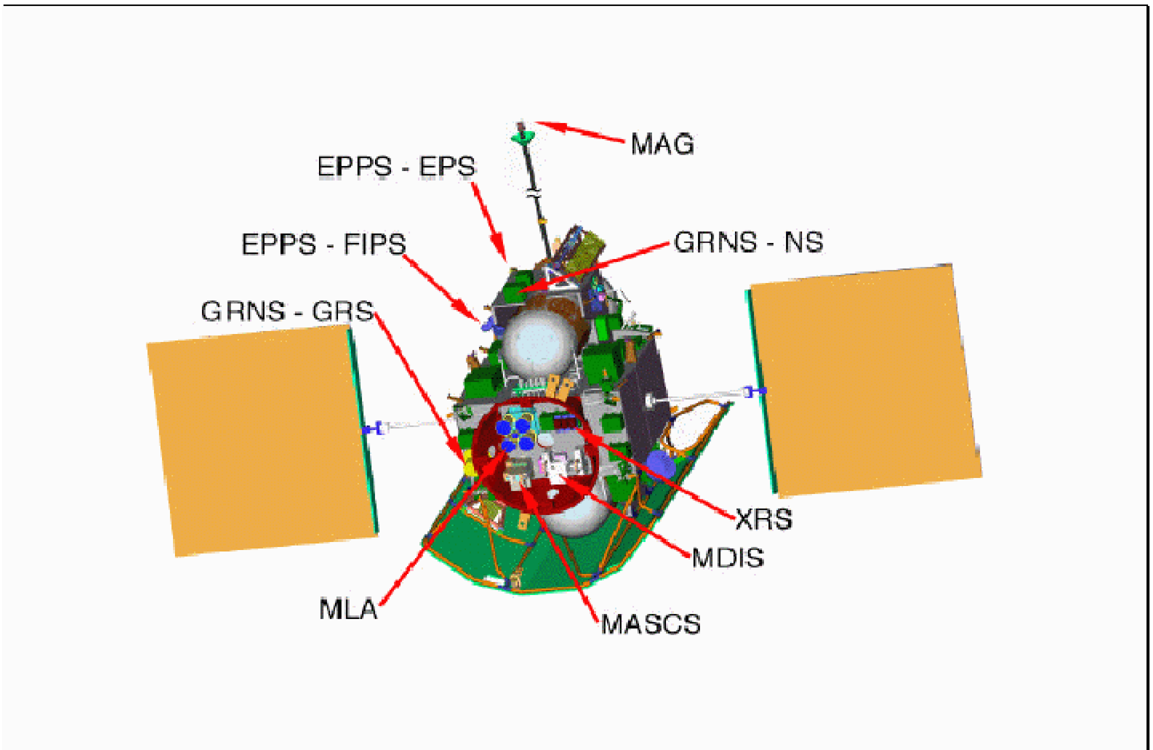
Experiment Data Record Software Interface Specification for the MESSENGER Mercury Atmospheric and Surface Composition Spectrometer/ Visible and Infrared Spectrograph (MASCS/VIRS)

