MESSENGER MASCS VIRS Calibrated Data Record, Derived Data Record, and Derived Analysis Product Software Interface Specification

Version 5.4
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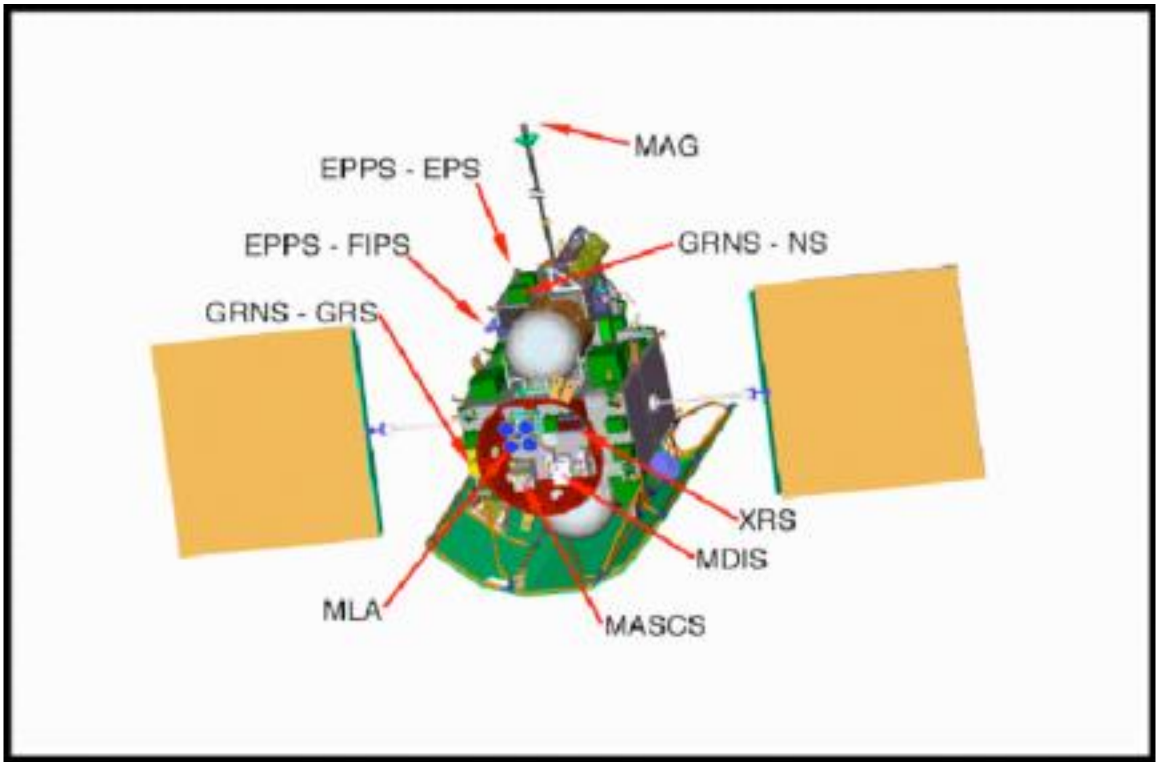


Prepared by:

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, Table 3, Section 6.3, Appendix A, B	1. Replaced sample PDS labels with new versions containing PRODUCT_VERSION_ID. 2. Added PRODUCT_VERSION_ID to VICINDEX.TAB column list. 3. Updated VIRSNC.FMT and VIRSVC.FMT columns to match files delivered in PDS Release 5.
1.7	9/15/10	J. Ward, GEO	6.1.3, 6.1.4	1. Added EXTRAS directory tables. 2. Updated DATA directory structure.
1.8	5/5/11	J. Ward, GEO	6.1.3, 6.1.4	Updated to reflect new data directory structure.
1.9	6/10/11	J. Ward, GEO	Table 2, Figure 4, 6.1.4, 6.3.3, Appendix A, B	1. Added “temperature-corrected” to Table 2. 2. Fixed labeling in Figure 4. 3. Updated EXTRAS directory contents. 4. Revised column 34 & 35 format file descriptions.
2.0	6/14/11	S. Ensor, SOC	Document Review	Replaced signature page with Document Review information.
2.1	6/17/11	J. Ward, GEO	6.1.4	Renamed SUPERTABLE.XLS TO MASTER_CRUISE_TABLE.XLS.
2.2	1/24/12	N. Izenberg, MASCS; J. Ward, GEO	2, 6.3.2, 6.1.4, Appendix A, B	1. Added refs to calibration updates: Dark current calibration improvement; Noise spectrum definition revision. 2. Added new documents to DOCUMENT and EXTRAS directory contents. 3. Revised descriptions for columns 23 & 24 in VIRSNC.FMT & VIRSVC.FMT.
2.3	4/6/12	N. Izenberg, MASCS; J. Ward, GEO	All	1. Deleted J2000 geometry fields from CDR records. 2. Added SITE_ID keyword to CDR labels. 3. Added new DDR data product.
2.4	4/10/12	J. Ward, GEO	5.3.4.1-5.3.4.4, Appendix B	1. Revised SITE_ID in sample CDR labels. 2. Fixed START_BYTE error in Appendix B.
2.5	4/13/12	J. Ward, GEO	Section 7	Removed Section 7 Archive Release schedule.
2.6	4/30/12	J. Ward, GEO	Fig. 4, Tables 3a-3b, Section 6.1.4	Revised directory structure.
2.7	5/4/12	J. Ward, GEO	Section 6.3.2, Appendix C, D	Revised DDR format files.
2.8	5/14/12	J. Ward, GEO	Appendix B	Fixed typo in VIRSVC.FMT, column 44.
2.9	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.
3.0	5/18/12	J. Ward,	6.1.4, Figure 4,	1. Edited catalog directory contents.

		GEO	Tables 3a-3b	2. Minor edits to directory structure. 3. Removed length column from index table contents table.
3.1	5/22/12	J. Ward, GEO	5.3.4.4, Table 3b, Appendix C, D	1. Fixed typos in DDR format files and sample labels. 2. Removed "ANY_LAMP_ON" column from DDR index table.
3.2	7/17/12	J. Ward, GEO	6.1.4	Updated EXTRAS directory contents.
3.3	12/13/12	N. Izenberg, MASCS; J. Ward, GEO	6.1.4, 6.3.1.2, Appendices A-D	Calibration update (added to list in section2), DQI revision (updated format files). Updated DOCUMENT and EXTRAS directory contents.
3.4	4/22/13	P. Bedini, SOC; J. Ward, GEO	All	Editorial changes.
3.5	4/25/13	J. Ward, GEO	All	Added new Derived Analysis Product (DAP).
3.6	6/5/13	N. Izenberg	5.23, 5.3.4.5	Sections on DAP details.
3.7	6/13/13	J. Ward, GEO	All	Additional edits.
3.8	6/17/13	N. Izenberg	5.2.3	Additional edits. Version submitted for PDS peer review.
3.9	12/4/13	J. Ward, GEO	2, 6.1.4	Added Applicable Document. Updated DOCUMENT and EXTRAS directory contents.
4.0	12/6/13	J. Ward, GEO	6.1.4	Minor edit.
4.1	1/10/14	J. Ward, GEO, N. Izenberg	5.2.1, 5.2.2, 6.1.2, 6.1.4	Minor edits.
4.2	1/16/14	J. Ward, GEO	6.1.4	Minor typo.
4.3	2/18/14	J. Ward, GEO	6.1.4	Added Ca Chamberlain model document.
4.4	7/8/14	N. Izenberg	5.4.2, 6.3.1 5.5 Various	MET/UT fixes, standardization between products. Invalid number adjustments. Minor edits.
4.5	7/10/14	J. Ward, GEO	Appendices A-D	Added INVALID_CONSTANT keyword to VIRS format files.
4.6	1/14/16	S. Ensor, SOC	All	Final mission edits.
4.7	1/21/16	J. Ward, GEO	All	Additional minor edits.
4.8	1/27/16	J. Ward, GEO	6.1.4	Additional minor edits.
4.9	2/22/16	J. Ward, GEO	5.1, 6.1.4, Appendices A-D	Additional minor edits.
5.0	8/22/16	J. Ward, GEO	5.2.2, 5.3.4, 6.1.2-6.1.4, 6.3	Added applicable information for new data products, UVVS+VIRS Combined DDR and UVVS Atmosphere Summary DDR, UVVS FUV Surface DDR.

5.1	1/23/17	J. Ward, GEO	Appendix I	Added Appendix I.
5.2	3/30/17	N. Izenberg, D. Domingue, R. Klima, J, Ward, GEO	5.2.1.1, 5.2.2, 5.2.3, 6.3.2.2	1. Added photometric normalization description for V1 and V2. 2. Added flat-field analysis information. 3. Updated for version 2 of the VIRS DDR and DAP datasets. 4. Additional minor edits.
5.3	4/7/17	J. Ward, GEO	6.1.4	Additional minor edits.
5.4	4/11/17	J. Ward, GEO	6.1.4	Additional minor edits.

Table of Contents

1. Purpose and Scope of Document

1.1 Purpose

This document provides users of the MESSENGER Visible and Infrared Spectrograph (VIRS) data products with a detailed description of the instrument (Figure 1), as well as Calibrated Data Record (CDR), Derived Data Record (DDR), and Derived Analysis Product (DAP) generation and storage. The VIRS 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/DAP data product SIS and a CDR/DDR/DAP archive volume SIS.

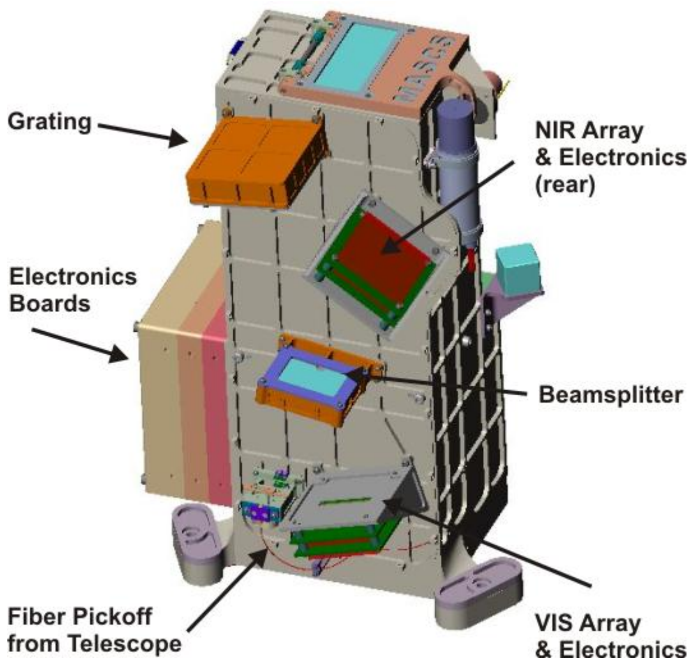


Figure 1: MASCS Instrument, VIRS subsystem.

1.2 Scope

This specification is useful to those who wish to understand the format and content of the VIRS CDRs, DDRs, and DAPs. Typically, these individuals include software engineers, data analysts, and planetary scientists. The SIS applies to the CDR/DDR/DAP data products produced during the course of MESSENGER mission operations. Experiment data records (EDRs), the raw, uncalibrated data from MASCS VIRS, are addressed in the VIRS EDR SIS (Applicable Document 8). EDR data products are archived in a separate PDS archive volume. This document has been updated for version 2 of the VIRS DDR and DAP data sets (MESS-E/V/H-MASCS-4-VIRS-DDR-V2.0 and MESS-E/V/H-MASCS-5-VIRS-DAP-V2.0).

2. Applicable Documents

The MESSENGER MASCS VIRS CDR/DDR/DAP 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/VIRS EDR SIS: APL doc no. SIE-06-045 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. VIRS IR Dark Analysis Report 1: Operational Changes: R. Klima & MASCS Team, SRE-01-11.
12. VIRS IR Dark Analysis Report 2: Calibration Changes: R. Klima & MASCS Team, SRE-02-11.
13. VIRS Calibration Changes for PDS Delivery 9: R. Klima and the MASCS Team. SRE-05-12.
14. VIRS Calibration Changes for PDS Delivery 11: MASCS/VIRS Instrument Team. SRE-01-13.
15. Hillier, J., Buratti, B., Hill, K., 1999. Multispectral photometry of the Moon and absolute calibration of the Clementine UV/VIS camera. Icarus 141, 205-225.
16. Domingue, D.L., Denevi, B.W., Murchie, S.L., Hash, C.D., 2016. Application of multiple photometric models to disk-resolved measurements of Mercury's surface: Insights into Mercury's regolith characteristics. Icarus 268, 172-203.
17. Domingue, D.L, D'Amore, M., Ferrari, S., Helvert, J., Izenberg, N., 2017. Analysis of the MESSENGER MASCS Photometric Targets Part I: Photometric Standardization for Examining Spectral Variability Across Mercury's Surface. In prep.
18. Kaasalainen, M., J. Torppa, K. Muinonen, 2001. Optimization Methods for Asteroid Lightcurve Inversion II. The Complete Inverse Problem. Icarus 153, 37-51.
19. Shkuratov Y., Kaydash, V., Korokhin, V., Velikodsky, Y., Opanasenko, N., Videen, G., 2011. Optical measurements of the Moon as a tool to study its surface. Planet. Space Sci. 59, 1326-1371.

20. MASCS/VIRS Lamp-Based Flat Field Report: R. Klima, G. Holsclaw & the MASCS team, 2017.

3. Relationships with other Interfaces

The VIRS 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 VIRS and UVVS CDRs, DDRs, and DAPs have 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, the 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 fed 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 (115-190 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, Na, and Ca) and from newly discovered species (Mg, Al, Mn, and Ca^+). In addition to determining the composition and structure of the exosphere, these confirmed detections provide the basis for determining exospheric processes, studying the relationship between surface and exospheric composition, and studying surface-exosphere-magnetosphere interactions. Searches were made for numerous additional predicted species (e.g. S, C, Si, Fe, OH, and Mg^+). Observations were also acquired that covered emissions from O, which may or may not have been detected by Mariner 10, and K, which is known from ground-based observations but which was difficult for UVVS given that the strongest resonance line was outside the UVVS wavelength range. These searches are still undergoing analysis and will provide stringent upper limits even if no detections are found through detailed analysis.

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 UVVS data products are described in a separate UVVS data product SIS. The VIRS data products are described below.

		VIRS	**UVVS**
Focal length		210 mm	125 mm
Grating		100 g/mm sinusoidal profile	2400 g/mm blazed at 330 nm
Spectral resolution	**FUV channel**	N/A	0.3 nm
	MUV channel	N/A	0.7 nm
	VIS channel	4.7 nm	0.6 nm
	IR channel	4.7 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 R1081 PMT - CsI
	MUV channel	N/A	Hamamatsu R759 PMT - CsTe
	VIS channel	Hamamatsu S3901-512SPL Si Diode Array	Hamamatsu R760P PMT - BiAlkali
	IR channel	Hamamatsu G8162-256S 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 H for additional details about the MASCS instrument.

5.2 Data Product Overview

Please see Appendix I for a summary table of all MASCS data products.

5.2.1 Calibrated Data Records (CDRs)

The VIRS CDRs consist of calibrated data derived from MASCS VIRS Experiment Data Records (EDRs). The EDRs are the raw data records used to derive surface reflectance data used for scientific analysis. The science EDRs contain raw counts of the VIRS detectors for the assigned integration times and pointing orientations. The VIRS instrument shutter can be closed for on-board dark observations, or the instrument can be pointed to empty space for space-darks. Additionally there are two on-board "grain-of-wheat" size lamps that are periodically used to illuminate the detectors to acquire "flat-field" observations. Wavelength range and sensitivity of each detector are 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 values 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 which are stored in CDRs.

There are two EDR data products produced by the VIRS instrument, one for each detector (VIS and NIR). These are identified in the EDR PDS labels as “VIRSVIS” and “VIRSNIR” standard data products, respectively. There is also a MASCS housekeeping EDR data product generated by the MASCS instrument. This is identified in the EDR PDS labels as the “MASCSHK” standard data product. There is one CDR product derived for each detector (VIS and NIR) using the EDR and associated housekeeping data from the HK EDR. The housekeeping EDR is defined in both the UVVS and the VIRS EDR SISs. VIRS and Housekeeping data are input into the VIRS calibration pipeline to derive Calibrated Data Records, which are identified as “VIRSCVIS” and “VIRSCNIR” CDRs.

For the VIRS CDR data products, one CDR contains all the calibrated data from one observation. However, one observation generated a variable number of spectra and a variable number of CCSDS (Consultative Committee for Space Data Systems) -standard packets. Thus, there is not a one-to-one correspondence between CCSDS packets and VIRS EDRs or CDRs, but there should be a correspondence between VIRS EDRs and CDRs modulated by dark spectra taken by VIRS used as part of calibration data.

Each CDR data product consists of two files. One file contains the data itself, arranged in a PDS binary table format. The other file is a detached PDS label, which describes the content of the data file. The label defines the start time and end of the observation, product creation time, etc. The label points to an associated format file that defines the columns of the binary table contained within the data file. At high instrument temperatures, NIR pixels begin to saturate due to elevated background noise. Saturated pixel values are denoted in the CDR by NaN or other invalid indicators.

There are four types of spectra stored in each CDR data file: RAW_SPECTRUM_DATA (table column 20), CORRECTED_COUNTS_SPECTRUM_DATA (table column 22), CALIBRATED_RADIANCE_SPECTRUM_DATA (table column 23), and NOISE_SPECTRUM_DATA (table column 24). Please see the table column definitions in section 6.3 for detailed descriptions of these columns.

5.2.1.1 MASCS Lamp-Based Flat-field

VIRS contained internal stimulus lamps that illuminated both detector channels. During the orbital mission, calibration sequences were conducted to monitor time- or temperature-dependent changes in the pixel-to-pixel sensitivity in both the Si and InGaAs detectors. Due to high temperatures and corresponding high dark current, the InGaAs detector was saturated during almost all lamp observations. The Si detector, however, was unsaturated for most temperatures. We examined these data in an effort to derive a flat-field correction from the lamp data. However, efforts to normalize the variable lamp signal and model changes in the flat-field as a function of temperature were found not to improve the data beyond the existing lab-based calibration, and thus have not been applied to the PDS data. See VIRS_FLATFIELD_REPORT.PDF in the DOCUMENT directory for the flat-field derivation and additional information.

5.2.2 Derived Data Records (DDRs)

For the VIRS DDR data products, one DDR contains all the derived reflectance data from one observation. Not all CDRs were converted to DDRs; lamp calibrations, dark calibrations, data looking solely out into space, and star calibrations do not provide meaningful reflectance information. Thus, there is not a one-to-one correspondence between VIRS CDRs and DDRs, but there should be a correspondence between VIRS CDRs and DDRs that target the surface of planets (Earth, Moon, Venus, Mercury). 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 adjustment was then applied to Mercury reflectance data to normalize viewing geometry to a uniform set of incidence, emission, and phase angles (45°, 45°, and 90°, respectively). At high temperatures in the extended mission, the VIRS shutter sometimes failed to operate, resulting in bad interleaved dark corrections. Observations with frozen shutter anomalies have not been processed to DDR.

Each DDR data product consists of two files, following the same divisions as the CDR: data and label files. There are four types of spectra stored in each DDR data file: IOF_SPECTRUM_DATA (table column 14), PHOTOM_IOF_SPECTRUM_DATA (table column 15), IOF_NOISE_SPECTRUM_DATA (table column 16), and PHOTOM_IOF_NOISE_SPECTRUM_DATA (table column 17).

Table 2 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.

The UVVS+VIRS Combined DDRs are described in a separate specification document, UVVS_VIRS_COMBINED_DDR_SPEC.PDF, located in the DOCUMENT directory of this volume.

5.2.3 Derived Data Products (DAPs)

For the VIRS DAP data products, one DAP contains a 500 meter per pixel mosaic map of 1 wavelength (750 nm) of VIRS spectral data for footprints covering the whole planet. MASCS/VIRS mosaics include MASCS/VIRS footprints collected after orbit insertion. A metric defined as M = footprint_area / (cos(e)*cos(i)) was computed for each footprint of each observation. In the case of individual spectra that cover the same location, spectra with the lowest metric value were stacked on top, and are the only ones captured in the final map layer. The spectra examined for inclusion in the mosaic come from CDRs converted to photometrically normalized reflectance using the same method as the VIRS Version 2 DDRs. Mosaicked spectra must have M > 0, emission angle < 80 degrees and incidence angle < 70 degrees for footprints with latitude in [-65,65] or incidence angle < footprint's latitude + 5 degrees for other footprints.

The mosaic product has nine layers. Each layer information is derived from the CDR and the spectrum of the topmost spectrum at a given map location.

1) Reflectance @750 nm, taken from DDR for spectrum with maximum M value
2) Interpolated reflectance @750nm derived from layer 1 using a spatial interpolation algorithm
3) Incidence angle (of maximum M value spectrum), taken from CDR
4) Emission angle (of maximum M value spectrum), taken from CDR
5) Phase angle (of maximum M value spectrum), taken from CDR
6) Observation area (of maximum M value spectrum), derived from footprint dimension from CDR
7) Observations, CDR date (of maximum M value spectrum)
8) Observations, CDR time (of maximum M value spectrum)
9) Observations Spectrum number, taken from CDR (of maximum M value spectrum)

Processing Step	**VIRSNC.FMT/ VIRSVC.FMT Column**
1. Determine time (integration) for each spectrum of a given VIRS observation.	SPECTRUM_UTC_TIME (column 21)
2. The first scan of the VIS detector is anomalous in magnitude- set the first scan to the average of the next few scans.	This is an operation on the way to CORRECTED_COUNTS_SPECTRUM_DATA (not preserved in CDR)
3. Determine dark curve and subtract darks from data.	This is an operation on the way to CORRECTED_COUNTS_SPECTRUM_DATA (not preserved in CDR)
4. Subtract scattered light, other corrections (e.g. temperature).	CORRECTED_COUNTS_SPECTRUM_DATA (column 22)
5. Apply temperature-corrected lab-measured sensitivity, convert to radiance at sensor.	CALIBRATED_RADIANCE_SPECTRUM_DATA (column 23)
6. Determine pointing parameters (geometry fields calculated from SPICE) for every spectrum.	All geometry fields
7. Assign data quality flags and indicators.	DATA_QUALITY_INDEX (column 28)
Processing Step	**VIRSND.FMT/ VIRSVD.FMT Column**
8. Filter out non-surface observations.	Uses Footprint corner data
9. Divide by solar spectrum for reflectance.	IOF_SPECTRUM_DATA (column 14) and IOF_NOISE_SPECTRUM_DATA (column 16)
10. Apply photometric normalization.	PHOTOM_IOF_SPECTRUM_DATA

	(column 15) and PHOTOM_IOF_NOISE_SPECTRUM_DATA (column 17)
Processing Step	
11. Ingest DDR dataset and select footprints.	
12. Create map layers.	

Table 2: VIRS EDR to CDR to DDR to DAP Processing Steps.

5.3 Data Processing

5.3.1 Data Processing Level

The CDR/DDR/DAP archive includes level 3 (CDR), level 4 (DDR), and level 5 (DAP) data as defined by the Committee on Data Management and Computation (CODMAC, Appendix F). 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 VIRS CDR/DDR/DAP files were produced by the MESSENGER Science Operations Center (SOC), operated jointly by APL and ACT. The 'PIPE-MASCS2CDR', 'PIPE-MASCS2DDR', and 'PIPE_VIRS_CREATE_PDS_DAP' 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 used for producing the CDRs and DDRs are included in the archive. The CDR/DDR/DAP 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 transfer to the Geosciences and Atmospheres Nodes. The transfer 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 VIRS are located in the CALIB directory. Calibration and data reduction details and tables are described in the VIRS_EDR2CDR.TXT, VIRS_CDR2DDR.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 2). The SOC was located at 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 VIRS and UVVS 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 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 provides an independent method of verifying the integrity of the archive after it has been 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 is expected that the Nodes would 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/DAPs. Regenerated data were included in the next scheduled delivery.

