEEE_REAL
   START_BYTE      = 745
   DESCRIPTION     = "SPARE column."
END_OBJECT    = COLUMN
```

APPENDIX C- UVVSHDRD_SUR.FMT FILE

```
/*** ALL VALUES TAKEN DIRECTLY FROM UVVS HEADER CDR ***/

OBJECT        = COLUMN
   NAME           = SC_TIME
   COLUMN_NUMBER  = 1
   BYTES          = 4
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 1
   DESCRIPTION    = "Spacecraft time in integer seconds that is transmitted
   to the MESSENGER subsystems by the Integrated Electronics Module. This is
   assigned as the start time of the UVVS observation. A UVVS observation is
   defined as all the scan data contained within one UVVS science packet.
   This is due to the highly configurable nature of the instrument, i.e. it
   can be commanded to take multiple scans over multiple wavelengths. Unit is
   in mission elapsed time which is the number of seconds since launch. PER
   OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = PACKET_SUBSECONDS
   COLUMN_NUMBER  = 2
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 5
   DESCRIPTION    = "The subsecond time in milliseconds that the telemetry
   packet was initiated. SC_TIME plus PACKET_SUBSECONDS is the spacecraft
   time of the first integration. Values of this field are in units of 5
   milliseconds. For example, a value of 10 refers to a time of 50
   milliseconds. PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = START_POS
   COLUMN_NUMBER  = 3
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 7
   DESCRIPTION    = "Start position where grating drive begins a scan.
   Grating drive step position corresponds to a given wavelength being
   observed by an instrument. PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = STEP_COUNT
   COLUMN_NUMBER  = 4
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 9
   DESCRIPTION    = "Number of steps the grating drive will take in a scan.
   This directly corresponds to the range of wavelengths that will be
   observed in one UVVS observation. PER OBSERVATION column."
END_OBJECT    = COLUMN
```

```
OBJECT        = COLUMN
   NAME           = INT_TIME
   COLUMN_NUMBER  = 5
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 11
   DESCRIPTION    = "Integration time in grating drive loop control
   interrupt periods (nominally 3000 Hz). For example, the actual
   integration time in seconds is INT_TIME/3000. PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = STEP_TIME
   COLUMN_NUMBER  = 6
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 13
   DESCRIPTION    = "Step time in grating drive loop control interrupt
   periods (nominally 3000 Hz). For example, the actual step time in
   seconds is STEP_TIME/3000. PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = PHASE_OFFSET
   COLUMN_NUMBER  = 7
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 15
   DESCRIPTION    = "Phase offset in grating drive loop control interrupt
   periods. Phase offset between the beginning of grating drive step and
   the start of a PMT integration in units of 0.3 milliseconds. Default
   value is 0 (no phase offset).  By setting the phase offset to a
   non-zero value (reserved for contingency operations), the user will
   tell the software to initiate a step before the end of an integration,
   accounting for latencies in the motor controller. PER OBSERVATION
   column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SCAN_CYCLES
   COLUMN_NUMBER  = 8
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 17
   DESCRIPTION    = "Number of times to repeat scan. PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = ZIGZAG
   COLUMN_NUMBER  = 9
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 19
   DESCRIPTION    = "Indicates whether grating drive moves in a 'triangle'
   (stepping up, then stepping down), or 'sawtooth' (stepping up, then
   'flying' down) motion. A 'triangle' observation takes one grating scan
```

```
   stepping up the grating, then reverses direction and takes the next
   grating scan stepping back down the grating. A 'sawtooth' observation
   takes one grating scan stepping up the grating, then 'flies' the grating
   back to the START_POSITION to take the next observation. =0 disable,
   =1 enable. PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = COMPRESSION
   COLUMN_NUMBER  = 10
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 21
   DESCRIPTION    = "Selectable data size, =0 16 bit data, =1 9 bit data.
   Used to help determine the total number of data points contained
   in the observation. PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SLIT_MASK_POS
   COLUMN_NUMBER  = 11
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 23
   DESCRIPTION    = "Indicates whether slit mask is in atmospheric (open)
   or surface (closed) position. Atmospheric slit results in a 1 deg. by
   0.04 deg. instantaneous field of view (iFOV). Surface slit results in a
   0.05 deg. by 0.04 deg. iFOV. =0 closed, =1 open. PER OBSERVATION column."
END_OBJECT    = COLUMN