SIE-06-045 D



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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	6/23/06			Start of revision history. Version submitted to PDS for Release 4.
1.1	1/7/10	J. Ward, GEO	TOC, 5.3.4	1. Added page numbers to Table of Contents. 2. Replaced sample PDS labels with new versions containing PRODUCT_VERSION_ID.
1.2	1/12/10	J. Ward, GEO	6.3.2, Appendix	Updated column 64 of MASCS_HK.FMT to match delivered file in LABEL directory.
1.3	1/14/10	J. Ward, GEO	Title Page	Added “Experiment Data Record” to document title.
1.4	9/15/10	J. Ward, GEO	6.1.3, 6.1.4	Added EXTRAS directory tables.
1.5	12/09/10	J. Ward, GEO	7	Updated archive release schedule.
1.6	5/5/11	J. Ward, GEO	6.1.3, 6.1.4	Updated to reflect new data directory structure.
1.7	6/10/11	J. Ward, GEO	6.1.4	Updated EXTRAS directory contents.
1.8	6/14/11	S. Ensor, SOC	Document Review	Replaced signature page with Document Review information.
1.9	6/17/11	J. Ward, GEO	6.1.4	Renamed SUPERTABLE.XLS TO MASTER_CRUISE_TABLE.XLS.
2.0	12/21/11	J. Ward, GEO	6.1.4	Updated EXTRAS directory contents.
2.1	5/25/12	S. Ensor, SOC	2, 7, 6.1.2	1. Change document name from *Data Management and Science Analysis Plan* to *Data Management and Archiving Plan.* Update references. 2. Reference *Data Management and Archiving Plan* for release schedule and remove release schedule, table B-1, from this document. 3. Add mission phase for second year of orbital operations.
2.2	11/12/12	J. Ward, GEO	6.1.4	Updated EXTRAS directory contents.
2.3	7/7/2015	S.Ensor	Various, 5.4.2, 6.1.2	Change “Experimental Data Record” to “Experiment Data Record” in text. Note use of clock partitions in time tags in product labels following January 8, 2013 S/C clock reset. Update reference to PDS file naming standard (was 27.3 now 36.3).

Table of Contents

1. Purpose and Scope of Document

1.1 Purpose

This document will provide users of the MESSENGER Visible and Infrared Spectrograph (VIRS) data products with a detailed description of the Spectrograph instrument (Figure 1: VIRS subsystem) and EDR data product generation, data validation and storage. The VIRS data products are a deliverable to the Planetary Data System (PDS) and the scientific community that it supports. All data formats are based on the PDS standard.

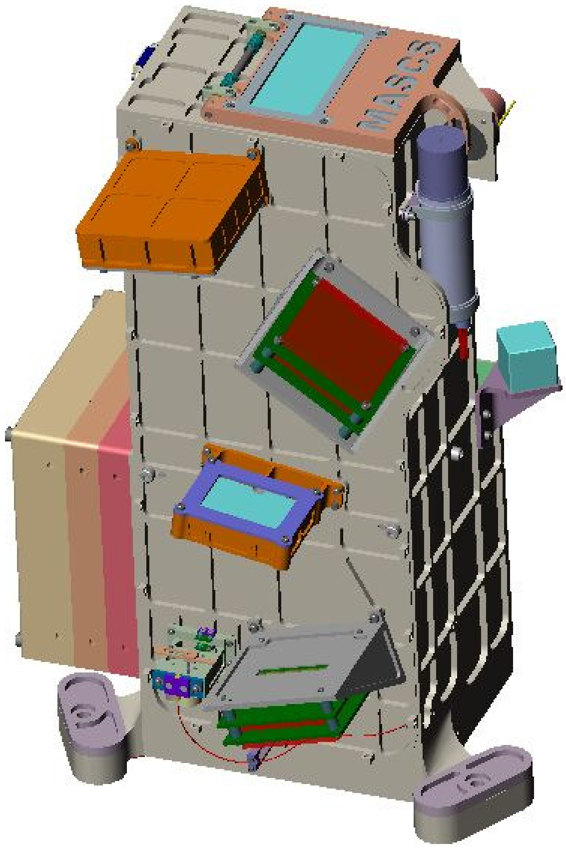


Figure 1: MASCS Instrument, VIRS subsystem.

In addition this SIS provides documentation on the format and content of the MESSENGER MASCS EDR PDS Volume Archive. The document is both an EDR data product SIS and an EDR archive volume SIS.

1.2 Scope

This specification is useful to those who wish to understand the format and content of the VIRS EDR data products. Typically, these individuals include software engineers, data analysts, and planetary scientists. The SIS applies to the EDR data products produced during the course of Messenger Mission operations. Calibrated and Reduced Data Records (CDRs and RDRs) are outside the scope of this SIS and are described in a separate SIS document. RDRs and CDRs are also archived in their own, separate PDS archive volume.