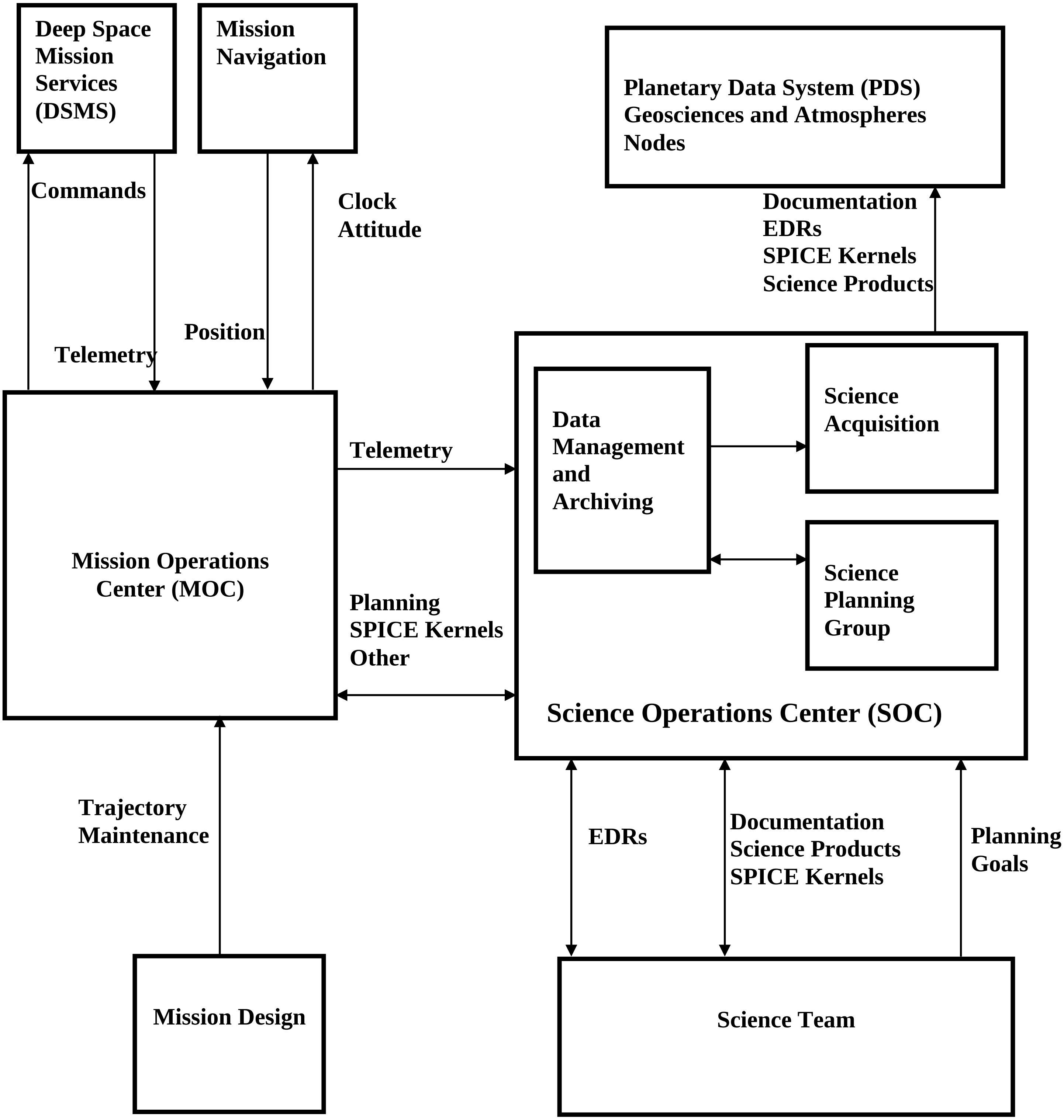


Figure 2: MESSENGER data flow.

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. For every CDR/DDR/DAP data file there exists a PDS label file. The following are examples of PDS labels, one each for the two CDR standard data products, “VIRSCNIR” and “VIRSCVIS”, the two DDR standard data products, “VIRSDNIR” and “VIRSDVIS”, and the one DAP special data product, "VIRSDAP" (section 5.2). Details about the label format are specified in section 6.3.

The UVVS+VIRS Combined DDR label and format are described in a separate specification document, UVVS_VIRS_COMBINED_DDR_SPEC.PDF, located in the DOCUMENT directory of this volume.

5.3.4.1 Example PDS Label for the VIRS NIR CDR Data Products

```
PDS_VERSION_ID                = "PDS3"

/*** FILE FORMAT ***/
RECORD_TYPE                   = FIXED_LENGTH
RECORD_BYTES                  = 5050
FILE_RECORDS                  = 20

/*** GENERAL DATA DESCRIPTION PARAMETERS ***/
PRODUCT_ID                    = "VIRSNC_MF3_09285_004616_DAT"
PRODUCT_VERSION_ID            = "V1 "
PRODUCT_CREATION_TIME         = 2009-12-04T21:12:48
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                   = "VIRS"
DATA_SET_ID                   = "MESS-E/V/H-MASCS-3-VIRS-CDR-CALDATA-V1.0"
STANDARD_DATA_PRODUCT_ID      = "VIRSCNIR"
MISSION_PHASE_NAME            = "MERCURY 3 FLYBY"
TARGET_NAME                   = "MERCURY"
SITE_ID                       = {"1234", "5678"}
START_TIME                    = 2009-10-12T00:46:17
STOP_TIME                     = 2009-10-12T00:47:00
SPACECRAFT_CLOCK_START_COUNT  = "163795843.705"
SPACECRAFT_CLOCK_STOP_COUNT   = "163795886.455"
^TABLE                        = "VIRSNC_MF3_09285_004616.DAT"

OBJECT                        = TABLE
   COLUMNS                       = 62
   INTERCHANGE_FORMAT            = BINARY
```

```
   ROW_BYTES                     = 5050
   ROWS                          = 20
   DESCRIPTION                   = "
      This table contains MESSENGER VIRS spectra collected in the near
      Infrared wavelength as well as 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:
     msgr20091011.bc
     msgr20091012.bc
     msgr20091013.bc
     msgr_dyn_v600.tf
     msgr_v200.tf
     msgr_mascs_v011.ti
     naif0009.tls
     pck00008.tpc
     pck00008_MSGR.tpc
     messenger_0793.tsc
     de405.bsp
     msgr_20040803_20120401_od170sc.bsp
   "

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

5.3.4.2 Example PDS Label for the VIRS VIS CDR Data Products

```
PDS_VERSION_ID                = "PDS3"

/*** FILE FORMAT ***/
RECORD_TYPE                   = FIXED_LENGTH
RECORD_BYTES                  = 9658
FILE_RECORDS                  = 20

/*** GENERAL DATA DESCRIPTION PARAMETERS ***/
PRODUCT_ID                    = "VIRSVC_MF3_09285_004616_DAT"
PRODUCT_VERSION_ID            = "V1 "
PRODUCT_CREATION_TIME         = 2009-12-04T21:14:22
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                   = "VIRS"
DATA_SET_ID                   = "MESS-E/V/H-MASCS-3-VIRS-CDR-CALDATA-V1.0"
```

```
STANDARD_DATA_PRODUCT_ID       = "VIRSCVIS"
MISSION_PHASE_NAME             = "MERCURY 3 FLYBY"
TARGET_NAME                    = "MERCURY"
SITE_ID                        = {"1234", "5678"}
START_TIME                     = 2009-10-12T00:46:17
STOP_TIME                      = 2009-10-12T00:47:00
SPACECRAFT_CLOCK_START_COUNT   = "163795843.705"
SPACECRAFT_CLOCK_STOP_COUNT    = "163795886.455"
^TABLE                         = "VIRSVC_MF3_09285_004616.DAT"

OBJECT                         = TABLE
   COLUMNS                        = 62
   INTERCHANGE_FORMAT             = BINARY
   ROW_BYTES                      = 9658
   ROWS                           = 20
   DESCRIPTION                    = "
      This table contains MESSENGER VIRS spectra collected in the visible
      wavelength as well as 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:
     msgr20091011.bc
     msgr20091012.bc
     msgr20091013.bc
     msgr_dyn_v600.tf
     msgr_v200.tf
     msgr_mascs_v011.ti
     naif0009.tls
     pck00008.tpc
     pck00008_MSGR.tpc
     messenger_0793.tsc
     de405.bsp
     msgr_20040803_20120401_od170sc.bsp
   "

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

5.3.4.3 *Example PDS Label for the VIRS NIR DDR Data Products*

```
PDS_VERSION_ID                 = "PDS3"

/*** FILE FORMAT ***/
RECORD_TYPE                    = FIXED_LENGTH
RECORD_BYTES                   = 5338
FILE_RECORDS                   = 20

/*** GENERAL DATA DESCRIPTION PARAMETERS ***/
```

```
PRODUCT_ID                      = "VIRSND_MF3_09285_004616_DAT"
PRODUCT_VERSION_ID              = "V1 "
PRODUCT_CREATION_TIME           = 2013-12-04T21:12:48
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                     = "VIRS"
DATA_SET_ID                     = "MESS-E/V/H-MASCS-4-VIRS-DDR-V2.0"
STANDARD_DATA_PRODUCT_ID        = "VIRSDNIR"
MISSION_PHASE_NAME              = "MERCURY 3 FLYBY"
TARGET_NAME                     = "MERCURY"
SITE_ID                         = {"1234", "5678"}
START_TIME                      = 2012-10-12T00:46:17
STOP_TIME                       = 2012-10-12T00:47:00
SPACECRAFT_CLOCK_START_COUNT    = "163795843.705"
SPACECRAFT_CLOCK_STOP_COUNT     = "163795886.455"
^TABLE                          = "VIRSND_MF3_09285_004616.DAT"

OBJECT                          = TABLE
   COLUMNS                         = 62
   INTERCHANGE_FORMAT              = BINARY
   ROW_BYTES                       = 5338
   ROWS                            = 20
   DESCRIPTION                     = "
      This table contains MESSENGER VIRS spectra collected in the near
      Infrared wavelength, converted to reflectance and photometrically
      normalized, as well as 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:
     msgr20091011.bc
     msgr20091012.bc
     msgr20091013.bc
     msgr_dyn_v600.tf
     msgr_v200.tf
     msgr_mascs_v011.ti
     naif0009.tls
     pck00008.tpc
     pck00008_MSGR.tpc
     messenger_0793.tsc
     de405.bsp
     msgr_20040803_20120401_od170sc.bsp
   "

   ^STRUCTURE = "VIRSND.FMT"
END_OBJECT                      = TABLE
```

```
END
```

5.3.4.4 *Example PDS Label for the VIRS VIS DDR Data Products*

```
PDS_VERSION_ID                = "PDS3"

/*** FILE FORMAT ***/
RECORD_TYPE                   = FIXED_LENGTH
RECORD_BYTES                  = 10458
FILE_RECORDS                  = 20

/*** GENERAL DATA DESCRIPTION PARAMETERS ***/
PRODUCT_ID                    = "VIRSVD_MF3_09285_004616_DAT"
PRODUCT_VERSION_ID            = "V1 "
PRODUCT_CREATION_TIME         = 2013-12-04T21:14:22
PRODUCT_TYPE                  = "DDR"
SOFTWARE_NAME                 = "PIPE-MASCS2DDR"
SOFTWARE_VERSION_ID           = "2.0"
INSTRUMENT_HOST_NAME          = "MESSENGER"
INSTRUMENT_NAME               = "
 MERCURY ATMOSPHERIC AND SURFACE COMPOSITION SPECTROMETER"
INSTRUMENT_ID                 = "MASCS"
DETECTOR_ID                   = "VIRS"
DATA_SET_ID                   = "MESS-E/V/H-MASCS-4-VIRS-DDR-V2.0"
STANDARD_DATA_PRODUCT_ID      = "VIRSDVIS"
MISSION_PHASE_NAME            = "MERCURY 3 FLYBY"
TARGET_NAME                   = "MERCURY"
SITE_ID                       = {"1234", "5678"}
START_TIME                    = 2012-10-12T00:46:17
STOP_TIME                     = 2012-10-12T00:47:00
SPACECRAFT_CLOCK_START_COUNT  = "163795843.705"
SPACECRAFT_CLOCK_STOP_COUNT   = "163795886.455"
^TABLE                        = "VIRSVD_MF3_09285_004616.DAT"

OBJECT                        = TABLE
   COLUMNS                       = 62
   INTERCHANGE_FORMAT            = BINARY
   ROW_BYTES                     = 10458
   ROWS                          = 20
   DESCRIPTION                   = "
      This table contains MESSENGER VIRS spectra collected in the visible
      wavelength, converted to reflectance and photometrically normalized
      as well as 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:
     msgr20091011.bc
     msgr20091012.bc
     msgr20091013.bc
     msgr_dyn_v600.tf
```

```
     msgr_v200.tf
     msgr_mascs_v011.ti
     naif0009.tls
     pck00008.tpc
     pck00008_MSGR.tpc
     messenger_0793.tsc
     de405.bsp
     msgr_20040803_20120401_od170sc.bsp
   "

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

5.3.4.5 Example PDS Label for the VIRS DAP Data Product

```
PDS_VERSION_ID                = PDS3

/*** FILE FORMAT ***/
RECORD_TYPE                   = UNDEFINED

/* Derived Analysis Product Identification */

DATA_SET_ID                   = "MESS-E/V/H-MASCS-5-VIRS-DAP-V2.0"
PRODUCT_ID                    = "VIRS_DAP_500MPP_V01"

INSTRUMENT_HOST_NAME          = "MESSENGER"
INSTRUMENT_NAME               = "
 MERCURY ATMOSPHERIC AND SURFACE COMPOSITION SPECTROMETER"
INSTRUMENT_ID                 = "MASCS"
DETECTOR_ID                   = "VIRS"
TARGET_NAME                   = "MERCURY"
PRODUCT_TYPE                  = "DAP"
PRODUCT_CREATION_TIME         = 2013-05-09T14:57:48
START_TIME                    = 2011-03-29T02:02:40
STOP_TIME                     = 2013-03-17T22:55:43
SPACECRAFT_CLOCK_START_COUNT  = "1/209851629.245"
SPACECRAFT_CLOCK_STOP_COUNT   = "2/5884942.235"
PRODUCT_VERSION_ID            = "V1"
PRODUCER_INSTITUTION_NAME     = "APPLIED COHERENT TECHNOLOGY CORPORATION"
SOFTWARE_NAME                 = "ACT_PIPE_virs_create_pds_DAP"
SOFTWARE_VERSION_ID           = "1.0"

NOTE                          = "This label describes nine
                                     data files:
  1. An image file containing the mosaic of MASCS/VIRS reflectance @750nm,
  2. An image file containing the interpolated mosaic of MASCS/VIRS
     reflectance @750nm,
  3. An image file containing the incidence angle of MASCS/VIRS observations
     used in mosaic,
  4. An image file containing the emission angle of MASCS/VIRS observations
     used in mosaic,
  5. An image file containing the phase angle of MASCS/VIRS observations used
     in mosaic,
  6. An image file containing the area of MASCS/VIRS observations used in
     mosaic,
```

```
  7. An image file containing the CDR Date of MASCS/VIRS observations used in
     mosaic,
  8. An image file containing the CDR Time of MASCS/VIRS observations used in
     mosaic,
  9. An image file containing the spectrum number of MASCS/VIRS observations
     used in mosaic.

  The CDR date, CDR time can be used to find the CDR where the observation
  source data is stored, while the spectrum number can be used to find the
  CDR record associated to the observation."

/* Description of Reflectance image file */

OBJECT          = RFL_FILE
  ^RFL_IMAGE     = "VIRS_DAP_500MPP_V01_RFL.IMG"
  RECORD_TYPE   = FIXED_LENGTH
  RECORD_BYTES  = 122648
  FILE_RECORDS  = 15331

  OBJECT               = RFL_IMAGE
    LINES              = 15331
    LINE_SAMPLES       = 30662
    SAMPLE_TYPE        = PC_REAL
    SAMPLE_BITS        = 32
    UNIT               = "Reflectance"
    BANDS              = 1
    BAND_NAME          = "REFLECTANCE 750NM"
    BAND_STORAGE_TYPE  = BAND_SEQUENTIAL
    MISSING_CONSTANT   = -999.0
  END_OBJECT           = RFL_IMAGE

END_OBJECT      = RFL_FILE


/* Description of interpolated Reflectance image file */

OBJECT          = INTRFL_FILE
  ^INTRFL_IMAGE  = "VIRS_DAP_500MPP_V01_INTRFL.IMG"
  RECORD_TYPE   = FIXED_LENGTH
  RECORD_BYTES  = 122648
  FILE_RECORDS  = 15331

  OBJECT               = INTRFL_IMAGE
    LINES              = 15331
    LINE_SAMPLES       = 30662
    SAMPLE_TYPE        = PC_REAL
    SAMPLE_BITS        = 32
    UNIT               = "Reflectance"
    BANDS              = 1
    BAND_NAME          = "INTERPOLATED REFLECTANCE 750NM"
    BAND_STORAGE_TYPE  = BAND_SEQUENTIAL
    MISSING_CONSTANT   = -999.0
  END_OBJECT           = INTRFL_IMAGE

END_OBJECT      = INTRFL_FILE
```

```
/* Description of incidence angle image file */

OBJECT           = INC_FILE
  ^INC_IMAGE      = "VIRS_DAP_500MPP_V01_INC.IMG"
  RECORD_TYPE    = FIXED_LENGTH
  RECORD_BYTES   = 122648
  FILE_RECORDS   = 15331

  OBJECT                = INC_IMAGE
    LINES               = 15331
    LINE_SAMPLES        = 30662
    SAMPLE_TYPE         = PC_REAL
    SAMPLE_BITS         = 32
    UNIT                = "Deg"
    BANDS               = 1
    BAND_NAME           = "INCIDENCE ANGLE"
    BAND_STORAGE_TYPE   = BAND_SEQUENTIAL
    MISSING_CONSTANT    = -999.0
  END_OBJECT            = INC_IMAGE

END_OBJECT       = INC_FILE


/* Description of emission angle image file */

OBJECT           = EMI_FILE
  ^EMI_IMAGE      = "VIRS_DAP_500MPP_V01_EMI.IMG"
  RECORD_TYPE    = FIXED_LENGTH
  RECORD_BYTES   = 122648
  FILE_RECORDS   = 15331

  OBJECT                = EMI_IMAGE
    LINES               = 15331
    LINE_SAMPLES        = 30662
    SAMPLE_TYPE         = PC_REAL
    SAMPLE_BITS         = 32
    UNIT                = "Deg"
    BANDS               = 1
    BAND_NAME           = "EMISSION ANGLE"
    BAND_STORAGE_TYPE   = BAND_SEQUENTIAL
    MISSING_CONSTANT    = -999.0
  END_OBJECT            = EMI_IMAGE

END_OBJECT       = EMI_FILE


/* Description of phase angle image file */

OBJECT           = PHA_FILE
  ^PHA_IMAGE      = "VIRS_DAP_500MPP_V01_PHA.IMG"
  RECORD_TYPE    = FIXED_LENGTH
  RECORD_BYTES   = 122648
  FILE_RECORDS   = 15331

  OBJECT                = PHA_IMAGE
    LINES               = 15331
    LINE_SAMPLES        = 30662
```

```
    SAMPLE_TYPE        = PC_REAL
    SAMPLE_BITS        = 32
    UNIT               = "Deg"
    BANDS              = 1
    BAND_NAME          = "PHASE ANGLE"
    BAND_STORAGE_TYPE  = BAND_SEQUENTIAL
    MISSING_CONSTANT   = -999.0
  END_OBJECT           = PHA_IMAGE

END_OBJECT      = PHA_FILE


/* Description of observations area image file */

OBJECT          = AREA_FILE
  ^AREA_IMAGE     = "VIRS_DAP_500MPP_V01_AREA.IMG"
  RECORD_TYPE   = FIXED_LENGTH
  RECORD_BYTES  = 122648
  FILE_RECORDS  = 15331

  OBJECT               = AREA_IMAGE
    LINES              = 15331
    LINE_SAMPLES       = 30662
    SAMPLE_TYPE        = PC_REAL
    SAMPLE_BITS        = 32
    UNIT               = "Km^2"
    BANDS              = 1
    BAND_NAME          = "OBSERVATION AREA"
    BAND_STORAGE_TYPE  = BAND_SEQUENTIAL
    MISSING_CONSTANT   = -999.0
  END_OBJECT           = AREA_IMAGE

END_OBJECT      = AREA_FILE


/* Description of observations CDR Date image file */

OBJECT          = CDRDATE_FILE
  ^CDRDATE_IMAGE = "VIRS_DAP_500MPP_V01_CDRDATE.IMG"
  RECORD_TYPE   = FIXED_LENGTH
  RECORD_BYTES  = 122648
  FILE_RECORDS  = 15331

  OBJECT               = CDRDATE_IMAGE
    LINES              = 15331
    LINE_SAMPLES       = 30662
    SAMPLE_TYPE        = LSB_INTEGER
    SAMPLE_BITS        = 32
    BANDS              = 1
    BAND_NAME          = "CDR DATE"
    BAND_STORAGE_TYPE  = BAND_SEQUENTIAL
    MISSING_CONSTANT   = -999
    DESCRIPTION        = "Obervation CDR date in the form YYDOY"
  END_OBJECT           = CDRDATE_IMAGE

END_OBJECT      = CDRDATE_FILE
```

```
/* Description of observations CDR Time image file */

OBJECT          = CDRTIME_FILE
  ^CDRTIME_IMAGE = "VIRS_DAP_500MPP_V01_CDRTIME.IMG"
  RECORD_TYPE   = FIXED_LENGTH
  RECORD_BYTES  = 122648
  FILE_RECORDS  = 15331

  OBJECT               = CDRTIME_IMAGE
    LINES              = 15331
    LINE_SAMPLES       = 30662
    SAMPLE_TYPE        = LSB_INTEGER
    SAMPLE_BITS        = 32
    BANDS              = 1
    BAND_NAME          = "CDR TIME"
    BAND_STORAGE_TYPE  = BAND_SEQUENTIAL
    MISSING_CONSTANT   = -999
    DESCRIPTION        = "Obervation CDR time in the form HHMMSS.
                          In case the number has only 5 digits then prepend
                          a 0 to it"
  END_OBJECT           = CDRTIME_IMAGE

END_OBJECT      = CDRTIME_FILE


/* Description of observations spectrum number image file */

OBJECT          = SPENUM_FILE
  ^SPENUM_IMAGE = "VIRS_DAP_500MPP_V01_SPENUM.IMG"
  RECORD_TYPE   = FIXED_LENGTH
  RECORD_BYTES  = 122648
  FILE_RECORDS  = 15331

  OBJECT               = SPENUM_IMAGE
    LINES              = 15331
    LINE_SAMPLES       = 30662
    SAMPLE_TYPE        = LSB_INTEGER
    SAMPLE_BITS        = 32
    BANDS              = 1
    BAND_NAME          = "SPECTRUM NUMBER"
    BAND_STORAGE_TYPE  = BAND_SEQUENTIAL
    MISSING_CONSTANT   = -999
  END_OBJECT           = SPENUM_IMAGE

END_OBJECT      = SPENUM_FILE

/* Map projection information about this DAP is in the */
/* IMAGE_MAP_PROJECTION object below.                  */