OBJECT        = COLUMN
   NAME           = GD_SETTLE_CTR
   COLUMN_NUMBER  = 12
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 25
   DESCRIPTION    = "Number of times during integration that the grating
   drive wandered outside target range. This can happen very rarely with an
   encoder misread, or motor misstep, and would result in an offset of
   step-number to wavelength correlations for subsequent observations in a
   given scan. PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = NUM_SCAN_VALUES
   COLUMN_NUMBER  = 13
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 27
   DESCRIPTION    = "Total number of values or data points in the entire scan
   observation. Used to determine the number of valid data points in the
   SCAN_DATA column. Maximum value is 3626. PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = STEP_SIZE
```

```
   COLUMN_NUMBER  = 14
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 29
   DESCRIPTION    = "Step size in arcmin units. PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = COADD
   COLUMN_NUMBER  = 15
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 31
   DESCRIPTION    = "Number of steps coadded to make a single observation.
   Default = 1, i.e. one step per observation. PER OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CALIBRATION_SOFTWARE_VERSION
   COLUMN_NUMBER  = 16
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 33
   DESCRIPTION    = "Indicates version of calibration software used to
   generate UVVS Surface Reflectance Science DDR. Increments with
   reprocessing of DDRs. PER OBSERVATION column."
END_OBJECT    = COLUMN
```

APPENDIX D- UVVSSCID_SUR.FMT FILE

```
OBJECT        = COLUMN
   NAME             = BIN_NUMBER
   COLUMN_NUMBER    = 1
   BYTES            = 2
   DATA_TYPE        = MSB_UNSIGNED_INTEGER
   START_BYTE       = 1
   DESCRIPTION    = "BIN of steps in the observation."
END_OBJECT    = COLUMN

/* SPICE DERIVED GEOMETRY VALUES */

OBJECT        = COLUMN
   NAME             = TARGET_LATITUDE_SET
   COLUMN_NUMBER    = 2
   BYTES            = 40
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 3
   ITEMS            = 5
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "This indicates the BIN-average latitudes at the
   locations where the field-of-view center and corners intersect the planet
   surface. Format: (center, corner 1, corner 2, corner 3, corner 4).
   Unit = degrees."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = TARGET_LONGITUDE_SET
   COLUMN_NUMBER    = 3
   BYTES            = 40
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 43
   ITEMS            = 5
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "This indicates the BIN-average longitudes at the
   locations where the field-of-view center and corners intersect the planet
   surface. Format: (center, corner 1, corner 2, corner 3, corner 4).
   Unit = degrees."
END_OBJECT    = COLUMN


OBJECT        = COLUMN
   NAME             = SLIT_ROTATION_ANGLE
   COLUMN_NUMBER    = 4
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 83
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "BIN average angle of long dimension of the slit with the
   surface tangent line. Unit = degrees."
END_OBJECT    = COLUMN
```

```
OBJECT        = COLUMN
   NAME             = ALONG_TRACK_FOOTPRINT_SIZE
   COLUMN_NUMBER    = 5
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 91
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Derived BIN average length of UVVS footprints along
   track, accounting for smear across surface. Unit = meters."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = ACROSS_TRACK_FOOTPRINT_SIZE
   COLUMN_NUMBER    = 6
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 99
   MISSING_CONSTANT = -1.E32
   DESCRIPTION    = "Derived BIN width of UVVS footprints across track,
   accounting for jitter across surface. Unit = meters."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = INCIDENCE_ANGLE
   COLUMN_NUMBER    = 7
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 107
   MISSING_CONSTANT = -1.E32
   DESCRIPTION      = "Derived BIN average solar incidence angle of footprint
   center. Unit = degrees."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = EMISSION_ANGLE
   COLUMN_NUMBER    = 8
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 115
   MISSING_CONSTANT = -1.E32
   DESCRIPTION      = "Derived BIN average emission angle of footprint
   center. Unit = degrees."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = PHASE_ANGLE
   COLUMN_NUMBER    = 9
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 123
   MISSING_CONSTANT = -1.E32
   DESCRIPTION      = "Derived BIN average phase angle of footprint center.
   Unit = degrees."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
```

```
   NAME             = SOLAR_DISTANCE
   COLUMN_NUMBER    = 10
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 131
   MISSING_CONSTANT = -1.E32
   DESCRIPTION      = "Derived BIN average subsolar distance to footprint
   center on planet surface. Unit = kilometers."
END_OBJECT     = COLUMN