2. Applicable Documents

The MESSENGER VIRS SIS is responsive to the following Documents:

- 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
- Planetary Data System Standards Reference, Aug 1, 2003, Version 3.6. JPL D-7669, Part-2.
- MESSENGER Data Management and Archiving Plan. The Johns Hopkins University, APL. Document ID number 7384-9019
- [PLR] Appendix 7 to the discovery program Plan; Program Level Requirement for the MESSENGER Discovery project; June 20, 2001.
- MASCS Users Guide. Laboratory for Atmospheric and Space Physics, University of Colorado. Document ID number 20580-T5-5103
- Instrument Calibration Report Mercury Atmospheric and Surface Composition Spectrometer

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 will be electronically transferred to the PDS Geosciences and Atmospheres Nodes according to the delivery schedule in the MESSENGER Data Management and Archiving Plan. The VIRS and UVVS EDRs (detailed in the UVVS EDR SIS) have some data that would be useful in cross-comparison, therefore both the UVVS and VIRS EDR data will be grouped together in the MASCS EDR volume archive stored at both PDS nodes. The data in the EDR files themselves will be stored in a PDS TABLE object as binary tables.

4. Roles and Responsibilities

The roles and responsibilities of the instrument teams, Applied Physics Lab (APL), Applied Coherent Technology (ACT), and the Planetary Data System (PDS) are defined in the MESSENGER Data Management and Archiving Plan.

5. Data Product Characteristics and Environment

5.1 Overview

Visible and Infrared Spectrograph measures the visible and infrared surface reflectance. It is a concave grating spectrograph equipped with Si and InGaAs photodiode arrays.

Visible and infrared Spectrograph

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

An overview of the whole MASCS instrument is provided in the APPENDIX – MASCS Instrument Overview.

5.2 Data Product Overview

There are two EDR data products produced by the VIRS instrument, one for each detector (VIS and NIR). These are identified in the PDS label 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 PDS label as the "MASCSHK" standard data product. The housekeeping EDR is defined both in this SIS and in the UVVS SIS for completeness but is the same data product.

For the VIRS EDR data product, one EDR will contain all the data from one observation. However, one observation will generate a variable number of spectra and a variable number of CCSDS packets. Thus there is not a one-to-one correspondence between CCSDS packets and VIRS EDRs. Identification of which CCSDS packet belongs to a given observation will be done by correlating the packet MET with the planned start MET and planned duration of the observation set by the MASCS science team.

The MASCS Housekeeping EDR will contain all housekeeping packets generated in a given day. The day is defined as a 24-hour period from 00:00:00 to 23:59:59.999. A variable number of housekeeping packets will be generated each day; the data from each packet will be inserted as 1 row in the EDR binary table.

Each EDR data product consists of two files. One file contains the data itself, and is arranged in a PDS binary table format. The other file is a detached PDS label file, which describes the content of the data file. The label file defines the start time and end of the observation, product creation time, etc. The label file also defines the fields of the binary table contained within the data file.

5.3 Data Processing

5.3.1 Data Processing Level

For MESSENGER there is one archive for the VIRS instrument. The archive includes level 2 (or above) data as defined by the Committee on Data Management and Computation (CODMAC). The archive will also contain SPICE files, standard data products, relevant software, and documentation describing the generation of the products, Each product will have a unique file name *across* all MASCS data products, see section 6.1.2.