OBJECT                       = IMAGE_MAP_PROJECTION
  ^DATA_SET_MAP_PROJECTION   = "DAP_MAP.CAT"
  MAP_PROJECTION_TYPE        = "EQUIRECTANGULAR"
  A_AXIS_RADIUS              = 2439.4  <km>
  B_AXIS_RADIUS              = 2439.4  <km>
  C_AXIS_RADIUS              = 2439.4  <km>
  FIRST_STANDARD_PARALLEL    = "N/A"
```

```
  SECOND_STANDARD_PARALLEL     = "N/A"
  POSITIVE_LONGITUDE_DIRECTION = "EAST"
  CENTER_LATITUDE              = 0.0 <degree>
  CENTER_LONGITUDE             = 0.0 <degree>
  LINE_FIRST_PIXEL             = 1
  LINE_LAST_PIXEL              = 15331
  SAMPLE_FIRST_PIXEL           = 1
  SAMPLE_LAST_PIXEL            = 30662
  MAP_PROJECTION_ROTATION      = 0.0
  MAP_RESOLUTION               = 85.172067 <pixel/degree>
  MAP_SCALE                    = 500 <m/pixel>
  MAXIMUM_LATITUDE             = 90    <degree>
  MINIMUM_LATITUDE             = -90   <degree>
  WESTERNMOST_LONGITUDE        = -180  <degree>
  EASTERNMOST_LONGITUDE        = -179.999346   <degree>
  LINE_PROJECTION_OFFSET       = 7665.986075 <pixel>
  SAMPLE_PROJECTION_OFFSET     = 15331.472150 <pixel>
  COORDINATE_SYSTEM_TYPE       = "BODY-FIXED ROTATING"
  COORDINATE_SYSTEM_NAME       = "PLANETOCENTRIC"
END_OBJECT                     = IMAGE_MAP_PROJECTION

END
```

5.4 Standards Used in Generating Data Products

5.4.1 PDS Standards

The VIRS CDR/DDR/DAP 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. In the PDS standard, the VIRS CDR and DDR data are grouped into pairs; one file is a table of binary data and the other is a detached PDS label describing the data. The detached label file contains a pointer to the binary table file, which stores the housekeeping data, derived pointing data, and the spectra. Each DAP image plane is an .IMG file in the standard PDS format. The 9 images planes are described by a detached PDS label.

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 E) 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 E– 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 VIRS CDR/DDR/DAP data products are validated by the VIRS Instrument Scientist for science content and for compliance with PDS archive standards and the MESSENGER Data Management and Archiving Plan [Applicable Document 4]. "Invalid" data includes detector pixels that are saturated, detector pixels that receive no light, and photometric fields such as incidence, emission, and phase angles, and coordinate fields such as solar distance, where the MASCS footprint does not fall on the surface of Mercury. Invalid data in CDRs and advanced products is assigned a value of 1.e32.

6. Detailed Data Product Specifications

6.1 Data Archive Structure and Organization

The VIRS EDR data set is a static dataset. Static data sets, once produced and validated, are not subject to update or modification. The VIRS CDR/DDR/DAP 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 were 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 data products that are revised during the course of the mission. Revised data products or data products 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 then replaced the outdated files with the revised files in the data directories of the archive volume.

MASCS followed similar procedures as other instruments have historically. The CONFIDENCE_LEVEL_NOTE in the virs_*_ds.cat files located in the CATALOG directory was updated with each regeneration, and CDR/DDR/DAP 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/DAP geometry fields of all CDRs/DDRs/DAPs. 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 base file name for the VIRS CDR and DDR data products is "VIRSdL_mmm_YYDDD_HHMMSS" where:

```
VIRS: instrument name
   d: detector identifier. N = NIR, 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
MC2 = 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)

YY: the last two digits of the year in which the data was
acquired

DDD: The three digit day of year in which the data was
acquired.

HHMMSS: Is the 6 digit hour, minute, second of the start of
the observation.
```

The general form of the base file name for the VIRS DAP data product is "VIRS_DAP_500MPP_VXX_AAAAAAA" where:

```
VIRS: instrument name
 DAP: derived analysis product (DAP)
 MPP: meters per pixel (map scale, 500 mpp)
 VXX: version number.
 AAAAAAA: map layer type.
      RFL = reflectance at 750 nm at given coordinate
      INTRFL = interpolated reflectance at given coordinate
      INC = incidence angle at given coordinate
      EMI = emission angle at given coordinate
      PHA = phase angle at given coordinate
      AREA = footprint area at given coordinate
      CDRDATE = date of acquisition of the footprint at given coordinate
      CDRTIME = time of acquisition of that footprint at given coordinate
      SPENUM = spectrum number within the CDR of that footprint at
               given coordinate
```

The file naming convention of the UVVS+VIRS Combined DDR products are described in a separate specification document, UVVS_VIRS_COMBINED_DDR_SPEC.PDF, located in the DOCUMENT directory of this volume.

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

The following illustrations (Figures 3a-3c) show the directory structure 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 UVVS CDRs/DDRs are contained in the document UVVS_CDR_DDR_SIS.PDF, and details for the UVVS+VIRS Combined DDR are contained in the document UVVS_VIRS_COMBINED_DDR_SPEC.PDF, both located in the DOCUMENT directory. This archive volume is stored at both the Atmospheres and Geosciences PDS Nodes.

Figure 3a: Directory Structure Overview.

```
                                          <ROOT>
__________________________________________|____________________________
    |          |         |        |       |       |       |       |
<DOCUMENT> <CATALOG> <INDEX> <GEOMETRY>   |   <CALIB> <LABEL> <EXTRAS>
                                          <DATA>
                                          |
                             _____________|____________
                             |            |          |
                           <CDR>        <DDR>      <DAP>
                             |            |          |
                         [Fig. 3b]    [Fig. 3c]    <VIRS>
```

Figure 3b: CDR Directory Structure.

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

Figure 3c: DDR Directory Structure.

```
                                    <DDR>
                                      |
                                      |
                               <mission phase>
                                      |
______________________________________|___________________________________
   |                 |                |               |              |
<UVVS_             <UVVS_           <UVVS_          <UVVS_         <VIRS>
ATMOSPHERE>        SUMMARY_         SURFACE>        VIRS_            |
   |               ATMOSPHERE>         |            COMBINED>        |
___|_____________      |               |                |            |
   |         |         |       <MASCSYYYYMMDD>          |     <MASCSYYYYMMDD>
<models> <mercury  <species>           |                |            |
          year>        |            ___|___             |         ___|____
                       |            |     |             |          |    |
                   <mercury        FUV   MUV    <MASCSYYYYMMDD>   VIS  NIR
                    year>
```

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. will display appropriately.

VIRS_CDR_DDR_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_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. will display appropriately.

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.

UVVS_VIRS_COMBINED_DDR_SPEC.TXT - The MASCS UVVS/VIRS COMBINED DDR Specification: "MESSENGER MASCS UVVS+VIRS Combined Derived Data Record Specification" in ASCII text format. Only the text is provided; for illustrations, tables, etc. the PDF should be consulted.

UVVS_VIRS_COMBINED_DDR_SPEC.PDF - The MASCS UVVS/VIRS COMBINED DDR Specification: "MESSENGER MASCS UVVS+VIRS Combined Derived Data Record Specification" in Adobe Acrobat format. Note that, in contrast to the .TXT version, the illustrations, tables, etc. will display appropriately.

UVVS_VIRS_COMBINED_DDR_SPEC.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.

UVVSVIRS_DDR2DDR_COMBINED.TXT - Detailed procedures for UVVS-VIRS DDR to Combined DDR data reduction.

UVVSVIRS_DDR2DDR_COMBINED.LBL - The detached label for the UVVS-VIRS DDR to Combined 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. will display appropriately.

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. will display appropriately.

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. will display appropriately.

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.

UVVS_PROCESSING_UPDATES_PDS16.PDF - "MESSENGER MASCS UVVS Processing Updates - PDS 16" in Adobe Acrobat format. Describes the UVVS CDR and DDR processing updates for PDS delivery 16.

UVVS_PROCESSING_UPDATES_PDS16.TXT - "MESSENGER MASCS UVVS Processing Updates - PDS 16" in ASCII text format. Describes the UVVS CDR and DDR processing updates for PDS delivery 16.

UVVS_PROCESSING_UPDATES_PDS16.LBL - A detached PDS label that describes the HTML and PDF file.

VIRS_FLATFIELD_REPORT.PDF - "MASCS/VIRS Lamp-Based Flat Field Report" in Adobe Acrobat Format. Describes the results of an investigation to derive a flat-field correction for the MASCS VIRS surface observations.

VIRS_FLATFIELD_REPORT.HTM - "MASCS/VIRS Lamp-Based Flat Field Report" in HTML Format. Describes the results of an investigation to derive a flat-field correction for the MASCS VIRS surface observations.

VIRS_FLATFIELD_REPORT.LBL - A detached PDS label that describes the HTML and PDF file.

VIRS_TUTORIAL.PDF - MASCS VIRS Tutorial/User's Guide in PDF/A format.

VIRS_TUTORIAL.LBL - A detached PDS label that describes the PDF/A 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.

UVVS_VIRS_DDR_DS.CAT - Describes the general content of the MASCS UVVS+VIRS Combined DDR dataset.

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 CDR 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 CDR data set; the columns contain parameters that describe the observation, instrument, and spacecraft parameters.

UHCINDEX.LBL - Detached PDS label for UHCINDEX.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 CDR data set;

the columns contain parameters that describe the observation, instrument, and spacecraft parameters.

USCINDEX.LBL - Detached PDS label for USCINDEX.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.

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

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

Table 3a, 3b, 3c, and 3d below list the columns in the VICINDEX.TAB, VIDINDEX.TAB, VDAPINDEX.TAB, and UVDINDEX.TAB files, respectively. For any given data product, some of the fields are inapplicable and are set to N/A.

Column	Format	Example
VOLUME_ID	CHARACTER	“MESSMAS_2101”
FILE_SPECIFICATION_NAME	CHARACTER	“DATA/CDR/MF1/MASCS20080114/VIRS/VIS/VIRSVC_MF1_08014_191254.LBL”
MISSION_PHASE_NAME	CHARACTER	"MERCURY 1 FLYBY"
TARGET_NAME	CHARACTER	“MERCURY”
SITE_ID	CHARACTER	“1234, 5667”
PRODUCT_ID	CHARACTER	“VIRSVC_MF1_08014_191254_DAT”
PRODUCT_VERSION_ID	CHARACTER	"V1 "
PRODUCT_CREATION_TIME	TIME	2009-02-05T19:50:43
DATA_SET_ID	CHARACTER	“MESS-E/V/H-MASCS-3-VIRS-CDR-CALDATA-V1.0”
STANDARD_DATA_PRODUCT_ID	CHARACTER	VIRSCVIS
START_TIME	TIME	2008-01-14T19:12:55
STOP_TIME	TIME	2008-01-14T19:28:37
START_MET_PARTITION	ASCII_INTEGER	1
SPACECRAFT_CLOCK_START_COUNT	CHARACTER	“1/108825356.405”
SPACECRAFT_CLOCK_STOP_COUNT	CHARACTER	“1/108826298.924”
INT_TIME	ASCII_INTEGER	20
DARK_FREQ	ASCII_INTEGER	20
ANY_LAMP_ON	ASCII_INTEGER	0
BINNING	ASCII_INTEGER	1
SUMMARY_DATA_QUALITY	CHARACTER	“1000-9900-0011-2000”

Table 3a: VICINDEX.TAB Columns.

Column	Format	Example
VOLUME_ID	CHARACTER	“MESSMAS_2101”
FILE_SPECIFICATION_NAME	CHARACTER	“DATA/DDR/MF1/VIRS /MASCS20080114/VIS/VIRSVD_MF1_08014_191254.LBL”
MISSION_PHASE_NAME	CHARACTER	"MERCURY 1 FLYBY"
TARGET_NAME	CHARACTER	“MERCURY”

Column	Format	Example
SITE_ID	CHARACTER	“1234, 5667”
PRODUCT_ID	CHARACTER	“VIRSVD_MF1_08014_191254_DAT”
PRODUCT_VERSION_ID	CHARACTER	"V1 "
PRODUCT_CREATION_TIME	TIME	2017-02-21T14:40:47
DATA_SET_ID	CHARACTER	“MESS-E/V/H-MASCS-4-VIRS-DDR -V2.0”
STANDARD_DATA_PRODUCT_ID	CHARACTER	VIRSDVIS
START_TIME	TIME	2008-01-14T19:12:55
STOP_TIME	TIME	2008-01-14T19:28:38
START_MET_PARTITION	ASCII_INTEGER	1
SPACECRAFT_CLOCK_START_COUNT	CHARACTER	“1/108825355.905”
SPACECRAFT_CLOCK_STOP_COUNT	CHARACTER	“1/108826298.424”
INT_TIME	ASCII_INTEGER	20
DARK_FREQ	ASCII_INTEGER	20
BINNING	ASCII_INTEGER	0
SUMMARY_DATA_QUALITY	CHARACTER	“1000-9910-0011-2000”

Table 3b: VIDINDEX.TAB Columns.

Column	Format	Example
VOLUME_ID	CHARACTER	“MESSMAS_2101”
FILE_SPECIFICATION_NAME	CHARACTER	“DATA/DAP/VIRS /VIRS_DAP_500MPP_V01.LBL ”
MISSION_PHASE_NAME	CHARACTER	"N/A"
TARGET_NAME	CHARACTER	“MERCURY”
SITE_ID	CHARACTER	“N/A”
PRODUCT_ID	CHARACTER	“VIRS_DAP_500MPP_V01”
PRODUCT_VERSION_ID	CHARACTER	"V1 "
PRODUCT_CREATION_TIME	TIME	2013-06-05T12:30:31
DATA_SET_ID	CHARACTER	“MESS-E/V/H-MASCS-5-VIRS-DAP-V2.0”
STANDARD_DATA_PRODUCT_ID	CHARACTER	VIRSDAP
START_TIME	TIME	2011-03-29T02:02:40
STOP_TIME	TIME	2013-03-17T22:55:43
START_MET_PARTITION	ASCII_INTEGER	1
SPACECRAFT_CLOCK_START_COUNT	CHARACTER	“1/209851629”
SPACECRAFT_CLOCK_STOP_COUNT	CHARACTER	“2/5884942”

Table 3c: VDAPINDEX.TAB Columns.

Column	Format	Example
VOLUME_ID	CHARACTER	“MESSMAS_2001”
FILE_SPECIFICATION_NAME	CHARACTER	“DATA/DDR/OB4/UVVS_VIRS_COMBINED/MASCS20140625/UVVSVIRSD_14176_041429.LBL”
MISSION_PHASE_NAME	CHARACTER	"MERCURY ORBIT YEAR 4"
TARGET_NAME	CHARACTER	“MERCURY”
PRODUCT_ID	CHARACTER	“UVVSVIRSD_14176_041429_DAT”
PRODUCT_VERSION_ID	CHARACTER	"V1 "
PRODUCT_CREATION_TIME	TIME	2016-07-26T13:22:44
DATA_SET_ID	CHARACTER	“MESS-E/V/H-MASCS-4-UVVS/VIRS-DDR-V1.0”
STANDARD_DATA_PRODUCT_ID	CHARACTER	UVVSVIRSD
START_TIME	TIME	"N/A"
STOP_TIME	TIME	"N/A"
SPACECRAFT_CLOCK_START_COUNT	CHARACTER	"N/A"
SPACECRAFT_CLOCK_STOP_COUNT	CHARACTER	"N/A"

Column	Format	Example
SUMMARY_DATA_QUALITY	CHARACTER	“0000000”

Table 3d: UVDINDEX.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. A grating offset correction was implemented for PDS Release 16. This table is a record of the time periods relevant to and the magnitudes (in grating steps) of the offsets.

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 will 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.

UVVSSUMD.FMT - Format of the UVVS atmosphere summary DDR data table.

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

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

UVVSSCID_FUV_SUR.FMT - Format of the UVVS FUV surface science DDR data table.

UVVSVIRSD.FMT - Format of the UVVS+VIRS Combined DDR data table.

<EXTRAS> Directory

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

VIRS_AV/ - This subdirectory contains the VIRS animated visualization products, organized by mission phase and provided in .MP4 format. VIRS_AV_DESCRIPTION.PDF describes these products in detail.

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 images (*.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_SUMMARY_ATMOSPHERE>, <UVVS_SURFACE>, <UVVS_VIRS_COMBINED>, and <VIRS> directories. The <UVVS_ATMOSPHERE> directory is further subdivided into directories based on the Mercury year of data acquisition (01-04 for primary mission, 05+ for extended mission). The <UVVS_SUMMARY_ATMOSPHERE> directory is subdivided into species directories which are further subdivided into directories based on Mercury year. Each of the <UVVS_SURFACE>, <UVVS_VIRS_COMBINED>, and <VIRS> directories is subdivided into <MASCSYYYYMMDD> date directories. The VIRS directories are further subdivided into <VIS> and <NIR> detector subdirectories following the structure of the VIRS CDRs. The <UVVS_SURFACE> directories are further subdivided into <FUV> and <MUV> detector subdirectories. Within the Mercury year (<UVVS_ATMOSPHERE>, <UVVS_SUMMARY_ATMOSPHERE>), date (<UVVS_VIRS_COMBINED>), and detector (<UVVS_SURFACE>, <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 <ORB/UVVS_ATMOSPHERE>.

6.2 Data Format Description

VIRS CDRs and DDRs are stored in binary table format (*.DAT), while the VIRS DAP is stored as an image object (*.IMG). A detached PDS label file (*.LBL) provides a detailed description of the structure of the binary table and images, respectively.

6.3 Label and Header Descriptions

There are two types of binary tables in this dataset, one each for the NIR and VIS detectors. The table columns are identical, except for the *SPECTRUM_DATA in the CDR and the *_DATA columns in the DDR. These columns may contain up to 256 values for the NIR detector, but up to 512 values for the VIS detector. Replicas of the VIRSNC.FMT, VIRSVC.FMT, VIRSND.FMT, and VIRSVD.FMT format files can be found in Appendices A-D, respectively.

The following are detailed descriptions of the columns used in the VIRS CDR/DDR binary table objects. They are numbered in the column order in which they appear in the tables. Every column has the number of rows equal to the total number of VIRS spectra in the original EDR. PACKET columns, such as SEQ counter, have the same value for all spectra found in a given packet. PER SPECTRUM columns have different values for each spectrum in the CDR/DDR. The reference time for all PER SPECTRUM columns is: SC_TIME + PACKET_SUBSECONDS + PERIOD * SPECTRUM_NUMBER. OBSERVATION columns have the same value for the whole CDR/DDR - these are parameters such as integration time set during the VIRS setup command. All geometry fields utilize the standard J2000 center used by SPICE.

The UVVS+VIRS Combined DDR format is described in a separate specification document, UVVS_VIRS_COMBINED_DDR_SPEC.PDF, located in the DOCUMENT directory of this volume.

6.3.1 CDR Column Descriptions

6.3.1.1 Fields Obtained from Experiment Data Record (EDR)

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

CCSDS packet sequence counter. PACKET column.

2. SC_TIME
```
Bytes: 4        Type: MSB_UNSIGNED_INTEGER
```

Spacecraft time in integer seconds that is transmitted to MESSENGER subsystems by the Integrated Electronics Module. This is assigned to the first spectral observation contained in a science packet. All spectra contained in the science packet will be associated with this start time. Unit is in Mission Elapsed Time which is the number of seconds since launch. PACKET column.

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

Subsecond time in milliseconds that the telemetry packet was initiated. All spectra contained in the science packet will be associated with this subsecond start time. Unit is 5 milliseconds (i.e. all values will be to the nearest 5 milliseconds). PACKET column.

4. INT_TIME
```
Bytes: 2        Type: MSB_UNSIGNED_INTEGER
```

Amount of time the array detectors will integrate photon counts. Unit is 0.05 second. OBSERVATION column.

5. INT_COUNT
```
Bytes: 2        Type: MSB_UNSIGNED_INTEGER
```

Total amount of integrations that will be taken. OBSERVATION column.

6. PERIOD
```
Bytes: 2        Type: MSB_UNSIGNED_INTEGER
```

Interval time after which another integration will be started. Integrations are started at the top of every period. Unit is 0.05 second. There is a 5-unit overhead between consecutive integrations, so PERIOD (in units) = INT_TIME (in units) + 5. OBSERVATION column.

7. DARK_FREQ
```
Bytes: 2        Type: MSB_UNSIGNED_INTEGER
```

Dark counts will be collected every X integrations during a VIRS observation. OBSERVATION column.

8. TEMP_1
`Bytes: 4        Type: IEEE_REAL`

One of a redundant pair of array temperature sensors. A more complete description of this field can be found in the MASCS User's Guide (Applicable Document 6 in VIRS_CDR_DDR_DAP_SIS.PDF). Conversion from raw counts (DN) to degrees Celsius is:

TEMP_1 = -3.34338E-18 * DN^5 + 8.979E-15 * DN^4 + 3.8131E-11 * DN^3
- 2.703E-8 * DN^2 - 0.0061 * DN - 1.67826.

PER SPECTRUM column.

9. TEMP_2
`Bytes: 4        Type: IEEE_REAL`

One of a redundant pair of array temperature sensors. A more complete description of this field can be found in the MASCS User's Guide (Applicable Document 6 in VIRS_CDR_DDR_DAP_SIS.PDF). Conversion from raw counts (DN) to degrees Celsius is:

For the VIS detector it is the same as for TEMP_1
For the NIR detector it is:

TEMP_2 = -8.89100589E-18 * DN^5 - 9.72043502E-15 * DN^4
+ 1.73862825E-10 * DN^3 + 3.39958815E-7 * DN^2
- 0.00702301101 * DN - 22.2879012.

PER SPECTRUM column.

10. NIR_GAIN
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Gain of NIR array detector. A more complete description of this field can be found in the MASCS User's Guide (Applicable Document 6 in VIRS_CDR_DDR_DAP_SIS.PDF). 0=Low, 1= High, 999=N/A value when VIS detector is enabled. OBSERVATION column.

11. OTHER_CHANNEL_ON
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

The other array is powered on or off (VIS in a NIR packet, NIR in a VIS packet). A value of 0 is off, a value of 1 is on. OBSERVATION column.

12. NIR_LAMP_ON
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

NIR flat field lamp is powered on or off. A value of 0 is off, a value of 1 is on. OBSERVATION column.

13. VIS_LAMP_ON
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

VIS flat field lamp is powered on or off. A value of 0 is off, a value of 1 is on. OBSERVATION column.

14. BINNING
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Number of pixels that were binned together in the data. A flight-software update during the mission changed how the pixels were binned. For data with SPECTRUM_UTC_TIME prior to March 16, 2009, the pixels were co-added. For data with SPECTRUM_UTC_TIME on or after March 16, 2009, the multiple pixels were averaged. OBSERVATION column.

15. START_PIXEL

```
Bytes: 2       Type: MSB_UNSIGNED_INTEGER
```

Start pixel of data captured by the detector array. For VIS the value can be from 0-511. For NIR the value can be from 0-255. OBSERVATION column.

16. END_PIXEL

```
Bytes: 2       Type: MSB_UNSIGNED_INTEGER
```

End pixel of data captured by the detector array. For VIS the value can be from 0-511. For NIR the value can be from 0-255. The END_PIXEL must be greater than START_PIXEL. OBSERVATION column.

17. SPECTRUM_NUMBER

```
Bytes: 2       Type: MSB_UNSIGNED_INTEGER
```

Ordered number sequence for spectra in a given observation. First spectrum is 0, second is 1, third is 2, and so on. Note that for observations which span multiple science packets, the numbering sequence is continuous. PER SPECTRUM column.

18. SPECTRUM_MET