/* CALIBRATED ITEMS AND ADDITIONAL METADATA */

OBJECT         = COLUMN
   NAME            = MIDBIN_TIME
   COLUMN_NUMBER   = 11
   BYTES           = 8
   DATA_TYPE       = IEEE_REAL
   START_BYTE      = 139
   DESCRIPTION     = "A calculated value indicating the average mission
   elapsed time since launch of the BIN of steps.
   Unit = seconds. This is a double precision value. The formula used is:
   MIDBIN_TIME = average(MIDSTEP_TIME for each step).
   MIDSTEP_TIME values are taken from the source UVVS Science CDR steps
   that were incorporated into the BIN."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = BIN_UTC_TIME
   COLUMN_NUMBER   = 12
   BYTES           = 17
   DATA_TYPE       = CHARACTER
   START_BYTE      = 147
   DESCRIPTION     = "UTC time in YYDOYTHH:MM:SS.00 format in the middle of
   the BIN of steps."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = BIN_WAVELENGTH
   COLUMN_NUMBER   = 13
   BYTES           = 4
   DATA_TYPE       = IEEE_REAL
   START_BYTE      = 164
   DESCRIPTION     = "Center wavelength of BIN, Derived from average step
   wavelengths from wavelength equation. Unit = nanometers."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = IOF_BIN_DATA
   COLUMN_NUMBER   = 14
   BYTES           = 4
   DATA_TYPE       = IEEE_REAL
   START_BYTE      = 168
   DESCRIPTION     = "Derived column of BIN reflectance at sensor."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
```

```
   NAME           = PHOTOM_IOF_BIN_DATA
   COLUMN_NUMBER  = 15
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 172
   DESCRIPTION    = "Derived column of BIN photometrically corrected
   reflectance at sensor."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = IOF_BIN_NOISE_DATA
   COLUMN_NUMBER  = 16
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 176
   DESCRIPTION    = "Derived column of BIN reflectance noise/error propagated
   through post-calibration procedure.
   PER BIN column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = PHOTOM_IOF_BIN_NOISE_DATA
   COLUMN_NUMBER  = 17
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 180
   DESCRIPTION    = "Derived column of BIN photometrically corrected
   reflectance noise/error propagated through post-calibration procedure."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = FULLY_CORRECTED_COUNT_RATE
   COLUMN_NUMBER  = 18
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 184
   DESCRIPTION    = "Count rate of BIN. Unit = counts/second."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = STEP_RADIANCE_W
   COLUMN_NUMBER  = 19
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 188
   DESCRIPTION    = "BIN average calibrated radiance value
   Unit = W/(m^2 steradian micron)."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = PMT_TEMPERATURE
   COLUMN_NUMBER  = 20
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 192
   DESCRIPTION    = "BIN average PMT temperature in degrees C."
END_OBJECT    = COLUMN
```

```
OBJECT        = COLUMN
   NAME           = DATA_QUALITY_INDEX
   COLUMN_NUMBER  = 21
   BYTES          = 21
   DATA_TYPE      = CHARACTER
   START_BYTE     = 196
   DESCRIPTION    = "21 character index of data quality taken from the middle
   of the BIN of steps. Each digit signifies quality factor of measurements.
   Format: A-BCDEF-GHIJ-KLM-NOPQ
   A: SBOS trip
     0 = no trip
     1 = trip
     9 = Unknown. No information found from MASCS HK EDR for the time period
         START_TIME to STOP TIME.
   B: Footprint center on planet
     0 = not on planet
     1 = on planet
   C: Footprint C1 on planet
     0 = not on planet
     1 = on planet
   D: Footprint C2 on planet
     0 = not on planet
     1 = on planet
   E: Footprint C3 on planet
     0 = not on planet
     1 = on planet
   F: Footprint C4 on planet
     0 = not on planet
     1 = on planet
   G: Partial scan (macro cutoff)
     0 = No partial scan.
     1 = Partial scan.
   H: Temperature 1 flag for this UVVS detector
     0 = Temperature does not exceed 25 deg C threshold.
     1 = Temperature exceeds 25 deg C threshold but less than 45 deg C
     threshold.
     2 = Temperature exceeds 45 deg C threshold.
     9 = Unknown. No information found from MASCS HK EDR for the time period
         START_TIME to STOP TIME.
   I: UVVS noise spike flag
     0 = No noise spike detected.
     1 = Noise spike detected.
   J: VIRS operating flag
     0 = VIRS is not scanning during readout.
     1 = VIRS is scanning during readout.
     9 = Unknown. No information found from MASCS HK EDR for the time period
         START_TIME to STOP TIME.
   K: Buffer overflow flag
     0 = No buffer overflow.
     1 = Buffer overflow.
   L: Background subtraction method
     # = Method used
   M: Background quality flag (not yet implemented)
     0 = Not yet implemented.
     1 = Inside TBD threshold.
   N: SPICE Version Epoch. Indicates what SPICE is used to determine pointing
```