All data level products will be stored at the Science Operations Center (SOC) located at Johns-Hopkins University Applied Physics Laboratory (APL). Level 1 CODMAC data will be received at the SOC where it will be ingested via an automatic data processing system and stored in a database reserved for the VIRS instrument. Bundled with the sensor spectral data products will be scientific and engineering housekeeping data sampled by the VIRS instrument at the same time as the integral spectra onboard the spacecraft. Data downlink is telemetered through NASA's Deep Space Network (DSN) managed by the Jet Propulsion Laboratory in Pasadena, CA, and then forwarded to APL. Inputs to the SOC will consist of telemetry in the form of CCSDS packets. The data will be available via a real-time TCP stream service and post pass FTP file service. Level-0 VIRS raw spectral and engineering data is then broken out of the data stream and stored online at the SOC. The SOC will produce early versions of the data products by utilizing SPICE kernels to enable a "quick look" functionality that lets users view the coverage areas recorded by the sensor. The early versions will be of the same type, content, and format as the final science products with default values for unknown data. Unknown data refers to the PDS keywords corresponding to spacecraft position, sun position, target latitude and target longitude. The values for these keywords will be calculated via the use of SPICE kernels and will be filled in prior to delivery to PDS.

5.3.2 Data Product Generation

The VIRS EDR files will be produced by the MESSENGER SOC; operated jointly by APL and ACT. The 'PIPE-MASCS2EDR' software converts the data to the proper PDS labeled format. This software is not part of the deliverable to the PDS archive. The EDR data products are 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 are organized and stored in the directory structure described in section 6.1.3 for transmittal to the Geosciences and Atmospheres Nodes. The transmittal process is described in the following section, Data Flow. PDS will then provide public access to the data products through its online data distribution system. These products will be 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 will be required. Examples of ancillary data include calibration files and viewing geometry files (SPICE kernels). Calibration files and their use will be described in the UVVS RDR SIS and VIRS RDR SIS as well as in the MASCS Instrument Calibration Report. The GEOMETRY.TXT file mentioned in section 6.1.4 will contain the SPICE kernel types that will be needed by a user to generate viewing geometry. The SPICE kernel files will be archived with the PDS NAIF Node.

5.3.3 Data Flow

The MESSENGER SOC operates under the auspices of the MESSENGER Project Scientist to plan data acquisition and generate and validate data archives. The SOC supports and works with the Mission Operations Center (MOC), the Science Team, instrument scientists, and the PDS. The SOC will be located at the Johns-Hopkins University Applied Physics Lab (JHU/APL). During the mission operations phase the SOC will produce early versions of products that can be used by the science and instrument teams.

The MESSENGER SOC will deliver 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. The VIRS and UVVS archive volumes (detailed in a separate UVVS SIS) will be archived at both Nodes. Each package will comprise both data and ancillary data files, organized into directory structures consistent with the volume design described in Section 6.1.3.

In the week prior to the delivery date the directory structure will be compressed into a single "zip archive" file for transmittal to both PDS Nodes. The zip archive preserves the directory structure internally so that it can be recreated after electronic delivery to the PDS Node. The zip archive file is transmitted to the PDS Node via FTP to an account set up by the receiving Node. Also transmitted will be a checksum file created using the MD5 algorithm. This provides an independent method of verifying the integrity of the zip file after it has been sent. Within several days of transmittal the PDS Node will acknowledge receipt of the archive and checksum file. If acknowledgement is not received, or if problems are reported, the MESSENGER SOC will immediately take corrective action to effect successful transmittal.

After transmittal the PDS Node will uncompress the zip archive file and check for data integrity using the checksum file. The Node will then perform any additional verification and validation of the data provided and will report any discrepancies or problems to the MESSENGER SOC. It is expected that the Node will perform these checks in about two weeks. After inspection has been completed to the satisfaction of the PDS Node, the Node will issue to the MESSENGER SOC acknowledgement of successful receipt of the data.

Following receipt of a data delivery each Node will organize the data into PDS volume archive structure within its online data system. The Node will generate 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 will be made available publicly from PDS once accompanying labels and other documentation have been validated.