```
Bytes: 4       Type: MSB_UNSIGNED_INTEGER
```

A calculated value intended to reflect mission elapsed time (in seconds) since launch (for partition 1) or since reset (for partition 2) at the start of an individual VIRS spectrum. This is derived using the following formula:

SPECTRUM_MET = SC_TIME + floor(SPECTRUM_NUMBER * PERIOD * 0.050)

PER SPECTRUM column.

19. SPECTRUM_SUBSECONDS

```
Bytes: 2       Type: MSB_UNSIGNED_INTEGER
```

The calculated subsecond time in milliseconds that a VIRS integration was started. For each VIRS integration, SPECTRUM_MET plus SPECTRUM_SUBSECONDS gives the spacecraft time of the start of that integration. This is derived using the following formula:

SPECTRUM_SUBSECONDS = (PACKET_SUBSECONDS + SPECTRUM_NUMBER * PERIOD * 50) mod 1000.

PER SPECTRUM Column.

20. RAW_SPECTRUM_DATA

```
Bytes: 512     Type: MSB_INTEGER
Num Items: 256 Item Bytes: 2
```

Column of uncompressed raw spectra at full 16-bit resolution. One row per spectrum. NIR spectrum has up to 256 values (depending in binning and windowing), VIS has up to 512. Unit = counts. PER SPECTRUM column.

6.3.1.2 Calibrated Items and Additional Metadata

21. SPECTRUM_UTC_TIME
```
Bytes: 17      Type: CHARACTER
```

UTC time in YYDOYTHH:MM:SS.00 format translated from spacecraft time and packet subseconds (in integer seconds) that is transmitted to MESSENGER subsystems by the Integrated Electronics Module. PER SPECTRUM column.

22. CORRECTED_COUNTS_SPECTRUM_DATA
```
Bytes: 1024    Type: IEEE_REAL
Num Items: 256 Item Bytes: 4
```

Derived column of corrected counts spectra. Counts corrected for darks, and other instrument level corrections (e.g. temperature, scattered light, etc. as determined by most current calibration.) One row per spectrum. NIR spectrum has up to 256 values (depending on binning and windowing), VIS has up to 512. Unit = corrected counts/second. PER SPECTRUM column.

23. CALIBRATED_RADIANCE_SPECTRUM_DATA
```
Bytes: 1024    Type: IEEE_REAL
Num Items: 256 Item Bytes: 4
```

Derived column of radiance-at-sensor spectra. One row per spectrum. NIR spectrum has up to 256 values (depending on binning and windowing), VIS has up to 512. Unit = W/(m^2 steradian micron). Radiance from saturated pixels, or binned pixels with one saturated element, are set to 1e32. PER SPECTRUM column.

24. NOISE_SPECTRUM_DATA
```
Bytes: 1024    Type: IEEE_REAL
Num Items: 256 Item Bytes: 4
```

Derived column of noise/error propagated through calibration procedure. One row per spectrum. NIR spectrum has up to 256 values (depending on binning and windowing), VIS has up to 512. Unit = W/(m^2 steradian micron). Noise from saturated pixels, or binned pixels with one saturated element, are set to 1e32. PER SPECTRUM column.

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

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

26. CHANNEL_WAVELENGTHS
```
Bytes: 1024    Type: IEEE_REAL
Num Items: 256 Item Bytes: 4
```

Column of wavelengths paired to spectrum data channels. Wavelengths derived from calibration report equation 6.5:

$$\lambda = 215.16 + 2.330 \bullet n - 1.89\text{x}10^{-5} \bullet n^2 \text{ nm (VIS)}$$

$$\lambda = 896.50 + 2.330 \bullet n + 1.48\text{x}10^{-5} \bullet n^2 \text{ nm (NIR)}$$

where n is the detector channel number. Unit = nanometers. OBSERVATION column.

27. HK_DATA_FLAG
```
Bytes: 4       Type: MSB_INTEGER
```

Null, or indicates HK data rate in inverse seconds. OBSERVATION column.

28. DATA_QUALITY_INDEX

```
Bytes: 19      Type: CHARACTER
```

19 character index of data quality. Each digit signifies quality factor of measurements. PER SPECTRUM column.
Format: ABCD-EFGH-IJKL-MNOP
A: Dark Scan Flag, denotes shutter commanded closed for dark observation.
  0 = shutter not engaged
  1 = shutter engaged
* Note: The position monitor on the VIRS shutter is an LED-photodiode pair; the light path is blocked when the shutter is closed and is clear when the shutter is open. To avoid introducing light from the LED into the VIRS detectors, the LED is powered only when it is time (by the housekeeping packet schedule) to read the monitor and no VIRS scan is currently integrating. The "valid" flag indicates whether those 2 conditions were met the last time the MASCS team was due to check the monitor.
B: Temperature 1 Flag
  0 = Temperature does not exceed 15 deg C threshold.
  1 = Temperature exceeds 15 deg C threshold but less than 25 deg C threshold.
  2 = Temperature exceeds 25 deg C threshold but less than 40 deg C threshold.
  3 = Temperature exceeds 40 deg C threshold.
C: Temperature 2 Flag
  0 = Temperature does not exceed 15 deg C threshold.
  1 = Temperature exceeds 15 deg C threshold but less than 25 deg C threshold.
  2 = Temperature exceeds 25 deg C threshold but less than 40 deg C threshold.
  3 = Temperature exceeds 40 deg C threshold.
D: Grating Temperature Flag
  0 = Temperature does not exceed 15 deg C threshold.
  1 = Temperature exceeds 15 deg C threshold but less than 25 deg C threshold.
  2 = Temperature exceeds 25 deg C threshold but less than 40 deg C threshold.
  3 = Temperature exceeds 40 deg C threshold.
E: Anomalous Pixels
  Integer 0-9 = Indicates number of hot pixels found.
  Working Definition: The number of pixels with a noise spike (defined in DQI L, below).
  Procedure: The number of noise spike channels for spectra i. Repeat for all N spectra.
F: Partial Data Flag
  0 = No partial data.
  1 = Partial data exists.
  Working Definition: If any spectrum has nulls in the beginning or end, signifying data drop outs.
  Procedure: Given spectra i, evaluate first 10 channels and last 10 channels. If any channel has 0 value, set Partial Data Flag = 1.
G: Saturation Flag
  0 = No pixels saturated.
  1 = Saturated pixels exist.
H: Low Signal Level Flag
  0 = Signal level not below -32768 threshold.
  1 = Signal level below -32768 threshold.
I: Low VIS Wavelength Uncertainty Flag (not yet implemented, set to 0)
  0 = Uncertainty not above TBD threshold at low wavelengths.
  1 = Uncertainty above TBD threshold at low wavelengths.
J: High VIS Wavelength Uncertainty Flag (not yet implemented, set to 0)
  0 = Uncertainty not above TBD threshold at high wavelengths.
  1 = Uncertainty above TBD threshold at high wavelengths.
K: UVVS Operating Flag
  0 = UVVS is not scanning during readout.
  1 = UVVS is scanning during readout.
L: UVVS Noise Spike Flag
  0 = No noise spike detected.
  1 = Noise spike detected.
  Using VIRS VIS (512 channel spectrum, N spectra per CDR) as an example,

Working Definition: A noise spike is a data value in 1 or 2 channels that exceeds 3 standard deviations of the average for a given channel in a given observation.
Procedure: Calculate the standard deviation for channel 1 through all 1-N spectra. If spectra i has stdev >=3, then spectra i has a noise spike. Repeat calculation for channels 2-512. Keep track of the number of 'noise spike channels' per spectra.

M: 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

N: Dark Saturation Flag
Denotes that there are minimal unsaturated dark frames available for the polynomial fit of one or more pixels.
0 = All pixels in data record contain at least four unsaturated dark frames.
1 = One or more pixels in data record contain three or fewer unsaturated dark frames.

O-P: Spares

29. VIRS_GRATING_TEMP
```
Bytes: 4        Type: IEEE_REAL
```

Derived VIRS grating temperature from HK data in degrees Celsius. PER SPECTRUM column.

6.3.1.3 SPICE Derived Geometry Values

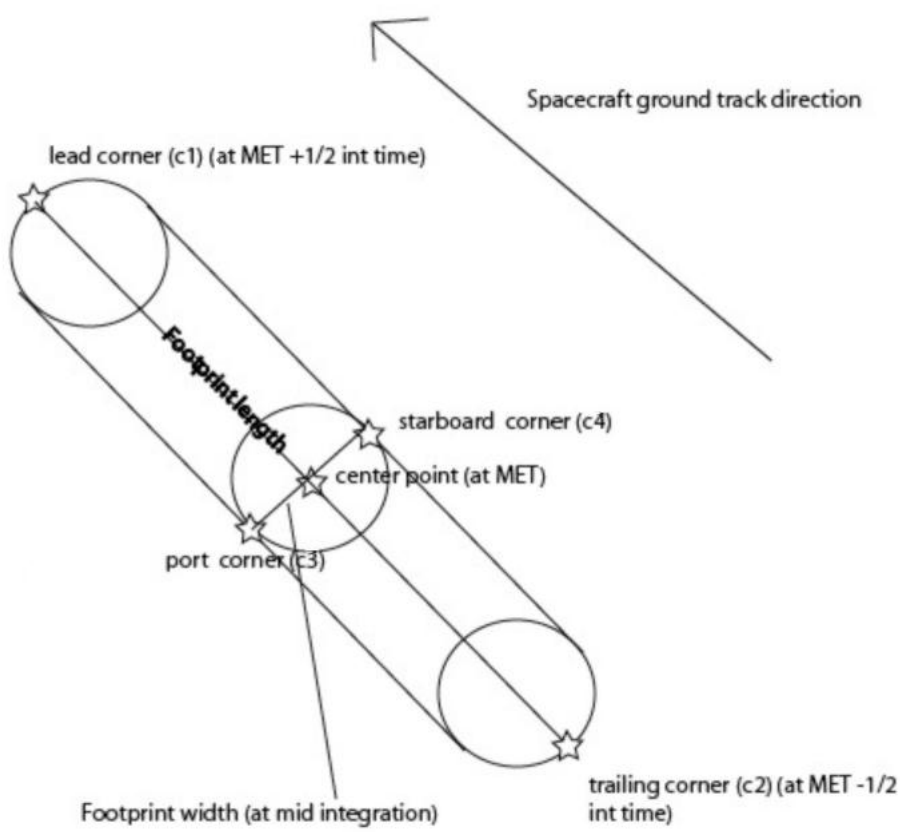


Figure 4: VIRS Geometry Illustration.

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

Derived latitude of footprint center, uprange edge (c1), downrange edge (c2), port, (c3) and starboard (c4) edges (5 total values, coordinates as in Figure 4; center point, c1, c2, c3, c4) on planet target corresponding to spectral observation. Unit = degrees. PER SPECTRUM column.

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

Derived longitude of footprint center, uprange edge (c1), downrange edge (c2), port, (c3) and starboard (c4) edges (5 total values, coordinates as in Figure 4; center point, c1, c2, c3, c4) on planet target corresponding to spectral observation. Unit = degrees. PER SPECTRUM column.

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

Derived length of VIRS footprint along track over the spectrum integration time, accounting for smear across surface. Unit = meters. PER SPECTRUM column.

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

Derived instantaneous width of VIRS footprint across track at the spectrum integration midpoint, accounting for jitter across surface. Unit = meters. PER SPECTRUM column.

34. FOOTPRINT_AZIMUTH
```
Bytes: 8        Type: IEEE_REAL
```

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

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

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

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

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

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

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

38. 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 SPECTRUM column.

39. SUBSPACECRAFT_LATITUDE
`Bytes: 8        Type: IEEE_REAL`

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

40. SUBSPACECRAFT_LONGITUDE
`Bytes: 8        Type: IEEE_REAL`

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

41. NADIR_ALTITUDE
`Bytes: 8        Type: IEEE_REAL`

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

42. SUBSOLAR_LATITUDE
`Bytes: 8        Type: IEEE_REAL`

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

43. SUBSOLAR_LONGITUDE
`Bytes: 8        Type: IEEE_REAL`

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

44. SOLAR_DISTANCE
`Bytes: 8        Type: IEEE_REAL`

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

45. PLANET_TRUE_ANOMALY
`Bytes: 8        Type: IEEE_REAL`

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

46. SPARE_1
`Bytes: 4        Type: IEEE_REAL`

SPARE column.

47. RIGHT_ASCENSION
`Bytes: 8        Type: IEEE_REAL`

Right ascension. Unit = degrees. PER SPECTRUM column.

48. DECLINATION
`Bytes: 8        Type: IEEE_REAL`

Declination. Unit = degrees. PER SPECTRUM column.

6.3.1.4 SPARE Columns

49. SPARE_2
```
Bytes: 4        Type: MSB_INTEGER
```

SPARE column.

50. SPARE_3
```
Bytes: 4        Type: MSB_INTEGER
```

SPARE column.

51. SPARE_4
```
Bytes: 4        Type: MSB_INTEGER
```

SPARE column.

52. SPARE_5
```
Bytes: 4        Type: MSB_INTEGER
```

SPARE column.

53. SPARE_6
```
Bytes: 4        Type: MSB_INTEGER
```

SPARE column.

54. SPARE_7
```
Bytes: 4        Type: MSB_INTEGER
```

SPARE column.

55. SPARE_8
```
Bytes: 4        Type: MSB_INTEGER
```

SPARE column.

56. SPARE_9
```
Bytes: 4        Type: MSB_INTEGER
```

SPARE column.

57. SPARE_10
```
Bytes: 4        Type: MSB_INTEGER
```

SPARE column.

58. SPARE_11
```
Bytes: 4        Type: MSB_INTEGER
```

SPARE column.

6.3.2 DDR Column Descriptions

6.3.2.1 Fields Obtained from Experiment Data Record (EDR)

1. SC_TIME
`Bytes: 4        Type: MSB_UNSIGNED_INTEGER`

Spacecraft time in integer seconds that is transmitted to MESSENGER subsystems by the Integrated Electronics Module. This is assigned to the first spectral observation contained in a science packet. All spectra contained in the science packet will be associated with this start time. Unit is in Mission Elapsed Time which is the number of seconds since launch. PACKET column.

2. PACKET_SUBSECONDS
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Subsecond time in milliseconds that the telemetry packet was initiated. All spectra contained in the science packet will be associated with this subsecond start time. Unit is 5 milliseconds (i.e. all values will be to the nearest 5 milliseconds). PACKET column.

3. INT_TIME
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Amount of time the array detectors will integrate photon counts. Unit is 0.05 second. OBSERVATION column.

4. INT_COUNT
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Total amount of integrations that will be taken. OBSERVATION column.

5. DARK_FREQ
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Dark counts will be collected every X integrations during a VIRS observation. OBSERVATION column.

6. TEMP_2
`Bytes: 4        Type: IEEE_REAL`

One of a redundant pair of array temperature sensors. A more complete description of this field can be found in the MASCS User's Guide (Applicable Document 6 in VIRS_CDR_DDR_DAP_SIS.PDF). Conversion from raw counts (DN) to degrees Celsius is:

For the VIS detector it is the same as for TEMP_1
For the NIR detector it is:

TEMP_2 = -8.89100589E-18 * DN^5 - 9.72043502E-15 * DN^4
+ 1.73862825E-10 * DN^3 + 3.39958815E-7 * DN^2
- 0.00702301101 * DN - 22.2879012.

For other temperature data (TEMP_1 and GRATING_TEMP) see CDR.
PER SPECTRUM column.

7. BINNING
`Bytes: 2        Type: MSB_UNSIGNED_INTEGER`

Number of pixels that were binned together in the data. A flight-software update during the mission changed how the pixels were binned. For data with SPECTRUM_UTC_TIME prior to March 16, 2009, the pixels were co-added.

For data with SPECTRUM_UTC_TIME on or after March 16, 2009, the multiple pixels were averaged. OBSERVATION column.

8. START_PIXEL
```
Bytes: 2        Type: MSB_UNSIGNED_INTEGER
```

Start pixel of data captured by the detector array. For VIS the value can be from 0-511. For NIR the value can be from 0-255. OBSERVATION column.

9. END_PIXEL
```
Bytes: 2        Type: MSB_UNSIGNED_INTEGER
```

End pixel of data captured by the detector array. For VIS the value can be from 0-511. For NIR the value can be from 0-255. The END_PIXEL must be greater than START_PIXEL. OBSERVATION column.

10. SPECTRUM_NUMBER
```
Bytes: 2        Type: MSB_UNSIGNED_INTEGER
```

Ordered number sequence for spectra in a given observation. First spectrum is 0, second is 1, third is 2, and so on. Note that for observations which span multiple science packets, the numbering sequence is continuous. PER SPECTRUM column.

11. SPECTRUM_MET
```
Bytes: 4        Type: MSB_UNSIGNED_INTEGER
```

A calculated value intended to reflect mission elapsed time (in seconds) since launch (for partition 1) or since reset (for partition 2) at the start of an individual VIRS spectrum. This is derived using the following formula:

SPECTRUM_MET = SC_TIME + floor(SPECTRUM_NUMBER * PERIOD * 0.050)

PER SPECTRUM column.

12. SPECTRUM_SUBSECONDS
```
Bytes: 2        Type: MSB_UNSIGNED_INTEGER
```

The calculated subsecond time in milliseconds that a VIRS integration was started. For each VIRS integration, SPECTRUM_MET plus SPECTRUM_SUBSECONDS gives the spacecraft time of the start of that integration. This is derived using the following formula:

SPECTRUM_SUBSECONDS = (PACKET_SUBSECONDS + SPECTRUM_NUMBER * PERIOD * 50) mod 1000.

PER SPECTRUM Column.

6.3.2.2 Derived Items and Additional Metadata

13. SPECTRUM_UTC_TIME
```
Bytes: 17       Type: CHARACTER
```

UTC time in YYDOYTHH:MM:SS.00 format translated from spacecraft time and packet subseconds (in integer seconds) that is transmitted to MESSENGER subsystems by the Integrated Electronics Module. PER SPECTRUM column.

14. IOF_SPECTRUM_DATA
```
Bytes: 1024     Type: IEEE_REAL
Num Items: 256 Item Bytes: 4
```

Derived column of reflectance-at-sensor spectra. One row per spectrum. NIR spectrum has up to 256 values (depending on binning and windowing), VIS has up to 512. Reflectance is a unitless parameter. Reflectance from saturated pixels, or binned pixels with one saturated element, are set to 1e32. PER SPECTRUM column.

15. PHOTOM_IOF_SPECTRUM_DATA

```
Bytes: 1024    Type: IEEE_REAL
Num Items: 256 Item Bytes: 4
```

Derived column of photometrically normalized reflectance-at-sensor spectra. One row per spectrum. NIR spectrum has up to 256 values (depending on binning and windowing), VIS has up to 512. Reflectance is a unitless parameter. Reflectance from saturated pixels, or binned pixels with one saturated element, are set to 1e32. PER SPECTRUM column.

The MASCS instrument was mounted on the spacecraft's instrument deck at a fixed 90° angle to the sun shield. MASCS observations were limited to 90° ± 12° in phase angle; this represents the allowable range within the spacecraft pitch and roll operations that would keep instrumentation and equipment safe behind the sun shield. The limitations on spacecraft pointing result in phase angles for MASCS that range from α = 78° to 102°. Most of the planet was observed at the minimum phase angle possible, between 78° and 80°, though the southernmost latitudes are observable only at a near 102°. To facilitate a direct comparison of absolute reflectance between any two measurements obtained at an arbitrary viewing geometry, we employed a photometric normalization. The majority of libraries of laboratory spectral measurements of planetary analog materials contain spectra acquired with an incidence angle of 30°, an emission angle of 0°, and a phase angle of 30°, a standard adopted to confine spectral variations among samples to those resulting from mineralogy. Normalization of MASCS observations to a typical laboratory geometry of i = 30°, e = 0°, α = 30° would involve extrapolation far beyond the range of angles of MASCS measurements and would likely result in large errors. We therefore chose to normalize all data to a viewing geometry of i = 45°, e = 45°, and α = 90°.

There are two versions of photometrically normalized data within the archive. Version 1 represents the photometric normalization employed prior to March 2017, and was applied to both the VIS and NIR data sets. Version 2 represents the photometric normalization employed to the VIS data only after March 2017, resulting from an in-depth examination of photometric observations acquired during orbit. The Version 1 correction is based on fly-by observations only.

Version 1 photometric normalization: This version models the dependence of reflectance on viewing geometry following the methodology of Hillier et al. (1999). The reflectance in the Hillier model is represented by the function f, which is the combination of a Lommel-Seeliger term describing the dependence on incidence and emission angle values and a phase function to represent phase angle effects:

$$f(i,e,\alpha) = \frac{\cos i}{\cos i + \cos e} p(\alpha) \tag{1}$$

where i, e, and α are the incidence, emission, and phase angles for a given observation, and $p(\alpha)$ is the phase function. A linear relation was found to adequately represent the phase function:

$$p(\alpha) = a_0 + a_1\alpha \tag{2}$$

where α_0 = 0.0576, α_1 = 3.52x10^4, and the phase angle α is in degrees. The values of the coefficients were found to be similar at 400 nm and 700 nm, implying that variations with wavelength are negligible. The photometrically standardized reflectance (r'(45,45,90)) for a given observation is defined as the reflectance at i = 45°, e = 45°, and α = 90° and is provided by:

$$r'(45, 45, 90) = r(i, e, \alpha)\frac{f(45, 45, 90)}{f(i, e, \alpha)} \tag{3}$$

where r(i,e,α) is the observed reflectance, $f(i,e,\alpha)$ Hillier predicted reflectance at the observational geometry, and f(45,45,90) is the Hillier predicted reflectanceat the standardization geometry.

Version 2 photometric normalization: Domingue et al. (2016) describe a set of photometric models based on the work of Kaasalainen et al. (2001) and Shkuratov et al. (2011), which were applied to the MDIS data set. The Kaasalainen-Shkuratov model that best described the MDIS data was the version applied to the MASCS/VIRS photometric data acquired during orbit (Domingue et al. 2017). The Kaasalainen-Shkuratov model is given by:

$$r(i, e, \alpha) = A_N e^{-\alpha\mu}\left[c_l\left(\frac{2cosi}{cosi + cose}\right) + (1 - c_l)cosi\right] \quad (4)$$

where A_N is the normal albedo, c_l is a partition parameter between the Lommel-Seeliger $\left(\frac{2cosi}{cosi+cose}\right)$ and Lambert ($cosi$) type scattering, and μ is the disk-function parameter associated with surface roughness (Shkuratov et al. 2011). The parameter values display a wavelength dependence that can be described with a polynomial. Table 4 provides the polynomial coefficient values for each parameter.

Coefficient	A_N	μ	C_l
A_4		1.04E-11	-6.20E-12
A_3	7.73E-10	-2.50E-08	1.52E-08
A_2	-1.57E-06	2.15E-05	-1.36E-05
A_1	1.17E-03	-7.86E-03	5.12E-03
A_0	-1.85E-01	1.54E+00	-3.25E-01

Table 4: Polynomial Coefficients

The photometrically standardized reflectance (r'(45,45,90)) for a given observation is defined as the reflectance at i = 45°, e = 45°, and α = 90°, and is provided by:

$$r'(45, 45, 90) = r(i, e, \alpha)\frac{f(45, 45, 90)}{f(i, e, \alpha)} \tag{5}$$

where $r(i,e,\alpha)$ is the observed reflectance, $f(i,e,\alpha)$ is the Kaasalainen-Shkuratov model predicted reflectance at the observational geometry, and f(45,45,90) is the Kaasalainen-Shkuratov model predicted reflectance at the standardization geometry.

16. IOF_NOISE_SPECTRUM_DATA