```
     fields in CDR. 'Predict' SPICE may change one or more times before
     settling on 'Final' pointing solutions about 2 weeks from data
     acquisition.
     0 = No SPICE
     1 = Predict
     2 = Actual
   O: Footprint center stability. Fraction of FOV smear during the BIN
     observation. 0-9 = 0.0 to 0.9 FOVs movement while obtaining the steps
     that comprise the BIN. A= 1.0 FOVs, B=1.1, C=1.2, etc. each letter
     representing 0.1 FOV increments. Z=2.6 or greater FOV's smear.
   P-Q: Spares"
END_OBJECT    = COLUMN


OBJECT        = COLUMN
   NAME           = OBSERVATION_TYPE
   COLUMN_NUMBER  = 22
   BYTES          = 30
   DATA_TYPE      = CHARACTER
   START_BYTE     = 217
   DESCRIPTION    = "Describes the type of observation being executed in the
   middle of the BIN of steps."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPARE
   COLUMN_NUMBER  = 23
   BYTES          = 8
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 247
   DESCRIPTION    = "SPARE column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPARE_2
   COLUMN_NUMBER  = 24
   BYTES          = 8
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 255
   DESCRIPTION    = "SPARE column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPARE_3
   COLUMN_NUMBER  = 25
   BYTES          = 8
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 263
   DESCRIPTION    = "SPARE column."
END_OBJECT    = COLUMN
```

APPENDIX E- UVVSSCID.FMT FILE

```
NOTE = "All 'PER SPECTRAL SCAN' geometry and time columns are defined at the
midpoint (middle wavelength) of the observed spectral scan."

OBJECT        = COLUMN
   NAME             = OBSERVATION_TYPE
   COLUMN_NUMBER    = 1
   BYTES            = 30
   DATA_TYPE        = CHARACTER
   START_BYTE       = 1
   DESCRIPTION      = "Name of the observation type. PER SPECTRAL SCAN."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = CDR_NAME
   COLUMN_NUMBER    = 2
   BYTES            = 27
   DATA_TYPE        = CHARACTER
   START_BYTE       = 31
   DESCRIPTION      = "Name of the CDR from which the data were extracted.
   PER SPECTRAL SCAN."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = OBS_SEQUENCE_INDEX
   COLUMN_NUMBER    = 3
   BYTES            = 2
   DATA_TYPE        = MSB_UNSIGNED_INTEGER
   START_BYTE       = 58
   DESCRIPTION      = "Counting index for a given observational sequence.
   Sequences are arranged consecutively in time, so this index allows the
   points within a given sequence to be identified. Resets to 1 with each
   new sequence. PER SPECTRAL SCAN."
END_OBJECT    = COLUMN

/* SPICE DERIVED GEOMETRY VALUES */

OBJECT        = COLUMN
   NAME             = PLANET_SUN_VECTOR_TG
   COLUMN_NUMBER    = 4
   BYTES            = 24
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 60
   ITEMS            = 3
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   DESCRIPTION      = "Derived (x,y,z) vector giving center-to-center
   planet-sun position in target body-fixed coordinate system at midpoint of
   scan. Unit = kilometers. PER SPECTRAL SCAN."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = PLANET_SC_VECTOR_TG
```

```
   COLUMN_NUMBER    = 5
   BYTES            = 24
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 84
   ITEMS            = 3
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   DESCRIPTION      = "Derived (x,y,z) vector giving center-to-center
   planet-spacecraft position in target body-fixed coordinate system at
   midpoint of scan. Unit = kilometers. PER SPECTRAL SCAN."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = BORESIGHT_UNIT_VECTOR_CENTER_TG
   COLUMN_NUMBER    = 6
   BYTES            = 24
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 108
   ITEMS            = 3
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   DESCRIPTION      = "Derived (x,y,z) vector giving look direction of MASCS
   UVVS center in target body-fixed coordinate system at midpoint of
   spectral scan. Unit = N/A. PER SPECTRAL SCAN."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = TARGET_LATITUDE
   COLUMN_NUMBER    = 7
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 132
   MISSING_CONSTANT = -1.E32
   DESCRIPTION      = "Latitude below the tangent point of the UVVS
   field-of-view center. Measured at midpoint of spectral scan.
   Unit = degrees. PER SPECTRAL SCAN."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = TARGET_LONGITUDE
   COLUMN_NUMBER    = 8
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 140
   MISSING_CONSTANT = -1.E32
   DESCRIPTION      = "Longitude below the tangent point of the UVVS
   field-of-view center. Measured at midpoint of spectral scan.
   Unit = degrees. PER SPECTRAL SCAN."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = TARGET_ALTITUDE
   COLUMN_NUMBER    = 9
   BYTES            = 24
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 148
   ITEMS            = 3
```