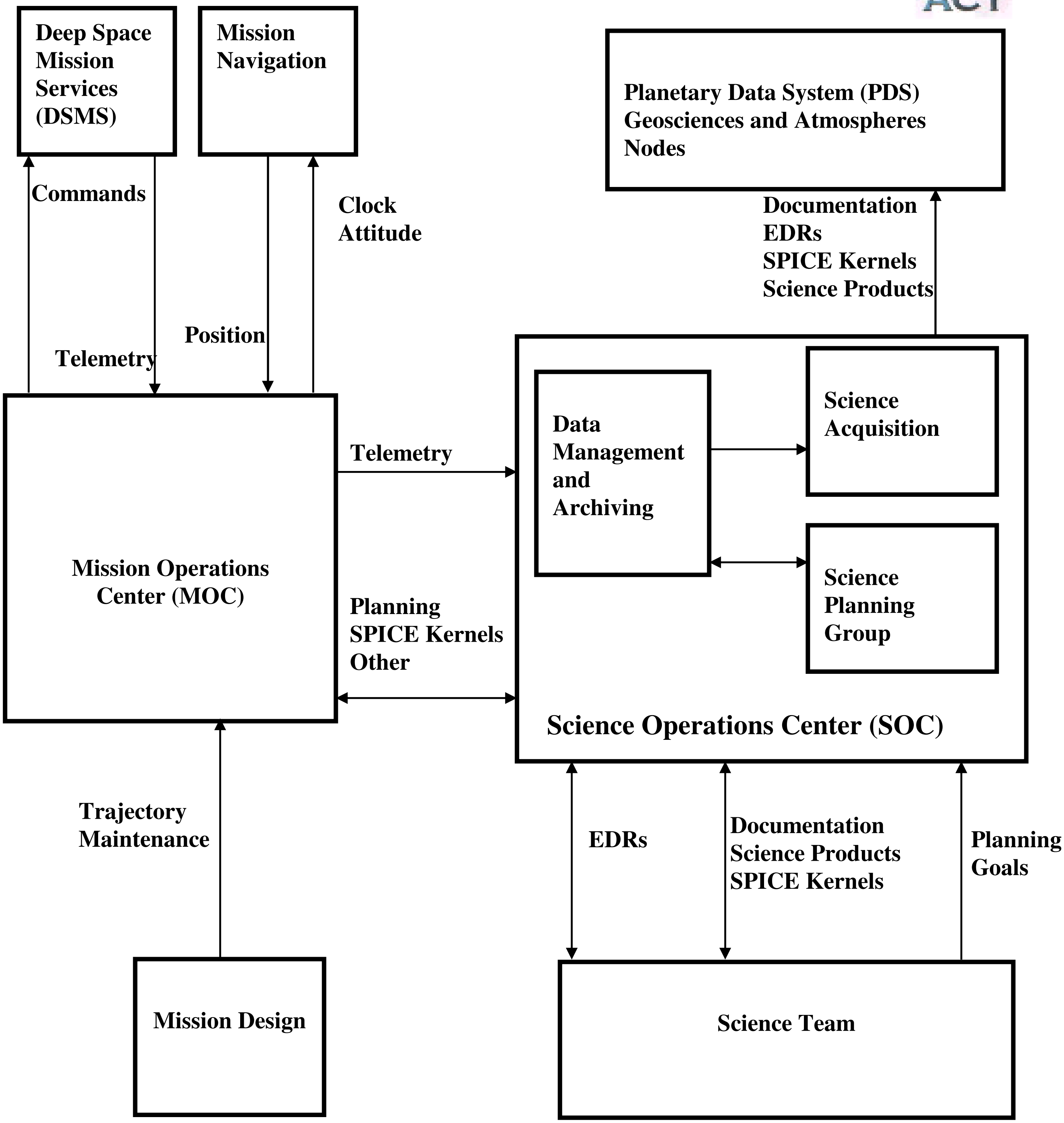


Figure 2. MESSENGER data flow

5.3.4 Labeling and Identification

The label area of the data file conforms to the PDS version 3 standards. For more information on this standard consult the PDS Standards Reference JPL D-7669 Document. The purpose of the PDS label is to describe the data product and provide ancillary information about the data product. For every EDR data file there exists a PDS label file. The following is an example of a PDS label. There are three standard data products, "VIRSNIR", "VIRSVIS", and "MASCSHK" (section 5.2). The data files are linked to the standard data product via the STANDARD_DATA_PRODUCT_ID. Details about the label format are specified later in section 6.3.