```
Bytes: 1024    Type: IEEE_REAL
Num Items: 256 Item Bytes: 4
```

Derived column of noise/error in reflectance propagated through post-calibration procedure. One row per spectrum. NIR spectrum has up to 256 values (depending on binning and windowing), VIS has up to 512. Unitless. Noise from saturated pixels, or binned pixels with one saturated element, are set to 1e32. PER SPECTRUM column.

17. PHOTOM_IOF_NOISE_SPECTRUM_DATA

```
Bytes: 1024    Type: IEEE_REAL
Num Items: 256 Item Bytes: 4
```

Derived column of noise/error in photometrically normalized reflectance propagated through post-calibration procedure. One row per spectrum. NIR spectrum has up to 256 values (depending on binning and windowing), VIS has up to 512. Unitless. Noise from saturated pixels, or binned pixels with one saturated element, are set to 1e32. PER SPECTRUM column.

18. SOFTWARE_VERSION

```
Bytes: 4       Type: IEEE_REAL
```

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

19. CHANNEL_WAVELENGTHS

```
NIR-
Bytes: 1024    Type: IEEE_REAL
Num Items: 256 Item Bytes: 4

VIS-
Bytes: 2048    Type: IEEE_REAL
Num Items: 512 Item Bytes: 4
```

Column of wavelengths paired to spectrum data channels. Wavelengths derived from calibration report equation 6.5:

$\lambda = 215.16 + 2.330 \bullet n - 1.89\text{x}10^{-5} \bullet n^2$ nm (VIS)

$\lambda = 896.50 + 2.330 \bullet n + 1.48\text{x}10^{-5} \bullet n^2$ nm (NIR)

where *n* is the detector channel number. Unit = nanometers. OBSERVATION column.

20. DATA_QUALITY_INDEX

```
Bytes: 19      Type: CHARACTER
```

19 character index of data quality. Each digit signifies quality factor of measurements. PER SPECTRUM column.
Format: ABCD-EFGH-IJKL-MNOP
A: Dark Scan Flag, denotes shutter commanded closed for dark observation.
  0 = shutter not engaged
  1 = shutter engaged
* Note: The position monitor on the VIRS shutter is an LED-photodiode pair; the light path is blocked when the shutter is closed and is clear when the shutter is open. To avoid introducing light from the LED into the VIRS detectors, the LED is powered only when it is time (by the housekeeping packet schedule) to read the monitor and no VIRS scan is currently integrating. The "valid" flag indicates whether those 2 conditions were met the last time the MASCS team was due to check the monitor.
B: Temperature 1 Flag
  0 = Temperature does not exceed 15 deg C threshold.
  1 = Temperature exceeds 15 deg C threshold but less than 25 deg C threshold.
  2 = Temperature exceeds 25 deg C threshold but less than 40 deg C threshold.
  3 = Temperature exceeds 40 deg C threshold.
C: Temperature 2 Flag
  0 = Temperature does not exceed 15 deg C threshold.
  1 = Temperature exceeds 15 deg C threshold but less than 25 deg C threshold.
  2 = Temperature exceeds 25 deg C threshold but less than 40 deg C threshold.
  3 = Temperature exceeds 40 deg C threshold.
D: Grating Temperature Flag
  0 = Temperature does not exceed 15 deg C threshold.
  1 = Temperature exceeds 15 deg C threshold but less than 25 deg C threshold.
  2 = Temperature exceeds 25 deg C threshold but less than 40 deg C threshold.
  3 = Temperature exceeds 40 deg C threshold.
E: Anomalous Pixels

Integer 0-9 = Indicates number of hot pixels found.
Working Definition: The number of pixels with a noise spike (defined in DQI L, below).
Procedure: The number of noise spike channels for spectra i. Repeat for all N spectra.
F: Partial Data Flag
0 = No partial data.
1 = Partial data exists.
Working Definition: If any spectrum has nulls in the beginning or end, signifying data drop outs.
Procedure: Given spectra i, evaluate first 10 channels and last 10 channels. If any channel has 0 value, set Partial Data Flag = 1.
G: Saturation Flag
0 = No pixels saturated.
1 = Saturated pixels exist.
H: Low Signal Level Flag
0 = Signal level not below -32768 threshold.
1 = Signal level below -32768 threshold.
I: Low VIS Wavelength Uncertainty Flag (not yet implemented, set to 0)
0 = Uncertainty not above TBD threshold at low wavelengths.
1 = Uncertainty above TBD threshold at low wavelengths.
J: High VIS Wavelength Uncertainty Flag (not yet implemented, set to 0)
0 = Uncertainty not above TBD threshold at high wavelengths.
1 = Uncertainty above TBD threshold at high wavelengths.
K: UVVS Operating Flag
0 = UVVS is not scanning during readout.
1 = UVVS is scanning during readout.
L: UVVS Noise Spike Flag
0 = No noise spike detected.
1 = Noise spike detected.
Using VIRS VIS (512 channel spectrum, N spectra per CDR) as an example,
Working Definition: A noise spike is a data value in 1 or 2 channels that exceeds 3 standard deviations of the average for a given channel in a given observation.
Procedure: Calculate the standard deviation for channel 1 through all 1-N spectra. If spectra i has stdev >=3, then spectra i has a noise spike. Repeat calculation for channels 2-512. Keep track of the number of 'noise spike channels' per spectra.
M: 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
N: Dark Saturation Flag
Denotes that there are minimal unsaturated dark frames available for the polynomial fit of one or more pixels.
0 = All pixels in data record contain at least four unsaturated dark frames.
1 = One or more pixels in data record contain three or fewer unsaturated dark frames.
O-P: Spares

6.3.2.3 SPICE Derived Geometry Values

The SPICE derived geometry values are taken directly from the CDR.

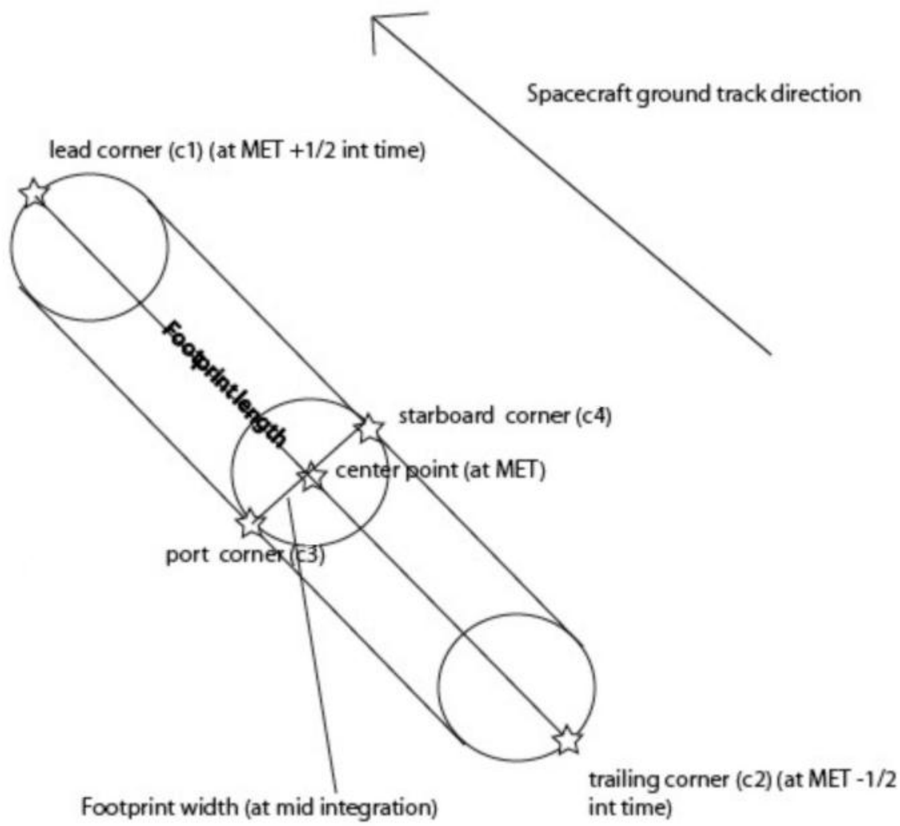


Figure 4: VIRS Geometry Illustration.

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

Derived latitude of footprint center, uprange edge (c1), downrange edge (c2), port, (c3) and starboard (c4) edges (5 total values, coordinates as in Figure 4; center point, c1, c2, c3, c4) on planet target corresponding to spectral observation. Unit = degrees. PER SPECTRUM column.

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

Derived longitude of footprint center, uprange edge (c1), downrange edge (c2), port, (c3) and starboard (c4) edges (5 total values, coordinates as in Figure 4; center point, c1, c2, c3, c4) on planet target corresponding to spectral observation. Unit = degrees. PER SPECTRUM column.

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

Derived length of VIRS footprint along track over the spectrum integration time, accounting for smear across surface. Unit = meters. PER SPECTRUM column.

24. ACROSS_TRACK_FOOTPRINT_SIZE

Bytes: 8 Type: IEEE_REAL

Derived instantaneous width of VIRS footprint across track at the spectrum integration midpoint, accounting for jitter across surface. Unit = meters. PER SPECTRUM column.

25. INCIDENCE_ANGLE
Bytes: 8 Type: IEEE_REAL

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

26. EMISSION_ANGLE
Bytes: 8 Type: IEEE_REAL

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

27. PHASE_ANGLE
Bytes: 8 Type: IEEE_REAL

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

28. SOLAR_DISTANCE
Bytes: 8 Type: IEEE_REAL

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

6.3.2.4 SPARE Columns

29. SPARE_1
Bytes: 4 Type: IEEE_REAL

SPARE column.

30. SPARE_2
Bytes: 4 Type: MSB_INTEGER

SPARE column.

31. SPARE_3
Bytes: 4 Type: MSB_INTEGER

SPARE column.

32. SPARE_4
Bytes: 4 Type: MSB_INTEGER

SPARE column.

33. SPARE_5
Bytes: 4 Type: MSB_INTEGER

SPARE column.

7. Appendices

APPENDIX A- VIRSNC.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. PACKET 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 MESSENGER subsystems by the Integrated Electronics Module. This is
   assigned to the first spectral observation contained in a science packet.
   All spectra contained in the science packet will be associated with this
   start time. Unit is in Mission Elapsed Time which is the number of
   seconds since launch. PACKET column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = PACKET_SUBSECONDS
   COLUMN_NUMBER  = 3
   BYTES           = 2
   DATA_TYPE       = MSB_UNSIGNED_INTEGER
   START_BYTE      = 7
   DESCRIPTION     = "Subsecond time in milliseconds that the telemetry
   packet was initiated. All spectra contained in the science packet will
   be associated with this subsecond start time. Unit is 5 milliseconds
   (i.e. all values will be to the nearest 5 milliseconds). PACKET column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = INT_TIME
   COLUMN_NUMBER  = 4
   BYTES           = 2
   DATA_TYPE       = MSB_UNSIGNED_INTEGER
   START_BYTE      = 9
   DESCRIPTION     = "Amount of time the array detectors will integrate
   photon counts. Unit is 0.05 second. OBSERVATION column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = INT_COUNT
   COLUMN_NUMBER  = 5
   BYTES           = 2
   DATA_TYPE       = MSB_UNSIGNED_INTEGER
   START_BYTE      = 11
```

```
   DESCRIPTION    = "Total amount of integrations that will be taken.
   OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = PERIOD
   COLUMN_NUMBER  = 6
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 13
   DESCRIPTION    = "Interval time after which another integration will be
   started.  Integrations are started at the top of every period.  Unit is
   0.05 second. There is a 5-unit overhead between consecutive integrations,
   so PERIOD (in units) = INT_TIME (in units) + 5. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DARK_FREQ
   COLUMN_NUMBER  = 7
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 15
   DESCRIPTION    = "Dark counts will be collected every X integrations
   during a VIRS observation. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = TEMP_1
   COLUMN_NUMBER  = 8
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 17
   DESCRIPTION    = "One of a redundant pair of array temperature sensors. A
   more complete description of this field can be found in the MASCS User's
   Guide (Applicable Document 6 in VIRS_CDR_DDR_DAP_SIS.PDF).
   Conversion from raw counts (DN) to degrees Celsius is:
   TEMP_1 = -3.34338E-18 * DN^5 + 8.979E-15 * DN^4 + 3.8131E-11 * DN^3
   - 2.703E-8 * DN^2 - 0.0061 * DN - 1.67826
   PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = TEMP_2
   COLUMN_NUMBER  = 9
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 21
   DESCRIPTION    = "One of a redundant pair of array temperature sensors. A
   more complete description of this field can be found in the MASCS User's
   Guide (Applicable Document 6 in VIRS_CDR_DDR_DAP_SIS.PDF).
   Conversion from raw counts (DN) to degrees Celsius is:
   For the VIS detector it is the same as for TEMP_1
   For the NIR detector it is:
   TEMP_2 = -8.89100589E-18 * DN^5 - 9.72043502E-15 * DN^4
   + 1.73862825E-10 * DN^3 + 3.39958815E-7 * DN^2
   - 0.00702301101 * DN - 22.2879012
   PER SPECTRUM column."
```

```
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = NIR_GAIN
   COLUMN_NUMBER  = 10
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 25
   DESCRIPTION    = "Gain of NIR array detector. A more complete description
   of this field can be found in the MASCS User's Guide (Applicable Document
   6 in VIRS_CDR_DDR_DAP_SIS.PDF). 0 is Low, 1 is High, 999 is N/A value
   when VIS detector is enabled. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = OTHER_CHANNEL_ON
   COLUMN_NUMBER  = 11
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 27
   DESCRIPTION    = "The other array is powered on or off (VIS in a NIR
   packet, NIR in a VIS packet. A value of 0 is off, a value of 1 is on.
   OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = NIR_LAMP_ON
   COLUMN_NUMBER  = 12
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 29
   DESCRIPTION    = "NIR flat field lamp is powered on or off. A value of 0
   is off, a value of 1 is on. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = VIS_LAMP_ON
   COLUMN_NUMBER  = 13
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 31
   DESCRIPTION    = "VIS flat field lamp is powered on or off. A value of 0
   is off, a value of 1 is on. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = BINNING
   COLUMN_NUMBER  = 14
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 33
   DESCRIPTION    = "Number of pixels that were binned together in the data.
   A flight-software update during the mission changed how the pixels are
   were binned. For data with SPECTRUM_UTC_TIME prior to March 16, 2009,
   the pixels were co-added. For data with SPECTRUM_UTC_TIME on or after
   March 16, 2009, the multiple pixels were averaged. OBSERVATION column."
END_OBJECT    = COLUMN
```

```
OBJECT         = COLUMN
   NAME           = START_PIXEL
   COLUMN_NUMBER  = 15
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 35
   DESCRIPTION    = "Start pixel of data captured by the detector array. For
   VIS the value can be from 0-511. For NIR the value can be from 0-255.
   OBSERVATION column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = END_PIXEL
   COLUMN_NUMBER  = 16
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 37
   DESCRIPTION    = "End pixel of data captured by the detector array. For
   VIS the value can be from 0-511. For NIR the value can be from 0-255.
   The END_PIXEL must be greater than START_PIXEL. OBSERVATION column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = SPECTRUM_NUMBER
   COLUMN_NUMBER  = 17
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 39
   DESCRIPTION    = "Ordered number sequence for spectra in a given
   observation. First spectrum is 0, second is 1, third is 2, and so on.
   Note that for observations which span multiple science packets, the
   numbering sequence is continuous. PER SPECTRUM column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = SPECTRUM_MET
   COLUMN_NUMBER  = 18
   BYTES          = 4
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 41
   DESCRIPTION    = "A calculated value intended to reflect mission elapsed
   time (in seconds) since launch (for partition 1) or since reset (for
   partition 2) at the start of an individual VIRS spectrum.
   This is derived using the following formula:
   SPECTRUM_MET = SC_TIME + floor(SPECTRUM_NUMBER*PERIOD*0.050)
   PER SPECTRUM column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = SPECTRUM_SUBSECONDS
   COLUMN_NUMBER  = 19
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 45
   DESCRIPTION    = "The calculated subsecond time in milliseconds that a
   VIRS integration was started. For each VIRS integration, SPECTRUM_MET
```

```
   plus SPECTRUM_SUBSECONDS gives the spacecraft time of the start of that
   integration. This is derived using the following formula:
   SPECTRUM_SUBSECONDS = (PACKET_SUBSECONDS + SPECTRUM_NUMBER * PERIOD * 50)
   mod 1000
   PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = RAW_SPECTRUM_DATA
   COLUMN_NUMBER  = 20
   BYTES          = 512
   DATA_TYPE      = MSB_INTEGER
   START_BYTE     = 47
   ITEMS          = 256
   ITEM_BYTES     = 2
   DESCRIPTION    = "Column of uncompressed raw data at full 16-bit
   resolution. One row per spectrum, NIR spectrum has up to 256 values
   (depending on binning and windowing), VIS has up to 512. Unit = counts.
    PER SPECTRUM column."
END_OBJECT    = COLUMN

/* CALIBRATED ITEMS AND ADDITIONAL METADATA */
OBJECT        = COLUMN
   NAME           = SPECTRUM_UTC_TIME
   COLUMN_NUMBER  = 21
   BYTES          = 17
   DATA_TYPE      = CHARACTER
   START_BYTE     = 559
   DESCRIPTION = "UTC time in YYDOYTHH:MM:SS.00 format translated from
   spacecraft time and packet subseconds (in integer seconds) that is
   transmitted to MESSENGER subsystems by the Integrated Electronics Module.
   PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CORRECTED_COUNTS_SPECTRUM_DATA
   COLUMN_NUMBER  = 22
   BYTES          = 1024
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 576
   ITEMS          = 256
   ITEM_BYTES     = 4
   DESCRIPTION = "Derived column of corrected counts spectra. Counts
   corrected for darks, and other instrument level corrections (e.g.
   temperature, scattered light, etc. as determined by most current
   calibration.) One row per spectrum. NIR spectrum has up to 256 values
   (depending on binning and windowing), VIS has up to 512. Unit = corrected
   counts/second. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = CALIBRATED_RADIANCE_SPECTRUM_DATA
   COLUMN_NUMBER    = 23
   BYTES            = 1024
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 1600
   ITEMS            = 256
```

```
   ITEM_BYTES       = 4
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived column of radiance-at-sensor spectra. One row per
   spectrum. NIR spectrum has up to 256 values (depending on binning and
   windowing), VIS has up to 512. Unit = W/(m^2 steradian micron). Radiance
   from saturated pixels, or binned pixels with one saturated element, are
   set to 1e32. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = NOISE_SPECTRUM_DATA
   COLUMN_NUMBER    = 24
   BYTES            = 1024
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 2624
   ITEMS            = 256
   ITEM_BYTES       = 4
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived column of noise/error propagated through
   calibration procedure. One row per spectrum. NIR spectrum has up to 256
   values (depending on binning and windowing), VIS has up to 512.
   Unit = W/(m^2 steradian micron). Noise from saturated pixels, or binned
   pixels with one saturated element, are set to 1e32. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CALIBRATION_SOFTWARE_VERSION
   COLUMN_NUMBER  = 25
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 3648
   DESCRIPTION = "Indicates version of calibration software used. Increments
   with reprocessing of CDRs. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CHANNEL_WAVELENGTHS
   COLUMN_NUMBER  = 26
   BYTES          = 1024
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 3652
   ITEMS          = 256
   ITEM_BYTES     = 4
   DESCRIPTION = "Column of wavelengths paired to spectrum data channels.
   Unit = nanometers. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = HK_DATA_FLAG
   COLUMN_NUMBER  = 27
   BYTES          = 4
   DATA_TYPE      = MSB_INTEGER
   START_BYTE     = 4676
   DESCRIPTION = "Null, or indicates HK data rate in inverse seconds.
   OBSERVATION column."
END_OBJECT    = COLUMN
```

```
OBJECT        = COLUMN
   NAME           = DATA_QUALITY_INDEX
   COLUMN_NUMBER  = 28
   BYTES          = 19
   DATA_TYPE      = CHARACTER
   START_BYTE     = 4680
   DESCRIPTION = "19 character index of data quality. Each digit signifies
   quality factor of measurements. PER SPECTRUM column.
   Format: ABCD-EFGH-IJKL-MNOP
    A: Dark Scan Flag, denotes shutter commanded closed for dark observation.
      0 = shutter not engaged
      1 = shutter engaged
    B: Temperature 1 Flag
      0 = Temperature does not exceed 15 deg C threshold.
      1 = Temperature exceeds 15 deg C threshold but less than 25 deg C
      threshold.
      2 = Temperature exceeds 25 deg C threshold but less than 40 deg C
      threshold.
      3 = Temperature exceeds 40 deg C threshold.
    C: Temperature 2 Flag
      0 = Temperature does not exceed 15 deg C threshold.
      1 = Temperature exceeds 15 deg C threshold but less than 25 deg C
      threshold.
      2 = Temperature exceeds 25 deg C threshold but less than 40 deg C
      threshold.
      3 = Temperature exceeds 40 deg C threshold.
    D: Grating Temperature Flag
      0 = Temperature does not exceed 15 deg C threshold.
      1 = Temperature exceeds 15 deg C threshold but less than 25 deg C
      threshold.
      2 = Temperature exceeds 25 deg C threshold but less than 40 deg C
      threshold.
      3 = Temperature exceeds 40 deg C threshold.
    E: Anomalous Pixels
      Integer 0-9 = Indicates number of hot pixels found.
      Working Definition: The number of pixels with a noise spike (defined
      in DQI L, below).
      Procedure: The number of noise spike channels for spectra i. Repeat
      for all N spectra.
    F: Partial Data Flag
      0 = No partial data.
      1 = Partial data exists.
      Working Definition: If any spectrum has nulls in the beginning or end,
      signifying data drop outs.
      Procedure: Given spectra i, evaluate first 10 channels and last 10
      channels. If any channel has 0 value, set Partial Data Flag = 1.
    G: Saturation Flag
      0 = No pixels saturated.
      1 = Saturated pixels exist.
    H: Low Signal Level Flag
      0 = Signal level not below -32768 threshold.
      1 = Signal level below -32768 threshold.
    I: Low VIS Wavelength Uncertainty Flag (not yet implemented, set to 0)
      0 = Uncertainty not above TBD threshold at low wavelengths.
      1 = Uncertainty above TBD threshold at low wavelengths.
    J: High VIS Wavelength Uncertainty Flag (not yet implemented, set to 0)
      0 = Uncertainty not above TBD threshold at high wavelengths.
```

```
      1 = Uncertainty above TBD threshold at high wavelengths.
    K: UVVS Operating Flag
      0 = UVVS is not scanning during readout.
      1 = UVVS is scanning during readout.
    L: UVVS Noise Spike Flag
      0 = No noise spike detected.
      1 = Noise spike detected.
      Using VIRS VIS (512 channel spectrum, N spectra per CDR) as an example,
      Working Definition: A noise spike is a data value in 1 or 2 channels
      that exceeds 3 standard deviations of the average for a given channel
      in a given observation.
      Procedure: Calculate the standard deviation for channel 1 through all
      1-N spectra. If spectra i has stdev >=3, then spectra i has a noise
      spike. Repeat calculation for channels 2-512. Keep track of the number
      of 'noise spike channels' per spectra.
    M: 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
    N: Dark Saturation Flag
      Denotes that there are minimal unsaturated dark frames available for
      the polynomial fit of one or more pixels.
      0 = All pixels in data record contain at least four unsaturated dark
      frames.
      1 = One or more pixels in data record contain three or fewer
      unsaturated dark frames.
    O-P: Spares"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = VIRS_GRATING_TEMP
   COLUMN_NUMBER  = 29
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 4699
   DESCRIPTION = "Derived VIRS grating temperature from HK data in degrees
   Celsius. PER SPECTRUM column."
END_OBJECT    = COLUMN

/*** SPICE DERIVED GEOMETRY VALUES ***/

OBJECT        = COLUMN
   NAME             = TARGET_LATITUDE_SET
   COLUMN_NUMBER    = 30
   BYTES            = 40
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 4703
   ITEMS            = 5
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived latitude of footprint center, uprange edge (c1),
   downrange edge (c2), port, (c3) and starboard (c4) edges (5 total values,
   coordinates as in Figure 4 of VIRS_CDR_DDR_DAP_SIS.PDF; center point,
```

```
   c1, c2, c3, c4) on planet target corresponding to spectral observation.
   Unit = degrees. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = TARGET_LONGITUDE_SET
   COLUMN_NUMBER    = 31
   BYTES            = 40
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 4743
   ITEMS            = 5
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived longitude of footprint center, uprange edge (c1),
   downrange edge (c2), port, (c3) and starboard (c4) edges (5 total values,
   coordinates as in Figure 4 of VIRS_CDR_DDR_DAP_SIS.PDF; center point,
   c1, c2, c3, c4) on planet target corresponding to spectral observation.
   Unit = degrees. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = ALONG_TRACK_FOOTPRINT_SIZE
   COLUMN_NUMBER    = 32
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 4783
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION    = "Derived length of VIRS footprint along track over the
   spectrum integration time, accounting for smear across surface.
   Unit = meters. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = ACROSS_TRACK_FOOTPRINT_SIZE
   COLUMN_NUMBER    = 33
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 4791
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived instantaneous width of VIRS footprint across track
   at the spectrum integration midpoint, accounting for jitter across
   surface. Unit = meters. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = FOOTPRINT_AZIMUTH
   COLUMN_NUMBER    = 34
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 4799
   MISSING_CONSTANT = -1.E32
   INVALID_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 SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = INCIDENCE_ANGLE
   COLUMN_NUMBER    = 35
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 4807
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived solar incidence angle of footprint center.
   Unit = degrees. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = EMISSION_ANGLE
   COLUMN_NUMBER    = 36
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 4815
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived emission angle of footprint center.
   Unit = degrees. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = PHASE_ANGLE
   COLUMN_NUMBER    = 37
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 4823
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived phase angle of footprint center. Unit = degrees.
   PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SLANT_RANGE_TO_CENTER
   COLUMN_NUMBER    = 38
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 4831
   MISSING_CONSTANT = -1.E32
   INVALID_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
   SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SUBSPACECRAFT_LATITUDE
   COLUMN_NUMBER    = 39
   BYTES            = 8
```

```
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 4839
   MISSING_CONSTANT = -1.E32
   DESCRIPTION = "Derived subspacecraft latitude on planet surface.
   Unit = degrees. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SUBSPACECRAFT_LONGITUDE
   COLUMN_NUMBER    = 40
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 4847
   MISSING_CONSTANT = -1.E32
   DESCRIPTION = "Derived subspacecraft longitude on planet surface.
   Unit = degrees. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = NADIR_ALTITUDE
   COLUMN_NUMBER    = 41
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 4855
   MISSING_CONSTANT = -1.E32
   DESCRIPTION = "Derived spacecraft altitude above nadir point.
   Unit = kilometers. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SUBSOLAR_LATITUDE
   COLUMN_NUMBER    = 42
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 4863
   MISSING_CONSTANT = -1.E32
   DESCRIPTION = "Derived subsolar latitude on planet surface.
   Unit = degrees. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SUBSOLAR_LONGITUDE
   COLUMN_NUMBER    = 43
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 4871
   MISSING_CONSTANT = -1.E32
   DESCRIPTION = "Derived subsolar longitude on planet surface.
   Unit = degrees. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SOLAR_DISTANCE
   COLUMN_NUMBER    = 44
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 4879
```

```
   MISSING_CONSTANT = -1.E32
   DESCRIPTION = "Derived subsolar distance to footprint center on planet
   surface. Unit = kilometers. PER SPECTRUM column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME             = PLANET_TRUE_ANOMALY
   COLUMN_NUMBER    = 45
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 4887
   MISSING_CONSTANT = -1.E32
   DESCRIPTION = "Derived true anomaly of planet. Unit = degrees. PER
   SPECTRUM column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME             = SPARE_1
   COLUMN_NUMBER    = 46
   BYTES            = 4
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 4895
   MISSING_CONSTANT = -1.E32
   DESCRIPTION = "SPARE column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME             = RIGHT_ASCENSION
   COLUMN_NUMBER    = 47
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 4899
   MISSING_CONSTANT = -1.E32
   DESCRIPTION = "Right ascension. Unit = degrees. PER SPECTRUM column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME             = DECLINATION
   COLUMN_NUMBER    = 48
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 4907
   MISSING_CONSTANT = -1.E32
   DESCRIPTION = "Declination. Unit = degrees. PER SPECTRUM column."
END_OBJECT     = COLUMN

/* SPARE COLUMNS */
OBJECT         = COLUMN
   NAME           = SPARE_2
   COLUMN_NUMBER  = 49
   BYTES          = 4
   DATA_TYPE      = MSB_INTEGER
   START_BYTE     = 4915
   DESCRIPTION = "SPARE column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
```

```
   NAME            = SPARE_3
   COLUMN_NUMBER   = 50
   BYTES           = 4
   DATA_TYPE       = MSB_INTEGER
   START_BYTE      = 4919
   DESCRIPTION = "SPARE column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = SPARE_4
   COLUMN_NUMBER   = 51
   BYTES           = 4
   DATA_TYPE       = MSB_INTEGER
   START_BYTE      = 4923
   DESCRIPTION = "SPARE column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = SPARE_5
   COLUMN_NUMBER   = 52
   BYTES           = 4
   DATA_TYPE       = MSB_INTEGER
   START_BYTE      = 4927
   DESCRIPTION = "SPARE column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = SPARE_6
   COLUMN_NUMBER   = 53
   BYTES           = 4
   DATA_TYPE       = MSB_INTEGER
   START_BYTE      = 4931
   DESCRIPTION     = "SPARE column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = SPARE_7
   COLUMN_NUMBER   = 54
   BYTES           = 4
   DATA_TYPE       = MSB_INTEGER
   START_BYTE      = 4935
   DESCRIPTION = "SPARE column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = SPARE_8
   COLUMN_NUMBER   = 55
   BYTES           = 4
   DATA_TYPE       = MSB_INTEGER
   START_BYTE      = 4939
   DESCRIPTION = "SPARE column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = SPARE_9
   COLUMN_NUMBER   = 56
   BYTES           = 4
```

```
   DATA_TYPE      = MSB_INTEGER
   START_BYTE     = 4943
   DESCRIPTION = "SPARE column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPARE_10
   COLUMN_NUMBER  = 57
   BYTES          = 4
   DATA_TYPE      = MSB_INTEGER
   START_BYTE     = 4947
   DESCRIPTION = "SPARE column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPARE_11
   COLUMN_NUMBER  = 58
   BYTES          = 4
   DATA_TYPE      = MSB_INTEGER
   START_BYTE     = 4951
   DESCRIPTION = "SPARE column."
END_OBJECT    = COLUMN
```