```
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   DESCRIPTION      = "Altitude (center, min, max) of the actual field-of-
   view slit projection. Measured at midpoint of spectral scan.
   Unit = kilometers. PER SPECTRAL SCAN."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = TARGET_LOCAL_TIME
   COLUMN_NUMBER    = 10
   BYTES            = 4
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 172
   DESCRIPTION      = "Local time of the tangent point of the UVVS
   field-of-view center. Local time is defined as 0 at midnight, 6 at dawn,
   and 12 at noon. Measured at midpoint of spectral scan. Unit= hour plus
   fraction of hour. (e.g. 1.5 = 90 minutes). PER SPECTRAL SCAN."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SUBSPACECRAFT_LATITUDE
   COLUMN_NUMBER    = 11
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 176
   MISSING_CONSTANT = -1.E32
   DESCRIPTION      = "Derived subspacecraft latitude on planet surface.
   Measured at the midpoint of spectral scan. Unit = degrees. PER SPECTRAL
   SCAN."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SUBSPACECRAFT_LONGITUDE
   COLUMN_NUMBER    = 12
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 184
   MISSING_CONSTANT = -1.E32
   DESCRIPTION      = "Derived subspacecraft longitude on planet surface.
   Measured at the midpoint of spectral scan. Unit = degrees. PER SPECTRAL
   SCAN."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SPACECRAFT_ALTITUDE
   COLUMN_NUMBER    = 13
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 192
   MISSING_CONSTANT = -1.E32
   DESCRIPTION      = "Derived spacecraft altitude above nadir point.
   Unit = kilometers. PER SPECTRAL SCAN."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SPACECRAFT_LOCAL_TIME
   COLUMN_NUMBER    = 14
```

```
   BYTES            = 4
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 200
   DESCRIPTION      = "Local time of the subspacecraft point. Local time is
   defined as 0 at midnight, 6 at dawn, and 12 at noon. Measured at midpoint
   of spectral scan. Unit= hour plus fraction of hour.
   (e.g. 1.5 = 90 minutes). PER SPECTRAL SCAN."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SUBSOLAR_LATITUDE
   COLUMN_NUMBER    = 15
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 204
   MISSING_CONSTANT = -1.E32
   DESCRIPTION      = "Derived subsolar latitude on planet surface.
   Measured at midpoint of spectral scan. Unit = degrees. PER SPECTRAL
   SCAN."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SUBSOLAR_LONGITUDE
   COLUMN_NUMBER    = 16
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 212
   MISSING_CONSTANT = -1.E32
   DESCRIPTION      = "Derived subsolar longitude on planet surface.
   Measured at midpoint of spectral scan. Unit = degrees. PER SPECTRAL
   SCAN."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = PLANET_TRUE_ANOMALY
   COLUMN_NUMBER    = 17
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 220
   MISSING_CONSTANT = -1.E32
   DESCRIPTION      = "Derived true anomaly of planet. Measured at midpoint
   of spectral scan. Unit = degrees. PER SPECTRAL SCAN."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = ORBIT_NUMBER
   COLUMN_NUMBER    = 18
   BYTES            = 4
   DATA_TYPE        = MSB_UNSIGNED_INTEGER
   START_BYTE       = 228
   DESCRIPTION      = "Mercury orbit number. PER SPECTRAL SCAN."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = MET_PARTITION
   COLUMN_NUMBER    = 19
   BYTES            = 4
```

```
   DATA_TYPE         = MSB_UNSIGNED_INTEGER
   START_BYTE        = 232
   DESCRIPTION       = "Spacecraft clock partition number used in conjunction
     with MET value to perform time conversion using SPICE kernels.
     Introduced due to the MET rollover on 2013-01-08 which reset the MET
     value to 1000."
END_OBJECT     = COLUMN