5.3.4.1 EXAMPLE PDS LABEL FOR THE VIRS EDR DATA PRODUCTS

```
PDS_VERSION_ID                 = "PDS3"

/*** FILE FORMAT ***/
RECORD_TYPE                    = FIXED_LENGTH
RECORD_BYTES                   = 1102
FILE_RECORDS                   = 20

/*** GENERAL DATA DESCRIPTION PARAMETERS ***/
PRODUCT_ID                     = "VIRSNE_MF3_09285_004616_DAT"
PRODUCT_VERSION_ID             = "V1 "
PRODUCT_CREATION_TIME          = 2009-12-02T21:05:30
PRODUCT_TYPE                   = "EDR"
SOFTWARE_NAME                  = "PIPE-MASCS2EDR"
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-2-VIRS-EDR-V1.0"
STANDARD_DATA_PRODUCT_ID       = "VIRSNIR"
MISSION_PHASE_NAME             = "MERCURY 3 FLYBY"
TARGET_NAME                    = "MERCURY"
START_TIME                     = 2009-10-12T00:46:16
STOP_TIME                      = 2009-10-12T00:46:52
SPACECRAFT_CLOCK_START_COUNT   = "163795842"
SPACECRAFT_CLOCK_STOP_COUNT    = "163795878"
^TABLE                         = "VIRSNE_MF3_09285_004616.DAT"

OBJECT                         = TABLE
COLUMNS                        = 24
INTERCHANGE_FORMAT             = BINARY
ROW_BYTES                      = 1102
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 EDR SIS.

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

^STRUCTURE = "VIRS.FMT"
```

```
END_OBJECT                    = TABLE
END
```

The following is an example of the contents of the MASCS housekeeping EDR PDS label. The housekeeping EDR contains instrument parameters that may be useful in analyzing the UVVS data. Details about the label format are specified in section 6.3. The large amount of table fields in the housekeeping EDR necessitate the use of an external format (.FMT) file which contains all the fields for the housekeeping EDR. This format file will be placed at the top-level of the MASCS data folder to optimize archive space. The complete layout of the format file can be found in APPENDIX – MASCS_HK.FMT.

5.3.4.2 EXAMPLE PDS LABEL FOR THE MASCS HOUSEKEEPING EDR

```
PDS_VERSION_ID                = "PDS3"
RECORD_TYPE                   = FIXED_LENGTH
RECORD_BYTES                  = 254
FILE_RECORDS                  = 1177
PRODUCT_ID                    = "MASCS_HK_09285_DAT"
PRODUCT_VERSION_ID            = "V1 "
PRODUCT_CREATION_TIME         = 2009-10-22T07:45:44
PRODUCT_TYPE                  = "EDR"
SOFTWARE_NAME                 = "PIPE-MASCS2EDR"
SOFTWARE_VERSION_ID           = "1.1"
INSTRUMENT_HOST_NAME          = "MESSENGER"
INSTRUMENT_NAME               = "
 MERCURY ATMOSPHERIC AND SURFACE COMPOSITION SPECTROMETER"
INSTRUMENT_ID                 = "MASCS"
DATA_SET_ID                   =
 {"MESS-E/V/H-MASCS-2-UVVS-EDR-V1.0","MESS-E/V/H-MASCS-2-VIRS-EDR-V1.0"}
STANDARD_DATA_PRODUCT_ID      = "MASCSHK"

MISSION_PHASE_NAME            = "MERCURY 3 FLYBY"
TARGET_NAME                   = "MERCURY"
START_TIME                    = 2009-10-12T00:00:08
STOP_TIME                     = 2009-10-12T19:32:24
SPACECRAFT_CLOCK_START_COUNT  = "163793074"
SPACECRAFT_CLOCK_STOP_COUNT   = "163863410"
^TABLE                        = "MASCS_HK_09285.DAT"

OBJECT                        = TABLE
COLUMNS                       = 95
INTERCHANGE_FORMAT            = BINARY
ROW_BYTES                     = 254
ROWS                          = 1177
DESCRIPTION                   = "
    This table contains MASCS Housekeeping data. Voltage, current, and
       temperature parameters are converted from raw DN counts into engineering
    data values.

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

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

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

5.4 Standards Used in Generating Data Products

5.4.1 PDS Standards

The VIRS EDR data products are constructed according to the data object concepts developed by the PDS. By adopting the PDS format, the data products are consistent in content and organization with other planetary data collections. In the PDS standard, the VIRS data is grouped into pairs, with one file containing the binary table data and a detached PDS label describing the data. The detached label file will contain a pointer to the binary table file which stores the housekeeping data, derived pointing data, and the spectra.

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[1] on January 8, 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/). For this reason the SPICE spacecraft clock coefficients file is included as part of the archive in order to calculate the conversion between MET and UTC.

5.4.3 Coordinate Systems

Table 1 lists the computational assumptions for the geometric and viewing data provided in the PDS label. <u>There are two coordinate systems in use:</u> 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.

TABLE 1. – COMPUTATIONAL ASSUMPTIONS