APPENDIX B- VIRSVC.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. PACKET 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 MESSENGER subsystems by the Integrated Electronics Module. This is
   assigned to the first spectral observation contained in a science packet.
   All spectra contained in the science packet will be associated with this
   start time. Unit is in Mission Elapsed Time which is the number of
   seconds since launch. PACKET column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = PACKET_SUBSECONDS
   COLUMN_NUMBER  = 3
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 7
   DESCRIPTION    = "Subsecond time in milliseconds that the telemetry
   packet was initiated. All spectra contained in the science packet will
   be associated with this subsecond start time. Unit is 5 milliseconds
   (i.e. all values will be to the nearest 5 milliseconds). PACKET column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = INT_TIME
   COLUMN_NUMBER  = 4
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 9
   DESCRIPTION    = "Amount of time the array detectors will integrate
   photon counts. Unit is 0.05 second. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = INT_COUNT
   COLUMN_NUMBER  = 5
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 11
   DESCRIPTION    = "Total amount of integrations that will be taken.
```

```
   OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = PERIOD
   COLUMN_NUMBER  = 6
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 13
   DESCRIPTION    = "Interval time after which another integration will be
   started.  Integrations are started at the top of every period.  Unit is
   0.05 second. There is a 5-unit overhead between consecutive integrations,
   so PERIOD (in units) = INT_TIME (in units) + 5. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DARK_FREQ
   COLUMN_NUMBER  = 7
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 15
   DESCRIPTION    = "Dark counts will be collected every X integrations
   during a VIRS observation. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = TEMP_1
   COLUMN_NUMBER  = 8
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 17
   DESCRIPTION    = "One of a redundant pair of array temperature sensors. A
   more complete description of this field can be found in the MASCS User's
   Guide (Applicable Document 6 in VIRS_CDR_DDR_DAP_SIS.PDF).
   Conversion from raw counts (DN) to degrees Celsius is:
   TEMP_1 = -3.34338E-18 * DN^5 + 8.979E-15 * DN^4 + 3.8131E-11 * DN^3
   - 2.703E-8 * DN^2 - 0.0061 * DN - 1.67826
   PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = TEMP_2
   COLUMN_NUMBER  = 9
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 21
   DESCRIPTION    = "One of a redundant pair of array temperature sensors. A
   more complete description of this field can be found in the MASCS User's
   Guide (Applicable Document 6 in VIRS_CDR_DDR_DAP_SIS.PDF).
   Conversion from raw counts (DN) to degrees Celsius is:
   For the VIS detector it is the same as for TEMP_1
   For the NIR detector it is:
   TEMP_2 = -8.89100589E-18 * DN^5 - 9.72043502E-15 * DN^4
   + 1.73862825E-10 * DN^3 + 3.39958815E-7 * DN^2
   - 0.00702301101 * DN - 22.2879012
   PER SPECTRUM column."
END_OBJECT    = COLUMN
```

```
OBJECT        = COLUMN
   NAME           = NIR_GAIN
   COLUMN_NUMBER  = 10
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 25
   DESCRIPTION    = "Gain of NIR array detector. A more complete description
   of this field can be found in the MASCS User's Guide (Applicable Document
   6 in VIRS_CDR_DDR_DAP_SIS.PDF). 0 is Low, 1 is High, 999 is N/A value
   when VIS detector is enabled. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = OTHER_CHANNEL_ON
   COLUMN_NUMBER  = 11
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 27
   DESCRIPTION    = "The other array is powered on or off (VIS in a NIR
   packet, NIR in a VIS packet. A value of 0 is off, a value of 1 is on.
   OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = NIR_LAMP_ON
   COLUMN_NUMBER  = 12
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 29
   DESCRIPTION    = "NIR flat field lamp is powered on or off. A value of 0
   is off, a value of 1 is on. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = VIS_LAMP_ON
   COLUMN_NUMBER  = 13
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 31
   DESCRIPTION    = "VIS flat field lamp is powered on or off. A value of 0
   is off, a value of 1 is on. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = BINNING
   COLUMN_NUMBER  = 14
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 33
   DESCRIPTION    = "Number of pixels that were binned together in the data.
   A flight-software update during the mission changed how the pixels are
   were binned. For data with SPECTRUM_UTC_TIME prior to March 16, 2009,
   the pixels were co-added. For data with SPECTRUM_UTC_TIME on or after
   March 16, 2009, the multiple pixels were averaged. OBSERVATION column."
END_OBJECT    = COLUMN
```

```
OBJECT        = COLUMN
   NAME           = START_PIXEL
   COLUMN_NUMBER  = 15
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 35
   DESCRIPTION    = "Start pixel of data captured by the detector array. For
   VIS the value can be from 0-511. For NIR the value can be from 0-255.
   OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = END_PIXEL
   COLUMN_NUMBER  = 16
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 37
   DESCRIPTION    = "End pixel of data captured by the detector array. For
   VIS the value can be from 0-511. For NIR the value can be from 0-255.
   The END_PIXEL must be greater than START_PIXEL. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPECTRUM_NUMBER
   COLUMN_NUMBER  = 17
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 39
   DESCRIPTION    = "Ordered number sequence for spectra in a given
   observation. First spectrum is 0, second is 1, third is 2, and so on.
   Note that for observations which span multiple science packets, the
   numbering sequence is continuous. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPECTRUM_MET
   COLUMN_NUMBER  = 18
   BYTES          = 4
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 41
   DESCRIPTION    = "A calculated value intended to reflect mission elapsed
   time (in seconds) since launch (for partition 1) or since reset (for
   partition 2) at the start of an individual VIRS spectrum.
   This is derived using the following formula:
   SPECTRUM_MET = SC_TIME + floor(SPECTRUM_NUMBER*PERIOD*0.050)
   PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPECTRUM_SUBSECONDS
   COLUMN_NUMBER  = 19
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 45
   DESCRIPTION    = "The calculated subsecond time in milliseconds that a
   VIRS integration was started. For each VIRS integration, SPECTRUM_MET
   plus SPECTRUM_SUBSECONDS gives the spacecraft time of the start of that
```

```
   integration. This is derived using the following formula:
   SPECTRUM_SUBSECONDS = (PACKET_SUBSECONDS + SPECTRUM_NUMBER * PERIOD * 50)
   mod 1000
   PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = RAW_SPECTRUM_DATA
   COLUMN_NUMBER  = 20
   BYTES          = 1024
   DATA_TYPE      = MSB_INTEGER
   START_BYTE     = 47
   ITEMS          = 512
   ITEM_BYTES     = 2
   DESCRIPTION    = "Column of uncompressed raw data at full 16-bit
   resolution. One row per spectrum, NIR spectrum has up to 256 values
   (depending on binning and windowing), VIS has up to 512. Unit = counts.
   PER SPECTRUM column."
END_OBJECT    = COLUMN

/* CALIBRATED ITEMS AND ADDITIONAL METADATA */
OBJECT        = COLUMN
   NAME           = SPECTRUM_UTC_TIME
   COLUMN_NUMBER  = 21
   BYTES          = 17
   DATA_TYPE      = CHARACTER
   START_BYTE     = 1071
   DESCRIPTION = "UTC time in YYDOYTHH:MM:SS.00 format translated from
   spacecraft time and packet subseconds (in integer seconds) that is
   transmitted to MESSENGER subsystems by the Integrated Electronics Module.
   PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CORRECTED_COUNTS_SPECTRUM_DATA
   COLUMN_NUMBER  = 22
   BYTES          = 2048
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 1088
   ITEMS          = 512
   ITEM_BYTES     = 4
   DESCRIPTION = "Derived column of corrected counts spectra. Counts
   corrected for darks, and other instrument level corrections (e.g.
   temperature, scattered light, etc. as determined by most current
   calibration.) One row per spectrum. NIR spectrum has up to 256 values
   (depending on binning and windowing), VIS has up to 512. Unit = corrected
   counts/second. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = CALIBRATED_RADIANCE_SPECTRUM_DATA
   COLUMN_NUMBER    = 23
   BYTES            = 2048
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 3136
   ITEMS            = 512
   ITEM_BYTES       = 4
```

```
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived column of radiance-at-sensor spectra. One row per
   spectrum. NIR spectrum has up to 256 values (depending on binning and
   windowing), VIS has up to 512. Unit = W/(m^2 steradian micron). Radiance
   from saturated pixels, or binned pixels with one saturated element, are
   set to 1e32. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = NOISE_SPECTRUM_DATA
   COLUMN_NUMBER    = 24
   BYTES            = 2048
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 5184
   ITEMS            = 512
   ITEM_BYTES       = 4
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived column of noise/error propagated through
   calibration procedure. One row per spectrum. NIR spectrum has up to 256
   values (depending on binning and windowing), VIS has up to 512.
   Unit = W/(m^2 steradian micron). Noise from saturated pixels, or binned
   pixels with one saturated element, are set to 1e32. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CALIBRATION_SOFTWARE_VERSION
   COLUMN_NUMBER  = 25
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 7232
   DESCRIPTION = "Indicates version of calibration software used. Increments
   with reprocessing of CDRs. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CHANNEL_WAVELENGTHS
   COLUMN_NUMBER  = 26
   BYTES          = 2048
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 7236
   ITEMS          = 512
   ITEM_BYTES     = 4
   DESCRIPTION = "Column of wavelengths paired to spectrum data channels.
   Unit = nanometers. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = HK_DATA_FLAG
   COLUMN_NUMBER  = 27
   BYTES          = 4
   DATA_TYPE      = MSB_INTEGER
   START_BYTE     = 9284
   DESCRIPTION = "Null, or indicates HK data rate in inverse seconds.
  OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
```

```
NAME           = DATA_QUALITY_INDEX
COLUMN_NUMBER  = 28
BYTES          = 19
DATA_TYPE      = CHARACTER
START_BYTE     = 9288
DESCRIPTION = "19 character index of data quality. Each digit signifies
quality factor of measurements. PER SPECTRUM column.
Format: ABCD-EFGH-IJKL-MNOP
 A: Dark Scan Flag, denotes shutter commanded closed for dark observation.
   0 = shutter not engaged
   1 = shutter engaged
 B: Temperature 1 Flag
   0 = Temperature does not exceed 15 deg C threshold.
   1 = Temperature exceeds 15 deg C threshold but less than 25 deg C
   threshold.
   2 = Temperature exceeds 25 deg C threshold but less than 40 deg C
   threshold.
   3 = Temperature exceeds 40 deg C threshold.
 C: Temperature 2 Flag
   0 = Temperature does not exceed 15 deg C threshold.
   1 = Temperature exceeds 15 deg C threshold but less than 25 deg C
   threshold.
   2 = Temperature exceeds 25 deg C threshold but less than 40 deg C
   threshold.
   3 = Temperature exceeds 40 deg C threshold.
 D: Grating Temperature Flag
   0 = Temperature does not exceed 15 deg C threshold.
   1 = Temperature exceeds 15 deg C threshold but less than 25 deg C
   threshold.
   2 = Temperature exceeds 25 deg C threshold but less than 40 deg C
   threshold.
   3 = Temperature exceeds 40 deg C threshold.
 E: Anomalous Pixels
   Integer 0-9 = Indicates number of hot pixels found.
   Working Definition: The number of pixels with a noise spike (defined
   in DQI L, below).
   Procedure: The number of noise spike channels for spectra i. Repeat
   for all N spectra.
 F: Partial Data Flag
   0 = No partial data.
   1 = Partial data exists.
   Working Definition: If any spectrum has nulls in the beginning or end,
   signifying data drop outs.
   Procedure: Given spectra i, evaluate first 10 channels and last 10
   channels. If any channel has 0 value, set Partial Data Flag = 1.
 G: Saturation Flag
   0 = No pixels saturated.
   1 = Saturated pixels exist.
 H: Low Signal Level Flag
   0 = Signal level not below -32768 threshold.
   1 = Signal level below -32768 threshold.
 I: Low VIS Wavelength Uncertainty Flag (not yet implemented, set to 0)
   0 = Uncertainty not above TBD threshold at low wavelengths.
   1 = Uncertainty above TBD threshold at low wavelengths.
 J: High VIS Wavelength Uncertainty Flag (not yet implemented, set to 0)
   0 = Uncertainty not above TBD threshold at high wavelengths.
   1 = Uncertainty above TBD threshold at high wavelengths.
```

```
    K: UVVS Operating Flag
      0 = UVVS is not scanning during readout.
      1 = UVVS is scanning during readout.
    L: UVVS Noise Spike Flag
      0 = No noise spike detected.
      1 = Noise spike detected.
      Using VIRS VIS (512 channel spectrum, N spectra per CDR) as an example,
      Working Definition: A noise spike is a data value in 1 or 2 channels
      that exceeds 3 standard deviations of the average for a given channel
      in a given observation.
      Procedure: Calculate the standard deviation for channel 1 through all
      1-N spectra. If spectra i has stdev >=3, then spectra i has a noise
      spike. Repeat calculation for channels 2-512. Keep track of the number
      of 'noise spike channels' per spectra.
    M: 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
    N: Dark Saturation Flag
      Denotes that there are minimal unsaturated dark frames available for
      the polynomial fit of one or more pixels.
      0 = All pixels in data record contain at least four unsaturated dark
      frames.
      1 = One or more pixels in data record contain three or fewer
      unsaturated dark frames.
    O-P: Spares"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME            = VIRS_GRATING_TEMP
   COLUMN_NUMBER  = 29
   BYTES           = 4
   DATA_TYPE       = IEEE_REAL
   START_BYTE      = 9307
   DESCRIPTION = "Derived VIRS grating temperature from HK data in degrees
   Celsius. PER SPECTRUM column."
END_OBJECT    = COLUMN

/*** SPICE DERIVED GEOMETRY VALUES ***/
OBJECT        = COLUMN
   NAME              = TARGET_LATITUDE_SET
   COLUMN_NUMBER     = 30
   BYTES             = 40
   DATA_TYPE         = IEEE_REAL
   START_BYTE        = 9311
   ITEMS             = 5
   ITEM_BYTES        = 8
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived latitude of footprint center, uprange edge (c1),
   downrange edge (c2), port, (c3) and starboard (c4) edges (5 total values,
   coordinates as in Figure 4 of VIRS_CDR_DDR_DAP_SIS.PDF; center point,
   c1, c2, c3, c4) on planet target corresponding to spectral observation.
   Unit = degrees. PER SPECTRUM column."
```

```
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = TARGET_LONGITUDE_SET
   COLUMN_NUMBER    = 31
   BYTES            = 40
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 9351
   ITEMS            = 5
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived longitude of footprint center, uprange edge (c1),
   downrange edge (c2), port, (c3) and starboard (c4) edges (5 total values,
   coordinates as in Figure 4 of VIRS_CDR_DDR_DAP_SIS.PDF; center point,
   c1, c2, c3, c4) on planet target corresponding to spectral observation.
   Unit = degrees. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = ALONG_TRACK_FOOTPRINT_SIZE
   COLUMN_NUMBER    = 32
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 9391
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived length of VIRS footprint along track over the
   spectrum integration time, accounting for smear across surface.
   Unit = meters. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = ACROSS_TRACK_FOOTPRINT_SIZE
   COLUMN_NUMBER    = 33
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 9399
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived instantaneous width of VIRS footprint across track
   at the spectrum integration midpoint, accounting for jitter across
   surface. Unit = meters. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = FOOTPRINT_AZIMUTH
   COLUMN_NUMBER    = 34
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 9407
   MISSING_CONSTANT = -1.E32
   INVALID_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 SPECTRUM column."
```

```
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = INCIDENCE_ANGLE
   COLUMN_NUMBER    = 35
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 9415
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived solar incidence angle of footprint center.
   Unit = degrees. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = EMISSION_ANGLE
   COLUMN_NUMBER    = 36
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 9423
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived emission angle of footprint center.
   Unit = degrees. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = PHASE_ANGLE
   COLUMN_NUMBER    = 37
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 9431
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived phase angle of footprint center. Unit = degrees.
   PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SLANT_RANGE_TO_CENTER
   COLUMN_NUMBER    = 38
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 9439
   MISSING_CONSTANT = -1.E32
   INVALID_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
   SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SUBSPACECRAFT_LATITUDE
   COLUMN_NUMBER    = 39
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 9447
```

```
   MISSING_CONSTANT = -1.E32
   DESCRIPTION = "Derived subspacecraft latitude on planet surface.
   Unit = degrees. PER SPECTRUM column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME             = SUBSPACECRAFT_LONGITUDE
   COLUMN_NUMBER    = 40
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 9455
   MISSING_CONSTANT = -1.E32
   DESCRIPTION = "Derived subspacecraft longitude on planet surface.
   Unit = degrees. PER SPECTRUM column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME             = NADIR_ALTITUDE
   COLUMN_NUMBER    = 41
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 9463
   MISSING_CONSTANT = -1.E32
   DESCRIPTION = "Derived spacecraft altitude above nadir point.
   Unit = kilometers. PER SPECTRUM column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME             = SUBSOLAR_LATITUDE
   COLUMN_NUMBER    = 42
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 9471
   MISSING_CONSTANT = -1.E32
   DESCRIPTION = "Derived subsolar latitude on planet surface.
   Unit = degrees. PER SPECTRUM column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME             = SUBSOLAR_LONGITUDE
   COLUMN_NUMBER    = 43
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 9479
   MISSING_CONSTANT = -1.E32
   DESCRIPTION = "Derived subsolar longitude on planet surface.
   Unit = degrees. PER SPECTRUM column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME             = SOLAR_DISTANCE
   COLUMN_NUMBER    = 44
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 9487
   MISSING_CONSTANT = -1.E32
   DESCRIPTION = "Derived subsolar distance to footprint center on planet
```