/* CALIBRATED ITEMS AND ADDITIONAL METADATA */

OBJECT         = COLUMN
   NAME              = MID_SPECTRUM_TIME
   COLUMN_NUMBER     = 20
   BYTES             = 8
   DATA_TYPE         = IEEE_REAL
   START_BYTE        = 236
   DESCRIPTION       = "A calculated value indicating the mission elapsed
   time since launch at the middle of an individual UVVS spectral scan.
   Unit = seconds. PER SPECTRAL SCAN."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME              = UTC_TIME
   COLUMN_NUMBER     = 21
   BYTES             = 17
   DATA_TYPE         = CHARACTER
   START_BYTE        = 244
   DESCRIPTION       = "UTC time in YYDOYTHH:MM:SS.00 format derived from the
   MID_SPECTRUM_TIME using SPICE kernels. PER SPECTRAL SCAN."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME              = WAVELENGTH
   COLUMN_NUMBER     = 22
   BYTES             = 200
   DATA_TYPE         = IEEE_REAL
   START_BYTE        = 261
   ITEMS             = 25
   ITEM_BYTES        = 8
   DESCRIPTION       = "Wavelength vector of the spectral scan, which can be
   up to 25 elements. Shorter scans are padded with zeros. PER SPECTRAL
   SCAN."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME              = RADIANCE_KR
   COLUMN_NUMBER     = 23
   BYTES             = 200
   DATA_TYPE         = IEEE_REAL
   START_BYTE        = 461
   ITEMS             = 25
   ITEM_BYTES        = 8
   DESCRIPTION       = "Vector of calibrated radiances matched with scan
   WAVELENGTH; up to 25 elements. Shorter scans are padded with zeros.
   Unit = kiloRayleighs/nanometer. PER SPECTRAL SCAN."
END_OBJECT     = COLUMN
```

```
OBJECT        = COLUMN
   NAME             = RADIANCE_SNR
   COLUMN_NUMBER    = 24
   BYTES            = 200
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 661
   ITEMS            = 25
   ITEM_BYTES       = 8
   DESCRIPTION      = "Vector of calibrated radiance SNR matched with scan
   WAVELENGTH; up to 25 elements. Shorter scans are padded with zeros.
   Derived signal-to-noise in fully calibrated radiance, propagated from
   fully corrected count rate uncertainty and sensitivity uncertainty.
   Unitless fraction, applied to radiance. PER SPECTRAL SCAN."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = TOTAL_RADIANCE_KR
   COLUMN_NUMBER    = 25
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 861
   DESCRIPTION      = "Total radiance integrated over the specified emission
   line(s) in the given calibrated spectrum. Unit = kiloRayleighs. PER
   SPECTRAL SCAN."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = TOTAL_RADIANCE_SNR
   COLUMN_NUMBER    = 26
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 869
   DESCRIPTION      = "Derived SNR in the total radiance, propagated from
   radiance SNR. Unitless fraction, applied to total radiance. PER SPECTRAL
   SCAN."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SLIT_POS
   COLUMN_NUMBER    = 27
   BYTES            = 2
   DATA_TYPE        = MSB_UNSIGNED_INTEGER
   START_BYTE       = 877
   DESCRIPTION      = "Indicates whether slit mask is in atmospheric or
   surface position. Atmospheric slit results in a 1 deg. by 0.04 deg.
   instantaneous field of view (iFOV). Surface slit results in a 0.05 deg.
   by 0.04 deg. iFOV. Surface=0, Atmosphere=1.  Unitless, PER SPECTRAL
   SCAN."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SPARE_1
   COLUMN_NUMBER    = 28
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 879
   DESCRIPTION      = "SPARE column."
```

```
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SPARE_2
   COLUMN_NUMBER    = 29
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 887
   DESCRIPTION      = "SPARE column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SPARE_3
   COLUMN_NUMBER    = 30
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 895
   DESCRIPTION      = "SPARE column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SPARE_4
   COLUMN_NUMBER    = 31
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 903
   DESCRIPTION      = "SPARE column."
END_OBJECT    = COLUMN
```

APPENDIX F- SPICE Kernel Files Used In Messenger Data Products

The following SPICE kernel files are used to compute the UTC time and any geometric quantities found in the PDS labels. Kernel files are generated throughout the mission with a file naming convention specified by the MESSENGER project. The files are archived at and accessible from the PDS NAIF Node.

***.bsp**:
MESSENGER spacecraft ephemeris file. Also known as the Planetary Spacecraft Ephemeris Kernel (SPK) file.

*.**bc:**
Messenger spacecraft orientation file. Also known as the Attitude C-Kernel (CK) file.

***.tsc:**
Messenger spacecraft clock coefficients file. Also known as the Spacecraft Clock Kernel (SCLK) file.

***.tpc:**
Planetary constants file. Also known as the Planetary Constants Kernel (PcK) file.

***.tls:**
Leapseconds kernel file. Used in conjunction with the SCLK kernel to convert between Universal Time Coordinated (UTC) and MESSENGER MET (Mission Elapsed Time). Also called the Leap Seconds Kernel (LSK) file.

APPENDIX G- CODMAC/NASA Definition of Processing Levels for Science Data Sets

CODMAC Level	Proc. Type	Data Processing Level Description
1	Raw Data	Telemetry data with data embedded.
2	Edited Data	Corrected for telemetry errors and split or decommutated into a data set for a given instrument. Sometimes called Experiment Data Record (EDR). Data are also tagged with time and location of acquisition. Corresponds to NASA Level 0 data.
3	Calibrated Data	Edited data that are still in units produced by instrument, but have been corrected so that values are expressed in or are proportional to some physical unit such as radiance. No resampling, so edited data can be reconstructed. Corresponds to NASA Level 1A.
4	Resampled data	Data that have been resampled in the time or space domains in a such way that the original edited data cannot be reconstructed. Could be calibrated in addition to being resampled. Corresponds to NASA Level 1B.
5	Derived Data	Derived results, as maps, reports, graphics, etc. Corresponds to NASA Levels 2 through 5
6	Ancillary Data	Non-Science data needed to generate calibrated or resampled data sets. Consists of instrument gains, offsets; pointing information for scan platforms, etc.
7	Corrective Data	Other science data needed to interpret space-borne data sets. May include ground based data observations such as soil type or ocean buoy measurements of wind drift.
8	User Description	Description of why the data were required, any peculiarities associated with the data sets., and enough documentation to allow secondary user to extract information from the data.
n	n	Not Applicable

The above is based on the national research council committee on data management and computation (CODMAC) data levels.

APPENDIX H- ACRONYMS

ACT	Applied Coherent Technology Corporation
APL	The John Hopkins University Applied Physics Laboratory
ASCII	American Standard Code for Information Interchange