```
   surface. Unit = kilometers. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = PLANET_TRUE_ANOMALY
   COLUMN_NUMBER    = 45
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 9495
   MISSING_CONSTANT = -1.E32
   DESCRIPTION = "Derived true anomaly of planet. Unit = degrees. PER
   SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SPARE_1
   COLUMN_NUMBER    = 46
   BYTES            = 4
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 9503
   MISSING_CONSTANT = -1.E32
   DESCRIPTION = "SPARE column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = RIGHT_ASCENSION
   COLUMN_NUMBER    = 47
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 9507
   MISSING_CONSTANT = -1.E32
   DESCRIPTION = "Right ascension. Unit = degrees. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = DECLINATION
   COLUMN_NUMBER    = 48
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 9515
   MISSING_CONSTANT = -1.E32
   DESCRIPTION = "Declination. Unit = degrees. PER SPECTRUM column."
END_OBJECT    = COLUMN

/* SPARE COLUMNS */
OBJECT        = COLUMN
   NAME           = SPARE_2
   COLUMN_NUMBER  = 49
   BYTES          = 4
   DATA_TYPE      = MSB_INTEGER
   START_BYTE     = 9523
   DESCRIPTION = "SPARE column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPARE_3
   COLUMN_NUMBER  = 50
```

```
   BYTES           = 4
   DATA_TYPE       = MSB_INTEGER
   START_BYTE      = 9527
   DESCRIPTION = "SPARE column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME            = SPARE_4
   COLUMN_NUMBER   = 51
   BYTES           = 4
   DATA_TYPE       = MSB_INTEGER
   START_BYTE      = 9531
   DESCRIPTION = "SPARE column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME            = SPARE_5
   COLUMN_NUMBER   = 52
   BYTES           = 4
   DATA_TYPE       = MSB_INTEGER
   START_BYTE      = 9535
   DESCRIPTION = "SPARE column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME            = SPARE_6
   COLUMN_NUMBER   = 53
   BYTES           = 4
   DATA_TYPE       = MSB_INTEGER
   START_BYTE      = 9539
   DESCRIPTION = "SPARE column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME            = SPARE_7
   COLUMN_NUMBER   = 54
   BYTES           = 4
   DATA_TYPE       = MSB_INTEGER
   START_BYTE      = 9543
   DESCRIPTION = "SPARE column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME            = SPARE_8
   COLUMN_NUMBER   = 55
   BYTES           = 4
   DATA_TYPE       = MSB_INTEGER
   START_BYTE      = 9547
   DESCRIPTION = "SPARE column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME            = SPARE_9
   COLUMN_NUMBER   = 56
   BYTES           = 4
   DATA_TYPE       = MSB_INTEGER
   START_BYTE      = 9551
```

```
   DESCRIPTION = "SPARE column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPARE_10
   COLUMN_NUMBER  = 57
   BYTES          = 4
   DATA_TYPE      = MSB_INTEGER
   START_BYTE     = 9555
   DESCRIPTION = "SPARE column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPARE_11
   COLUMN_NUMBER  = 58
   BYTES          = 4
   DATA_TYPE      = MSB_INTEGER
   START_BYTE     = 9559
   DESCRIPTION = "SPARE column."
END_OBJECT    = COLUMN
```

APPENDIX C- VIRSND.FMT FILE

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

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 MESSENGER subsystems by the Integrated Electronics Module. This is
   assigned to the first spectral observation contained in a science packet.
   All spectra contained in the science packet will be associated with this
   start time. Unit is in Mission Elapsed Time which is the number of
   seconds since launch. PACKET column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = PACKET_SUBSECONDS
   COLUMN_NUMBER  = 2
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 5
   DESCRIPTION    = "Subsecond time in milliseconds that the telemetry
   packet was initiated. All spectra contained in the science packet will
   be associated with this subsecond start time. Unit is 5 milliseconds
   (i.e. all values will be to the nearest 5 milliseconds). PACKET column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = INT_TIME
   COLUMN_NUMBER  = 3
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 7
   DESCRIPTION    = "Amount of time the array detectors will integrate
   photon counts. Unit is 0.05 second. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = INT_COUNT
   COLUMN_NUMBER  = 4
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 9
   DESCRIPTION    = "Total amount of integrations that will be taken.
   OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DARK_FREQ
   COLUMN_NUMBER  = 5
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
```

```
   START_BYTE     = 11
   DESCRIPTION    = "Dark counts will be collected every X integrations
   during a VIRS observation. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = TEMP_2
   COLUMN_NUMBER  = 6
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 13
   DESCRIPTION    = "One of a redundant pair of array temperature sensors. A
   more complete description of this field can be found in the MASCS User's
   Guide (Applicable Document 6 in VIRS_CDR_DDR_DAP_SIS.PDF).
   Conversion from raw counts (DN) to degrees Celsius is:
   For the VIS detector it is:
   -3.34338E-18 * DN^5 + 8.979E-15 * DN^4 + 3.8131E-11 * DN^3
   - 2.703E-8 * DN^2 - 0.0061 * DN - 1.67826
   For the NIR detector it is:
   TEMP_2 = -8.89100589E-18 * DN^5 - 9.72043502E-15 * DN^4
   + 1.73862825E-10 * DN^3 + 3.39958815E-7 * DN^2
   - 0.00702301101 * DN - 22.2879012
   PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = BINNING
   COLUMN_NUMBER  = 7
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 17
   DESCRIPTION    = "Number of pixels that were binned together in the data.
   A flight-software update during the mission changed how the pixels are
   were binned. For data with SPECTRUM_UTC_TIME prior to March 16, 2009,
   the pixels were co-added. For data with SPECTRUM_UTC_TIME on or after
   March 16, 2009, the multiple pixels were averaged. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = START_PIXEL
   COLUMN_NUMBER  = 8
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 19
   DESCRIPTION    = "Start pixel of data captured by the detector array. For
   VIS the value can be from 0-511. For NIR the value can be from 0-255.
   OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = END_PIXEL
   COLUMN_NUMBER  = 9
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 21
   DESCRIPTION    = "End pixel of data captured by the detector array. For
   VIS the value can be from 0-511. For NIR the value can be from 0-255.
```

```
   The END_PIXEL must be greater than START_PIXEL. OBSERVATION column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = SPECTRUM_NUMBER
   COLUMN_NUMBER   = 10
   BYTES           = 2
   DATA_TYPE       = MSB_UNSIGNED_INTEGER
   START_BYTE      = 23
   DESCRIPTION     = "Ordered number sequence for spectra in a given
   observation. First spectrum is 0, second is 1, third is 2, and so on.
   Note that for observations which span multiple science packets, the
   numbering sequence is continuous. PER SPECTRUM column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = SPECTRUM_MET
   COLUMN_NUMBER   = 11
   BYTES           = 4
   DATA_TYPE       = MSB_UNSIGNED_INTEGER
   START_BYTE      = 25
   DESCRIPTION     = "A calculated value intended to reflect mission elapsed
   time (in seconds) since launch (for partition 1) or since reset (for
   partition 2) at the start of an individual VIRS spectrum.
   This is derived using the following formula:
   SPECTRUM_MET = SC_TIME + floor(SPECTRUM_NUMBER*PERIOD*0.050)
   PER SPECTRUM column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = SPECTRUM_SUBSECONDS
   COLUMN_NUMBER   = 12
   BYTES           = 2
   DATA_TYPE       = MSB_UNSIGNED_INTEGER
   START_BYTE      = 29
   DESCRIPTION     = "The calculated subsecond time in milliseconds that a
   VIRS integration was started. For each VIRS integration, SPECTRUM_MET
   plus SPECTRUM_SUBSECONDS gives the spacecraft time of the start of that
   integration. This is derived using the following formula:
   SPECTRUM_SUBSECONDS = (PACKET_SUBSECONDS + SPECTRUM_NUMBER * PERIOD * 50)
   mod 1000
   PER SPECTRUM column."
END_OBJECT     = COLUMN

/* CALIBRATED ITEMS AND ADDITIONAL METADATA */
OBJECT         = COLUMN
   NAME            = SPECTRUM_UTC_TIME
   COLUMN_NUMBER   = 13
   BYTES           = 17
   DATA_TYPE       = CHARACTER
   START_BYTE      = 31
   DESCRIPTION     = "UTC time in YYDOYTHH:MM:SS.00 format translated from
   spacecraft time and packet subseconds (in integer seconds) that is
   transmitted to MESSENGER subsystems by the Integrated Electronics Module.
   PER SPECTRUM column."
END_OBJECT     = COLUMN
```

```
OBJECT         = COLUMN
   NAME              = IOF_SPECTRUM_DATA
   COLUMN_NUMBER     = 14
   BYTES             = 1024
   DATA_TYPE         = IEEE_REAL
   START_BYTE        = 48
   ITEMS             = 256
   ITEM_BYTES        = 4
   INVALID_CONSTANT = 1.E32
   DESCRIPTION       = "Derived column of reflectance-at-sensor spectra. One
   row per spectrum. NIR spectrum has up to 256 values (depending on binning
   and windowing), VIS has up to 512. Reflectance is a unitless parameter.
   Reflectance from saturated pixels, or binned pixels with one saturated
   element, are set to 1e32. PER SPECTRUM column."
END_OBJECT     = COLUMN
OBJECT         = COLUMN
   NAME              = PHOTOM_IOF_SPECTRUM_DATA
   COLUMN_NUMBER     = 15
   BYTES             = 1024
   DATA_TYPE         = IEEE_REAL
   START_BYTE        = 1072
   ITEMS             = 256
   ITEM_BYTES        = 4
   INVALID_CONSTANT = 1.E32
   DESCRIPTION       = "Derived column of photometrically normalized
   reflectance-at-sensor spectra. One row per spectrum. NIR spectrum has up
   to 256 values (depending on binning and windowing), VIS has up to 512.
   Reflectance is a unitless parameter. Reflectance from saturated pixels,
   or binned pixels with one saturated element, are set to 1e32. PER
   SPECTRUM column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME              = IOF_NOISE_SPECTRUM_DATA
   COLUMN_NUMBER     = 16
   BYTES             = 1024
   DATA_TYPE         = IEEE_REAL
   START_BYTE        = 2096
   ITEMS             = 256
   ITEM_BYTES        = 4
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived column of noise/error in reflectance propagated
   through post-calibration procedure. One row per spectrum. NIR spectrum
   has up to 256 values (depending on binning and windowing), VIS has up to
   512.  Unitless. Noise from saturated pixels, or binned pixels with one
   saturated element, are set to 1e32. PER SPECTRUM column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME              = PHOTOM_IOF_NOISE_SPECTRUM_DATA
   COLUMN_NUMBER     = 17
   BYTES             = 1024
   DATA_TYPE         = IEEE_REAL
   START_BYTE        = 3120
   ITEMS             = 256
   ITEM_BYTES        = 4
   INVALID_CONSTANT = 1.E32
```

```
   DESCRIPTION = "Derived column of noise/error in photometrically normalized
   reflectance propagated through post-calibration procedure. One row per
   spectrum. NIR spectrum has up to 256 values (depending on binning and
   windowing), VIS has up to 512. Unitless. Noise from saturated pixels, or
   binned pixels with one saturated element, are set to 1e32. PER SPECTRUM
   column. "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SOFTWARE_VERSION
   COLUMN_NUMBER  = 18
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 4144
   DESCRIPTION = "Indicates version of calibration software used. Increments
   with reprocessing of DDRs. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CHANNEL_WAVELENGTHS
   COLUMN_NUMBER  = 19
   BYTES          = 1024
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 4148
   ITEMS          = 256
   ITEM_BYTES     = 4
   DESCRIPTION = "Column of wavelengths paired to spectrum data channels.
   Wavelengths derived from calibration report equation 6.5. See VIRS CDR-
   DDR SIS. Unit = nanometers. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DATA_QUALITY_INDEX
   COLUMN_NUMBER  = 20
   BYTES          = 19
   DATA_TYPE      = CHARACTER
   START_BYTE     = 5172
   DESCRIPTION = "19 character index of data quality. Each digit signifies
   quality factor of measurements. PER SPECTRUM column.
   Format: ABCD-EFGH-IJKL-MNOP
    A: Dark Scan Flag, denotes shutter commanded closed for dark observation.
      0 = shutter not engaged
      1 = shutter engaged
    B: Temperature 1 Flag
      0 = Temperature does not exceed 15 deg C threshold.
      1 = Temperature exceeds 15 deg C threshold but less than 25 deg C
      threshold.
      2 = Temperature exceeds 25 deg C threshold but less than 40 deg C
      threshold.
      3 = Temperature exceeds 40 deg C threshold.
    C: Temperature 2 Flag
      0 = Temperature does not exceed 15 deg C threshold.
      1 = Temperature exceeds 15 deg C threshold but less than 25 deg C
      threshold.
      2 = Temperature exceeds 25 deg C threshold but less than 40 deg C
      threshold.
      3 = Temperature exceeds 40 deg C threshold.
```

```
D: Grating Temperature Flag
  0 = Temperature does not exceed 15 deg C threshold.
  1 = Temperature exceeds 15 deg C threshold but less than 25 deg C
  threshold.
  2 = Temperature exceeds 25 deg C threshold but less than 40 deg C
  threshold.
  3 = Temperature exceeds 40 deg C threshold.
E: Anomalous Pixels
  Integer 0-9 = Indicates number of hot pixels found.
  Working Definition: The number of pixels with a noise spike (defined
  in DQI L, below).
  Procedure: The number of noise spike channels for spectra i. Repeat
  for all N spectra.
F: Partial Data Flag
  0 = No partial data.
  1 = Partial data exists.
  Working Definition: If any spectrum has nulls in the beginning or end,
  signifying data drop outs.
  Procedure: Given spectra i, evaluate first 10 channels and last 10
  channels. If any channel has 0 value, set Partial Data Flag = 1.
G: Saturation Flag
  0 = No pixels saturated.
  1 = Saturated pixels exist.
H: Low Signal Level Flag
  0 = Signal level not below -32768 threshold.
  1 = Signal level below -32768 threshold.
I: Low VIS Wavelength Uncertainty Flag (not yet implemented, set to 0)
  0 = Uncertainty not above TBD threshold at low wavelengths.
  1 = Uncertainty above TBD threshold at low wavelengths.
J: High VIS Wavelength Uncertainty Flag (not yet implemented, set to 0)
  0 = Uncertainty not above TBD threshold at high wavelengths.
  1 = Uncertainty above TBD threshold at high wavelengths.
K: UVVS Operating Flag
  0 = UVVS is not scanning during readout.
  1 = UVVS is scanning during readout.
L: UVVS Noise Spike Flag
  0 = No noise spike detected.
  1 = Noise spike detected.
  Using VIRS VIS (512 channel spectrum, N spectra per CDR) as an example,
  Working Definition: A noise spike is a data value in 1 or 2 channels
  that exceeds 3 standard deviations of the average for a given channel
  in a given observation.
  Procedure: Calculate the standard deviation for channel 1 through all
  1-N spectra. If spectra i has stdev >=3, then spectra i has a noise
  spike. Repeat calculation for channels 2-512. Keep track of the number
  of 'noise spike channels' per spectra.
M: 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
N: Dark Saturation Flag
  Denotes that there are minimal unsaturated dark frames available for
  the polynomial fit of one or more pixels.
  0 = All pixels in data record contain at least four unsaturated dark
```

```
      frames.
      1 = One or more pixels in data record contain three or fewer
      unsaturated dark frames.
    O-P: Spares"
END_OBJECT    = COLUMN

/*** SPICE DERIVED GEOMETRY VALUES TAKEN DIRECTLY FROM VIRS NIR CDR ***/

OBJECT        = COLUMN
   NAME             = TARGET_LATITUDE_SET
   COLUMN_NUMBER    = 21
   BYTES            = 40
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 5191
   ITEMS            = 5
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived latitude of footprint center, uprange edge (c1),
   downrange edge (c2), port, (c3) and starboard (c4) edges (5 total values,
   coordinates as in Figure 4 of VIRS_CDR_DDR_DAP_SIS.PDF; center point,
   c1, c2, c3, c4) on planet target corresponding to spectral observation.
   Unit = degrees. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = TARGET_LONGITUDE_SET
   COLUMN_NUMBER    = 22
   BYTES            = 40
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 5231
   ITEMS            = 5
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived longitude of footprint center, uprange edge (c1),
   downrange edge (c2), port, (c3) and starboard (c4) edges (5 total values,
   coordinates as in Figure 4 of VIRS_CDR_DDR_DAP_SIS.PDF; center point,
   c1, c2, c3, c4) on planet target corresponding to spectral observation.
   Unit = degrees. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = ALONG_TRACK_FOOTPRINT_SIZE
   COLUMN_NUMBER    = 23
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 5271
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived length of VIRS footprint along track over the
   spectrum integration time, accounting for smear across surface.
   Unit = meters. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = ACROSS_TRACK_FOOTPRINT_SIZE
```

```
   COLUMN_NUMBER    = 24
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 5279
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived instantaneous width of VIRS footprint across track
   at the spectrum integration midpoint, accounting for jitter across
   surface. Unit = meters. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = INCIDENCE_ANGLE
   COLUMN_NUMBER    = 25
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 5287
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived solar incidence angle of footprint center.
   Unit = degrees. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = EMISSION_ANGLE
   COLUMN_NUMBER    = 26
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 5295
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived emission angle of footprint center.
   Unit = degrees. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = PHASE_ANGLE
   COLUMN_NUMBER    = 27
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 5303
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived phase angle of footprint center. Unit = degrees.
   PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = SOLAR_DISTANCE
   COLUMN_NUMBER    = 28
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 5311
   MISSING_CONSTANT = -1.E32
   DESCRIPTION = "Derived subsolar distance to footprint center on planet
   surface. Unit = kilometers. PER SPECTRUM column."
END_OBJECT    = COLUMN
```

```
/* SPARE COLUMNS */

OBJECT         = COLUMN
   NAME              = SPARE_1
   COLUMN_NUMBER     = 29
   BYTES             = 4
   DATA_TYPE         = IEEE_REAL
   START_BYTE        = 5319
   MISSING_CONSTANT = -1.E32
   DESCRIPTION = "SPARE column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = SPARE_2
   COLUMN_NUMBER   = 30
   BYTES           = 4
   DATA_TYPE       = MSB_INTEGER
   START_BYTE      = 5323
   DESCRIPTION = "SPARE column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = SPARE_3
   COLUMN_NUMBER   = 31
   BYTES           = 4
   DATA_TYPE       = MSB_INTEGER
   START_BYTE      = 5327
   DESCRIPTION = "SPARE column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = SPARE_4
   COLUMN_NUMBER   = 32
   BYTES           = 4
   DATA_TYPE       = MSB_INTEGER
   START_BYTE      = 5331
   DESCRIPTION = "SPARE column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = SPARE_5
   COLUMN_NUMBER   = 33
   BYTES           = 4
   DATA_TYPE       = MSB_INTEGER
   START_BYTE      = 5335
   DESCRIPTION = "SPARE column."
END_OBJECT     = COLUMN
```

APPENDIX D- VIRSVD.FMT FILE

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

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 MESSENGER subsystems by the Integrated Electronics Module. This is
   assigned to the first spectral observation contained in a science packet.
   All spectra contained in the science packet will be associated with this
   start time. Unit is in Mission Elapsed Time which is the number of
   seconds since launch. PACKET column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = PACKET_SUBSECONDS
   COLUMN_NUMBER  = 2
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 5
   DESCRIPTION    = "Subsecond time in milliseconds that the telemetry
   packet was initiated. All spectra contained in the science packet will
   be associated with this subsecond start time. Unit is 5 milliseconds
   (i.e. all values will be to the nearest 5 milliseconds). PACKET column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = INT_TIME
   COLUMN_NUMBER  = 3
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 7
   DESCRIPTION    = "Amount of time the array detectors will integrate
   photon counts. Unit is 0.05 second. OBSERVATION column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = INT_COUNT
   COLUMN_NUMBER  = 4
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 9
   DESCRIPTION    = "Total amount of integrations that will be taken.
   OBSERVATION column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME            = DARK_FREQ
   COLUMN_NUMBER  = 5
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
```

```
   START_BYTE     = 11
   DESCRIPTION    = "Dark counts will be collected every X integrations
   during a VIRS observation. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = TEMP_2
   COLUMN_NUMBER  = 6
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 13
   DESCRIPTION    = "One of a redundant pair of array temperature sensors. A
   more complete description of this field can be found in the MASCS User's
   Guide (Applicable Document 6 in VIRS_CDR_DDR_DAP_SIS.PDF).
   Conversion from raw counts (DN) to degrees Celsius is:
   For the VIS detector it is:
   -3.34338E-18 * DN^5 + 8.979E-15 * DN^4 + 3.8131E-11 * DN^3
   - 2.703E-8 * DN^2 - 0.0061 * DN - 1.67826
   For the NIR detector it is:
   TEMP_2 = -8.89100589E-18 * DN^5 - 9.72043502E-15 * DN^4
   + 1.73862825E-10 * DN^3 + 3.39958815E-7 * DN^2
   - 0.00702301101 * DN - 22.2879012

   For other temperature data (TEMP_1 and GRATING_TEMP) see CDR.
   PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = BINNING
   COLUMN_NUMBER  = 7
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 17
   DESCRIPTION    = "Number of pixels that were binned together in the data.
   A flight-software update during the mission changed how the pixels are
   were binned. For data with SPECTRUM_UTC_TIME prior to March 16, 2009,
   the pixels were co-added. For data with SPECTRUM_UTC_TIME on or after
   March 16, 2009, the multiple pixels were averaged. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = START_PIXEL
   COLUMN_NUMBER  = 8
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 19
   DESCRIPTION    = "Start pixel of data captured by the detector array. For
   VIS the value can be from 0-511. For NIR the value can be from 0-255.
   OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = END_PIXEL
   COLUMN_NUMBER  = 9
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 21
```

```
   DESCRIPTION    = "End pixel of data captured by the detector array. For
   VIS the value can be from 0-511. For NIR the value can be from 0-255.
   The END_PIXEL must be greater than START_PIXEL. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPECTRUM_NUMBER
   COLUMN_NUMBER  = 10
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 23
   DESCRIPTION    = "Ordered number sequence for spectra in a given
   observation. First spectrum is 0, second is 1, third is 2, and so on.
   Note that for observations which span multiple science packets, the
   numbering sequence is continuous. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPECTRUM_MET
   COLUMN_NUMBER  = 11
   BYTES          = 4
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 25
   DESCRIPTION    = "A calculated value intended to reflect mission elapsed
   time (in seconds) since launch (for partition 1) or since reset (for
   partition 2) at the start of an individual VIRS spectrum.
   This is derived using the following formula:
   SPECTRUM_MET = SC_TIME + floor(SPECTRUM_NUMBER*PERIOD*0.050)
   PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPECTRUM_SUBSECONDS
   COLUMN_NUMBER  = 12
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 29
   DESCRIPTION    = "The calculated subsecond time in milliseconds that a
   VIRS integration was started. For each VIRS integration, SPECTRUM_MET
   plus SPECTRUM_SUBSECONDS gives the spacecraft time of the start of that
   integration. This is derived using the following formula:
   SPECTRUM_SUBSECONDS = (PACKET_SUBSECONDS + SPECTRUM_NUMBER * PERIOD * 50)
   mod 1000
   PER SPECTRUM column."
END_OBJECT    = COLUMN

/* CALIBRATED ITEMS AND ADDITIONAL METADATA */
OBJECT        = COLUMN
   NAME           = SPECTRUM_UTC_TIME
   COLUMN_NUMBER  = 13
   BYTES          = 17
   DATA_TYPE      = CHARACTER
   START_BYTE     = 31
   DESCRIPTION = "UTC time in YYDOYTHH:MM:SS.00 format translated from
   spacecraft time and packet subseconds (in integer seconds) that is
   transmitted to MESSENGER subsystems by the Integrated Electronics Module.
   PER SPECTRUM column."
```

```
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = IOF_SPECTRUM_DATA
   COLUMN_NUMBER    = 14
   BYTES            = 2048
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 48
   ITEMS            = 512
   ITEM_BYTES       = 4
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived column of reflectance-at-sensor spectra. One
   row per spectrum. NIR spectrum has up to 256 values (depending on binning
   and windowing), VIS has up to 512. Reflectance is a unitless parameter.
   Reflectance from saturated pixels, or binned pixels with one saturated
   element, are set to 1e32. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = PHOTOM_IOF_SPECTRUM_DATA
   COLUMN_NUMBER    = 15
   BYTES            = 2048
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 2096
   ITEMS            = 512
   ITEM_BYTES       = 4
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived column of photometrically normalized
   reflectance-at-sensor spectra. One row per spectrum. NIR spectrum has up
   to 256 values (depending on binning and windowing), VIS has up to 512.
   Reflectance is a unitless parameter. Reflectance from saturated pixels,
   or binned pixels with one saturated element, are set to 1e32. PER
   SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = IOF_NOISE_SPECTRUM_DATA
   COLUMN_NUMBER    = 16
   BYTES            = 2048
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 4144
   ITEMS            = 512
   ITEM_BYTES       = 4
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived column of noise/error in reflectance propagated
   through post-calibration procedure. One row per spectrum. NIR spectrum
   has up to 256 values (depending on binning and windowing), VIS has up to
   512.  Unitless. Noise from saturated pixels, or binned pixels with one
   saturated element, are set to 1e32. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = PHOTOM_IOF_NOISE_SPECTRUM_DATA
   COLUMN_NUMBER    = 17
   BYTES            = 2048
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 6192
```

```
   ITEMS            = 512
   ITEM_BYTES       = 4
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived column of noise/error in photometrically normalized
   reflectance propagated through post-calibration procedure. One row per
   spectrum. NIR spectrum has up to 256 values (depending on binning and
   windowing), VIS has up to 512. Unitless. Noise from saturated pixels, or
   binned pixels with one saturated element, are set to 1e32. PER SPECTRUM
   column. "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SOFTWARE_VERSION
   COLUMN_NUMBER  = 18
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 8240
   DESCRIPTION = "Indicates version of calibration software used. Increments
   with reprocessing of DDRs. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CHANNEL_WAVELENGTHS
   COLUMN_NUMBER  = 19
   BYTES          = 2048
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 8244
   ITEMS          = 512
   ITEM_BYTES     = 4
   DESCRIPTION = "Column of wavelengths paired to spectrum data channels.
   Wavelengths derived from calibration report equation 6.5. See VIRS CDR-
   DDR SIS. Unit = nanometers. OBSERVATION column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = DATA_QUALITY_INDEX
   COLUMN_NUMBER  = 20
   BYTES          = 19
   DATA_TYPE      = CHARACTER
   START_BYTE     = 10292
   DESCRIPTION = "19 character index of data quality. Each digit signifies
   quality factor of measurements. PER SPECTRUM column.
   Format: ABCD-EFGH-IJKL-MNOP
    A: Dark Scan Flag, denotes shutter commanded closed for dark observation.
      0 = shutter not engaged
      1 = shutter engaged
    B: Temperature 1 Flag
      0 = Temperature does not exceed 15 deg C threshold.
      1 = Temperature exceeds 15 deg C threshold but less than 25 deg C
      threshold.
      2 = Temperature exceeds 25 deg C threshold but less than 40 deg C
      threshold.
      3 = Temperature exceeds 40 deg C threshold.
    C: Temperature 2 Flag
      0 = Temperature does not exceed 15 deg C threshold.
      1 = Temperature exceeds 15 deg C threshold but less than 25 deg C
      threshold.
```

```
    2 = Temperature exceeds 25 deg C threshold but less than 40 deg C
    threshold.
    3 = Temperature exceeds 40 deg C threshold.
  D: Grating Temperature Flag
    0 = Temperature does not exceed 15 deg C threshold.
    1 = Temperature exceeds 15 deg C threshold but less than 25 deg C
    threshold.
    2 = Temperature exceeds 25 deg C threshold but less than 40 deg C
    threshold.
    3 = Temperature exceeds 40 deg C threshold.
  E: Anomalous Pixels
    Integer 0-9 = Indicates number of hot pixels found.
    Working Definition: The number of pixels with a noise spike (defined
    in DQI L, below).
    Procedure: The number of noise spike channels for spectra i. Repeat
    for all N spectra.
  F: Partial Data Flag
    0 = No partial data.
    1 = Partial data exists.
    Working Definition: If any spectrum has nulls in the beginning or end,
    signifying data drop outs.
    Procedure: Given spectra i, evaluate first 10 channels and last 10
    channels. If any channel has 0 value, set Partial Data Flag = 1.
  G: Saturation Flag
    0 = No pixels saturated.
    1 = Saturated pixels exist.
  H: Low Signal Level Flag
    0 = Signal level not below -32768 threshold.
    1 = Signal level below -32768 threshold.
  I: Low VIS Wavelength Uncertainty Flag (not yet implemented, set to 0)
    0 = Uncertainty not above TBD threshold at low wavelengths.
    1 = Uncertainty above TBD threshold at low wavelengths.
  J: High VIS Wavelength Uncertainty Flag (not yet implemented, set to 0)
    0 = Uncertainty not above TBD threshold at high wavelengths.
    1 = Uncertainty above TBD threshold at high wavelengths.
  K: UVVS Operating Flag
    0 = UVVS is not scanning during readout.
    1 = UVVS is scanning during readout.
  L: UVVS Noise Spike Flag
    0 = No noise spike detected.
    1 = Noise spike detected.
    Using VIRS VIS (512 channel spectrum, N spectra per CDR) as an example,
    Working Definition: A noise spike is a data value in 1 or 2 channels
    that exceeds 3 standard deviations of the average for a given channel
    in a given observation.
    Procedure: Calculate the standard deviation for channel 1 through all
    1-N spectra. If spectra i has stdev >=3, then spectra i has a noise
    spike. Repeat calculation for channels 2-512. Keep track of the number
    of 'noise spike channels' per spectra.
  M: 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
  N: Dark Saturation Flag
```

```
      Denotes that there are minimal unsaturated dark frames available for
      the polynomial fit of one or more pixels.
      0 = All pixels in data record contain at least four unsaturated dark
      frames.
      1 = One or more pixels in data record contain three or fewer
      unsaturated dark frames.
    O-P: Spares"
END_OBJECT    = COLUMN

/*** SPICE DERIVED GEOMETRY VALUES TAKEN DIRECTLY FROM VIRS VIS CDR ***/

OBJECT        = COLUMN
   NAME             = TARGET_LATITUDE_SET
   COLUMN_NUMBER    = 21
   BYTES            = 40
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 10311
   ITEMS            = 5
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived latitude of footprint center, uprange edge (c1),
   downrange edge (c2), port, (c3) and starboard (c4) edges (5 total values,
   coordinates as in Figure 4 of VIRS_CDR_DDR_DAP_SIS.PDF; center point,
   c1, c2, c3, c4) on planet target corresponding to spectral observation.
   Unit = degrees. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = TARGET_LONGITUDE_SET
   COLUMN_NUMBER    = 22
   BYTES            = 40
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 10351
   ITEMS            = 5
   ITEM_BYTES       = 8
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived longitude of footprint center, uprange edge (c1),
   downrange edge (c2), port, (c3) and starboard (c4) edges (5 total values,
   coordinates as in Figure 4 of VIRS_CDR_DDR_DAP_SIS.PDF; center point,
   c1, c2, c3, c4) on planet target corresponding to spectral observation.
   Unit = degrees. PER SPECTRUM column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME             = ALONG_TRACK_FOOTPRINT_SIZE
   COLUMN_NUMBER    = 23
   BYTES            = 8
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 10391
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION    = "Derived length of VIRS footprint along track over the
   spectrum integration time, accounting for smear across surface.
   Unit = meters. PER SPECTRUM column."
END_OBJECT    = COLUMN
```

```
OBJECT         = COLUMN
   NAME              = ACROSS_TRACK_FOOTPRINT_SIZE
   COLUMN_NUMBER     = 24
   BYTES             = 8
   DATA_TYPE         = IEEE_REAL
   START_BYTE        = 10399
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived instantaneous width of VIRS footprint across track
   at the spectrum integration midpoint, accounting for jitter across
   surface. Unit = meters. PER SPECTRUM column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME              = INCIDENCE_ANGLE
   COLUMN_NUMBER     = 25
   BYTES             = 8
   DATA_TYPE         = IEEE_REAL
   START_BYTE        = 10407
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived solar incidence angle of footprint center.
   Unit = degrees. PER SPECTRUM column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME              = EMISSION_ANGLE
   COLUMN_NUMBER     = 26
   BYTES             = 8
   DATA_TYPE         = IEEE_REAL
   START_BYTE        = 10415
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived emission angle of footprint center.
   Unit = degrees. PER SPECTRUM column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME              = PHASE_ANGLE
   COLUMN_NUMBER     = 27
   BYTES             = 8
   DATA_TYPE         = IEEE_REAL
   START_BYTE        = 10423
   MISSING_CONSTANT = -1.E32
   INVALID_CONSTANT = 1.E32
   DESCRIPTION = "Derived phase angle of footprint center. Unit = degrees.
   PER SPECTRUM column."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME              = SOLAR_DISTANCE
   COLUMN_NUMBER     = 28
   BYTES             = 8
   DATA_TYPE         = IEEE_REAL
   START_BYTE        = 10431
   MISSING_CONSTANT = -1.E32
```

```
   DESCRIPTION = "Derived subsolar distance to footprint center on planet
   surface. Unit = kilometers. PER SPECTRUM column."
END_OBJECT    = COLUMN

/* SPARE COLUMNS */

OBJECT        = COLUMN
   NAME             = SPARE_1
   COLUMN_NUMBER    = 29
   BYTES            = 4
   DATA_TYPE        = IEEE_REAL
   START_BYTE       = 10439
   MISSING_CONSTANT = -1.E32
   DESCRIPTION = "SPARE column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPARE_2
   COLUMN_NUMBER  = 30
   BYTES          = 4
   DATA_TYPE      = MSB_INTEGER
   START_BYTE     = 10443
   DESCRIPTION = "SPARE column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPARE_3
   COLUMN_NUMBER  = 31
   BYTES          = 4
   DATA_TYPE      = MSB_INTEGER
   START_BYTE     = 10447
   DESCRIPTION = "SPARE column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPARE_4
   COLUMN_NUMBER  = 32
   BYTES          = 4
   DATA_TYPE      = MSB_INTEGER
   START_BYTE     = 10451
   DESCRIPTION = "SPARE column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPARE_5
   COLUMN_NUMBER  = 33
   BYTES          = 4
   DATA_TYPE      = MSB_INTEGER
   START_BYTE     = 10455
   DESCRIPTION = "SPARE column."
END_OBJECT    = COLUMN
```

APPENDIX E- 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 F- 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 G- 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 Kernel (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
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
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
NS	Neutron Spectrometer
PCK	Planetary Constant Kernel (SPICE)
PDS	Planetary Data System
PMT	Photomultiplier Tube. Refers to the UVVS detectors.
RDR	Reduced Data Record
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 H- MASCS Instrument Overview

Ultraviolet and Visible Spectrometer

Focal length	125 mm
Grating	2400 g/mm blazed at 330 nm
Spectra resolution	0.5 nm FUV channel
	0.7 nm MUV channel
	0.6 nm VIS channel

Wavelength range:

FUV channel	115-190 nm (2^{nd} order)
MUV channel	160-320 nm (1^{st} order)
VIS channel	250-600 nm (1^{st} order)

Detector:

FUV channel	Hamamatsu R1081 PMT - CsI
MUV channel	Hamamatsu R759 PMT - CsTe
VIS channel	Hamamatsu R760P PMT - BiAlkali

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	100 g/mm sinusoidal profile
Spectral resolution	4.7 nm

Wavelength range:

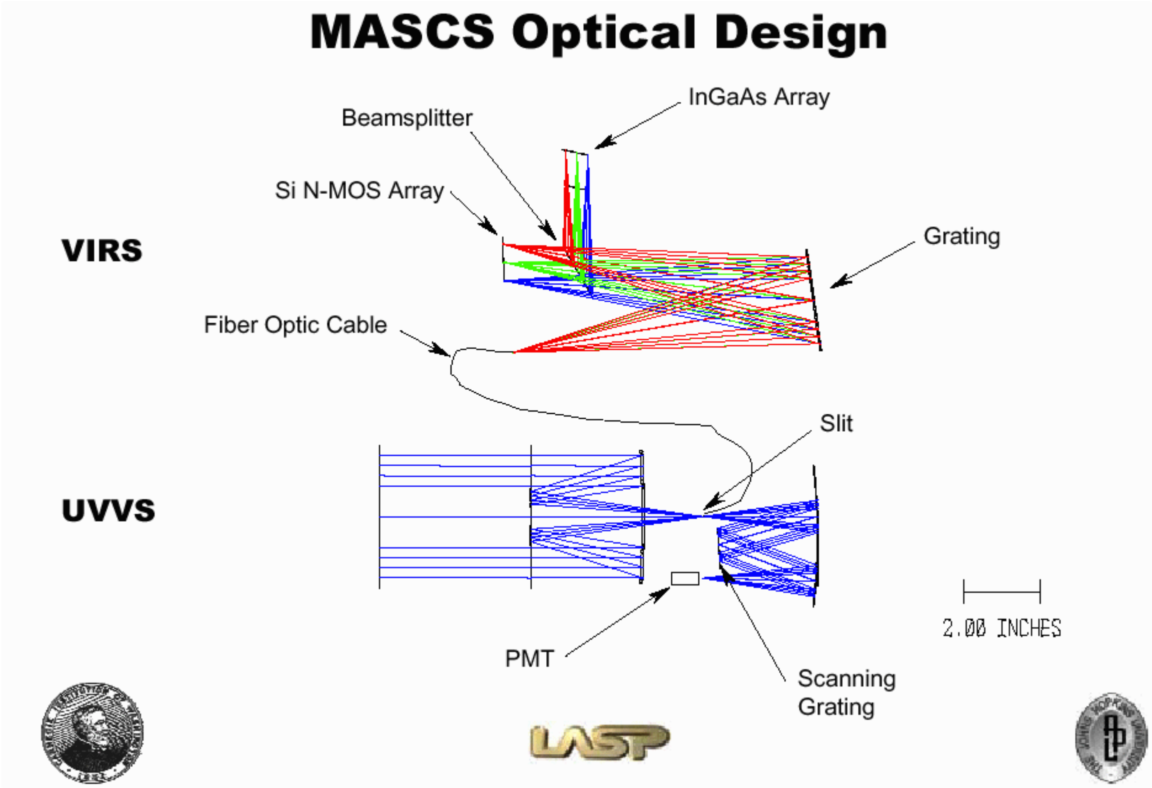
VIS channel	300-1050 nm
IR channel	850-1450 nm

Detector:

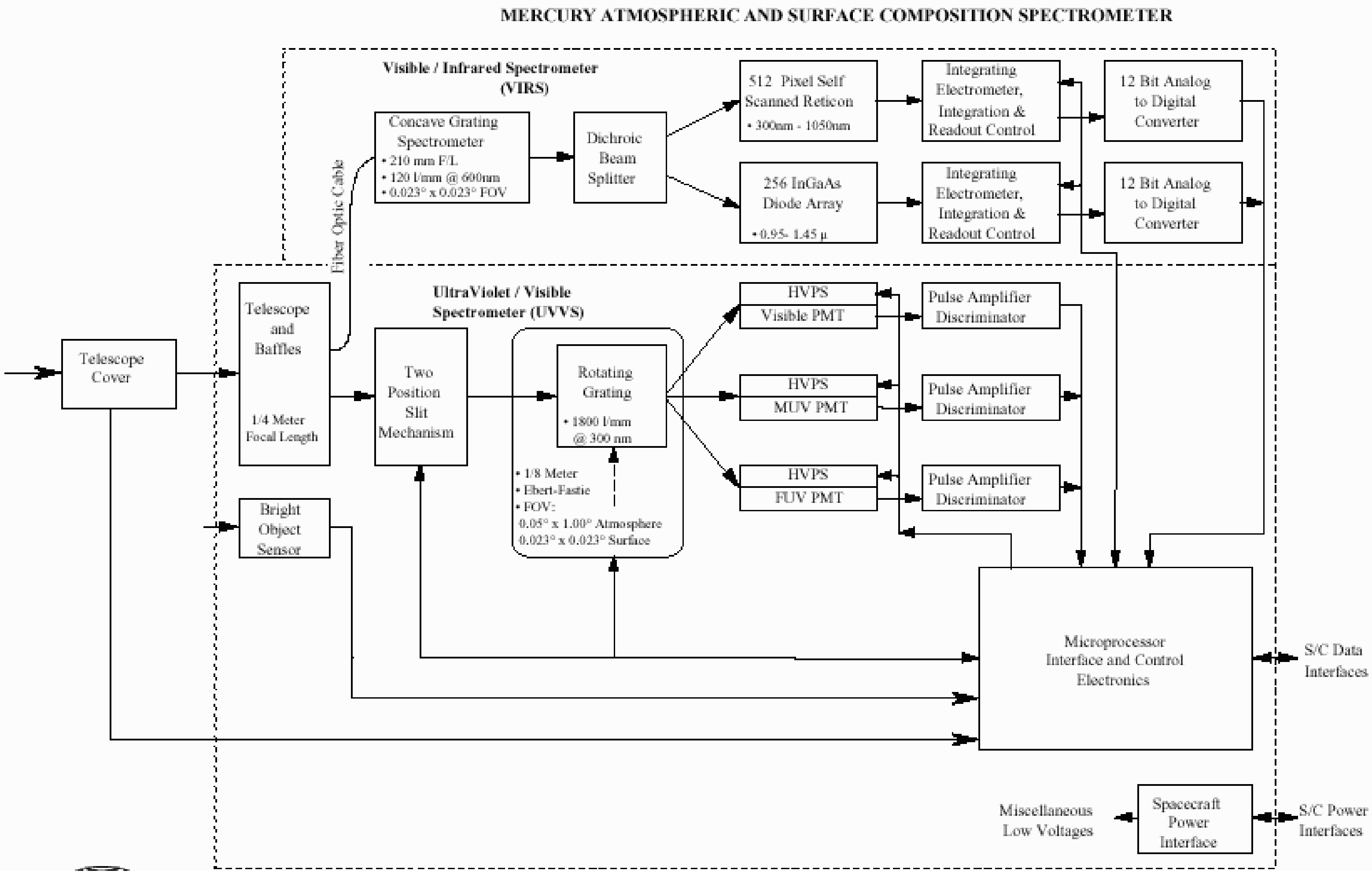
VIS channel	Hamamatsu S3901-512SPL Si Diode Array
IR channel	Hamamatsu G8162-256S InGaAs Diode Array

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
LASP

Mercury Atmospheric and Surface Composition Spectrometer



APPENDIX I- MASCS Data Product Summary

VOLUME_ID = MESSMAS_1001	Description	DATA_SET_ID	STANDARD_ DATA_ PRODUCT_ID	SIS Section
UVVS EDRs	UVVS Experiment Data Records	MESS-E/V/H-MASCS-2-UVVS-EDR-V1.0	UVVSFUV UVVSMUV UVVSVIS UVVSHK	UVVSEDRSIS 5.2
VIRS EDRs	VIRS Experiment Data Records	MESS-E/V/H-MASCS-2-VIRS-EDR-V1.0	VIRSNIR VIRSVIS VIRSHK	VIRSEDRSIS 5.2
VOLUME_ID = MESSMAS_2001	**Description**	**DATA_SET_ID**	**STANDARD_ DATA_ PRODUCT_ID**	**SIS Section**
UVVS CDRs	Calibrated data derived from UVVS EDRs	MESS-E/V/H-MASCS-3-UVVS-CDR-CALDATA-V1.0	UVVSCFUVHDR UVVSCFUVSCI UVVSCMUVHDR UVVSCMUVSCI UVVSCVISHDR UVVSCVISSCI	UVVS_CDR_DDR_SIS 5.2.1
UVVS MUV Surface DDRs	Reflectance data derived from UVVS MUV surface CDRs	MESS-E/V/H-MASCS-4-UVVS-DDR-V1.0	UVVSDMUVHDR UVVSDMUVSCI	UVVS_CDR_DDR_SIS 5.2.2.1
UVVS FUV Surface DDRs	Reflectance data derived from UVVS FUV surface CDRs	MESS-E/V/H-MASCS-4-UVVS-DDR-V1.0	UVVSDFUVHDR UVVSDFUVSCI	UVVS_CDR_DDR_SIS 5.2.2.2
UVVS Atmosphere DDRs	Time-ordered sequences of radiance values measured along lines of sight perpendicular to Mercury radius vectors	MESS-E/V/H-MASCS-4-UVVS-DDR-V1.0	UVVSDNALS UVVSDNALD UVVSDNANS UVVSDMGLS UVVSDMGLD UVVSDMGNS UVVSDCALS UVVSDCALD UVVSDCANS	UVVS_CDR_DDR_SIS 5.2.2.3
UVVS Atmosphere Summary DDRs	Orbit-level summary products that gather together all of the observations for a given species for a given orbit into a single file	MESS-E/V/H-MASCS-4-UVVS-DDR-V1.0	UVVSDNASUM UVVSDMGSUM UVVSDCASUM	UVVS_CDR_DDR_SIS 5.2.2.3
UVVS Atmospheric Model DDRs	A series of model fits to data averaged over specific Mercury true anomalies and local times	MESS-E/V/H-MASCS-4-UVVS-DDR-V1.0	UVVSDNAMOD UVVSDCAMOD	UVVS_CDR_DDR_SIS 5.2.2.4

VIRS CDRs	Calibrated data derived from VIRS EDRs	MESS-E/V/H-MASCS-3-VIRS-CDR-CALDATA-V1.0	VIRSCNIR VIRSCVIS	VIRS_CDR_DDR_DAP_SIS 5.2.1
VIRS DDRs	Reflectance data derived from VIRS CDRs	MESS-E/V/H-MASCS-4-VIRS-DDR-V2.0	VIRSDNIR VIRSDVIS	VIRS_CDR_DDR_DAP_SIS 5.2.2
VIRS DAPs	A 500 meter per pixel mosaic map of 1 wavelength (750 nm) of VIRS spectral data for footprints covering the planet Mercury	MESS-E/V/H-MASCS-5-VIRS-DAP-V2.0	VIRSDAP	VIRS_CDR_DDR_DAP_SIS 5.2.3
UVVS + VIRS Combined DDRs	Derived data from UVVS' middle ultraviolet (MUV) photomultiplier tube, and VIRS	MESS-E/V/H-MASCS-4-UVVS/VIRS-DDR-V1.0	UVVSVIRSD	UVVS_VIRS_COMBINED_DDR_SPEC 5.2.2