CCSDS	Consultative Committee for Space Data Systems
CDR	Calibrated Data Record
CK	MESSENGER spacecraft orientation file (SPICE)
CoDMAC	Committee on Data Management and Computation
Co-I	Co-Investigator
DDR	Derived Data Record
DEB	Digital Electronics Board
DN	Data Number, the raw telemetry count
DPU	Data Processing Unit
DSN	Deep Space Network
EDR	Experiment Data Records
EPPS	Energetic Particle and Plasma Spectrometer
ET	Ephemeris Time
FIPS	Fast Imaging Plasma Spectrometer
FOV	Field-of-View
FUV	Far Ultraviolet PMT channel of the UVVS
FPGA	Field Programmable Gate Array
FTP	File Transfer protocol
GC	Geochemistry Group
GDLCI	Grating Drive Loop Control Interrupt. Refers to timing unit in MASCS UVVS
GP	Geophysics Group
GRNS	Gamma-ray and Neutron Spectrometer
GRS	Gamma-ray Spectrometer
GSFC	Goddard Space Flight Center
HK	Housekeeping data
HVPS	High Voltage Power Supply
I&T	Integration and Test
I2C	Inter-Integrated Circuit
IEEE	Institute of Electrical and Electronics Engineers
IEM	Integrated Electronic Module
IR	Infrared channel of the MASCS instrument
J2000	The celestial reference frame defined using Julian epoch 2000
LVPS	Low Voltage Power Supply
LSK	Leapseconds Kernel (SPICE)
MAG	Magnetometer
MASCS	Mercury Atmospheric and Surface Composition Spectrometer
MDIS	Mercury Dual Imaging System
MESSENGER	Messenger, Surface, Space Environment, Geochemistry, and Ranging
MET	Mission Elapsed Time
MLA	Mercury Laser Altimeter
MOC	Mission Operations Center
MSB	Most Significant Bit
MUV	Mid Ultraviolet PMT channel of the UVVS
NAIF	Navigation and Ancillary Information Facility
NIR	Near Infra-red detector for the VIRS instrument
NS	Neutron Spectrometer
PCK	Planetary Constant Kernel (SPICE)
PDS	Planetary Data System
PMT	Photomultiplier Tube. Refers to the UVVS detectors.
RDR	Reduced Data Record
SBOS	Software Bright Object Sensor. Refers to detector saving mechanism on MASCS UVVS
SCLK	Spacecraft Clock Kernel (SPICE)
SIS	Software Interface Specification
SOC	Science Operations Center
SPICE	Spacecraft, Planet, Instrument, C-matrix Events, refers to the kernel files and functions used to

	generate viewing geometry
SPK	Spacecraft and Planets Kernel (SPICE)
UTC	Coordinated Universal Time
UVVS	Ultraviolet and Visible Spectrometer
VIS	Visible channel (applies to both VIS PMT and VIS Array detector in MASCS)
VIRS	Visible and Infrared Spectrograph
XRS	X-Ray Spectrometer

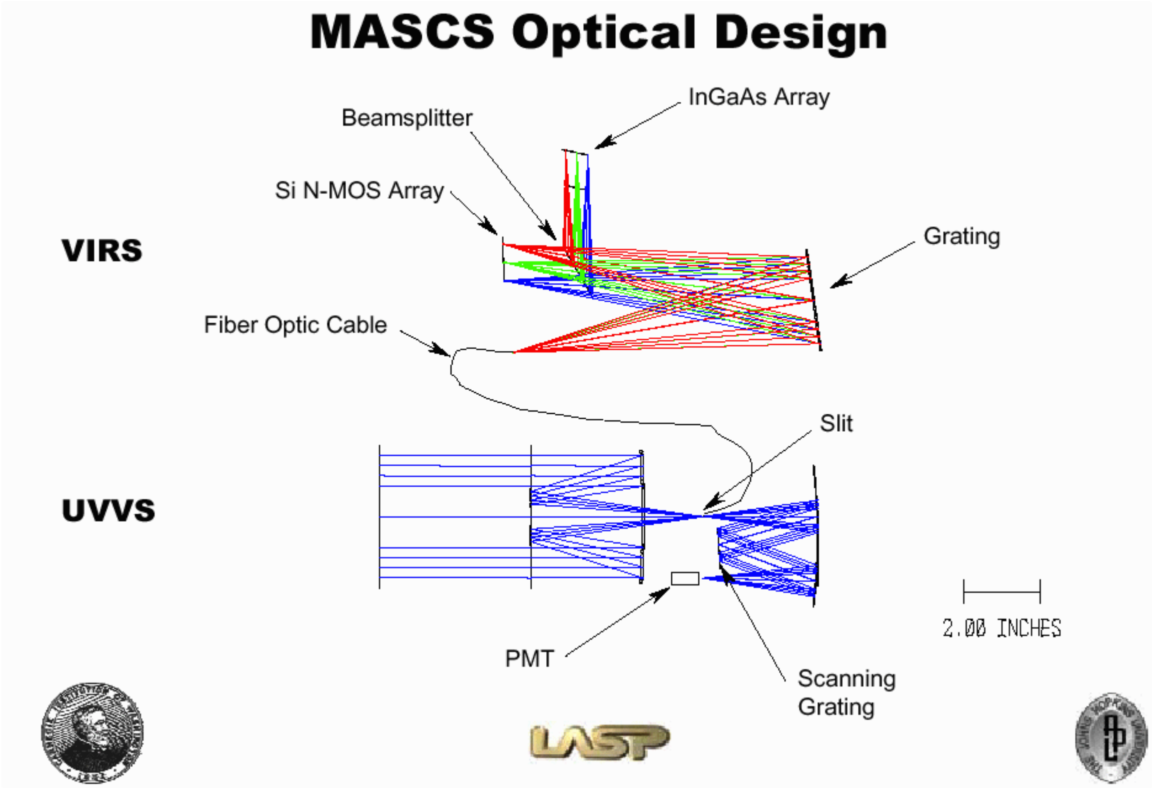
APPENDIX I- MASCS Instrument Overview

Ultraviolet and Visible Spectrometer

Focal length	125 mm	
Grating	1800 g/mm blazed at 300 nm	
Spectra resolution	0.5 nm FUV channel	
	1.0 nm MUV, VIS channels	
Wavelength range:		
	FUV channel	115-190 nm (2nd order)
	MUV channel	160-320 nm (1st order)
	VIS channel	250-600nm (1st order)
Detector:		
	FUV channel	Hamamatsu R 1081 PMT - CsI
	MUV channel	Hamamatsu R 759 PMT - CsTe
	VIS channel	Hamamatsu R 647 PMT - Bi Alkali
Field of view:		
	FUV, MUV, VIS	1.0° x 0.04° Atmosphere
	FUV, MUV, VIS	0.05° x 0.04° Surface

Visible and Infrared Spectrograph

Focal length	210 mm	
Grating	120 g/mm blazed at 600 nm	
Spectral resolution	4 nm	
Wavelength range:		
	VIS channel	300-1050 nm
	IR channel	850-1450 nm
Detector:		
	VIS channel	Hamamatsu S3902-512 Si Diode Array
	IR channel	Hamamatsu G8052-256 InGaAs Diode Array
Field of view:		
	0.023° diameter	


MASCS Optical Design
InGaAs Array
Beamsplitter
Si N-MOS Array
VIRS
Grating
Fiber Optic Cable
Slit
UVVS
2.00 INCHES
PMT
Scanning
Grating

Mercury Atmospheric and Surface Composition Spectrometer