```
<> The start time of observation (MET) is used for the geometric
   element computations.

<> 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.
```

[1] See instrument host catalog file in MASCS EDR volume catalog directory for more information on MESSENGER spacecraft clock reset.

```
<> 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 is
   outlined in APPENDIX - 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 will transfer data to PDS via electronic transfer and delivery methods as detailed in section 5.3.3. After verification of the data transfer PDS will provide public access to MESSENGER science data products through its online data distribution system. Data will be stored under a unique file name as defined in section 6.1.2.

5.5 Data Validation

The VIRS EDR data products will be validated by the VIRS Instrument scientist for science content and for compliance with PDS archive standards and the MESSENGER Data Management and Archiving Plan.

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 Calibrated and Reduced Data Set, which is contained in a separate volume archive, 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.

Calibration has not been performed on the data products stored in the EDR data archive volume. The EDR data archive volume is meant to contain the data in a format as close to that received from the MESSENGER spacecraft. The VIRS RDR data archive volume, which is separate from the EDR data archive volume, will contain calibrated data records and reduced data records created via calibration performed on the EDR data set. This calibration process is documented in the MASCS Instrument Calibration Report as well as in the VIRS RDR SIS.

6.1.1 Handling Errors

It is inevitable that errors will be introduced into the archive even with data validation procedures applied to the volumes. As errors are discovered, they are reported to the MESSENGER SOC. An ERRATA report file is maintained to track and document all discovered errors during the mission, including any EDRs that are revised during the course of the mission. Revised EDRs or EDRs that were missing from a previous PDS delivery will be provided at the next scheduled PDS delivery or at the final PDS delivery as needed. PDS will then replace the outdated files with the revised files in the data directories of the archive volume. The ERRATA report file is archived in the ROOT directory of the PDS archive volume.

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 EDR product is "VIRSdL_mmm_YYDDD_HHMMSS" where:

```
VIRS: instrument name
   d: detector identifier. N = NIR, V=VIS
   L: data level. E=EDR, C=CDR, R=RDR
 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 = second year of orbital operations
      OB3 = third year of orbital operations
      OB4 = fourth year of orbital operations
      OB5 = fifth year of orbital operations

     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 MASCS housekeeping EDR will be “MASCS_HK_YYDDD”, where:

```
YY: Is the last two digits of the year in which the data were
acquired.
DDD: Is the three digit (zero padded) day of the year in
which the data where acquired.
```

This identifies that the housekeeping EDR is common to both the UVVS and VIRS subsystems. For the VIRS EDR and housekeeping EDR the binary table file will end with a “.DAT” extension and the detached PDS label file will end with a “.LBL” extension.

6.1.3 Directory Structure and Contents for MASCS EDR Archive Volume

The following illustration shows the directory structure overview for the MASCS EDR Archive Volume. Note that the volume contains UVVS, VIRS, and HK EDRs. Details for the UVVS EDRs are contained in a separate UVVS SIS document. This archive volume is stored at both the Atmospheres and Geosciences PDS Nodes for reasons stated in section 3. A detailed description of the directory tree is provided following Table 2. Empty directories are not included on the volume.

<u>TABLE 2 Directory Structure Overview</u>

```
                                    <ROOT>
_______________________________________|______________________________________
     |            |           |          |           |            |         |
<GEOMETRY>  <INDEX>  <CATALOG>  <DATA>  <DOCUMENT>  <LABEL>  <EXTRAS>
                                       |
                                       |
                                     <mmm>
                                       |
                                       |
                               <MASCSYYYYMMDD>
                                       |
                                       |
                                       |
                                  _____|______________
                                  |          |       |
                                  |          |       |
                               <UVVS>    <VIRS>   <HK>
```

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. This provides users with an overview of the contents and organization of the associated volume, general instructions for its use, and contact 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 will be documented in this file. This includes revised EDRs meant to replace EDRs in a previous PDS delivery.

<DOCUMENT> Directory

The documentation files exist in several forms in order to facilitate access to the documents.
<> Files with extension **'TXT'** are ASCII text files that can be read by virtually all text editors.
<> Files with extension **'PDF'** are in Portable Document Format.

DOCINFO.TXT - Description of the DOCUMENT directory

VIRSEDRSIS.* - Contains the Software Interface Specification for the VIRS EDR data products. Different formats of the document exist.

UVVSEDRSIS.* - Contains the Software Interface Specification for the UVVS EDR data products. Different formats of the document exist.

<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.

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

INSTHOST.CAT – Describes the MESSENGER spacecraft.

MISSION.CAT – Describes the scientific goals and objectives of the MESSENGER program.

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

REF.CAT – Contains the reference objects, which reference additional documents that may be useful to the person using the MASCS EDR.

UVVS_DS.CAT, VIRS_DS.CAT – Describes the general content of the MASCS/VIRS and MASCS/UVVS datasets, and includes information about the duration of the mission and the person or group responsible for producing the 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. This includes a description of the structure and contents of each index table in the subdirectory AND usage notes.

INDEX.TAB – The EDR index file is organized as a table: there is one entry for each of the data /otfiles included in the VIRS data set; the columns contain parameters that describe the observation and instrument and spacecraft parameters. These parameters include state information, such as integration time, spacecraft clock count, time of observation, and instrument modes.

INDEX.LBL – Detached PDS label for INDEX.TAB.

<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.

<LABEL> Directory

This subdirectory contains format files that are referenced in the PDS labels for UVVS, VIRS and housekeeping 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 this directory.

UVVS.FMT – Format of MASCS UVVS EDR data products.

VIRS.FMT – Format of MASCS VIRS EDR data products.

MASCS_HK.FMT – Format of MASCS housekeeping data products.

<EXTRAS> Directory

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

VIRS_MISSING_PACKETS_R6.TXT – This file describes the investigation and resolution of the missing packet error described in the "Data Coverage and Quality" section of VIRS_DS.CAT (Note 6). 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_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_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.

MACRO_DEFINITION_TABLE.XLS – This is a table used to show commanded instrument parameters and other ancillary calculations such as expected durations and data volumes for MASCS macros commanding the spectrograph operation. This file can be viewed using Microsoft Excel. Note: this file is not yet available.

<DATA> Directory

This top level directory contains the EDR data products. Directly underneath the <DATA> directory are the <mmm> directories. The "mmm" characters define the mission phase, detailed in section 6.1.2 above. Below the mission phase directories are the <MASCSYYYYMMDD> directories. The "YYYYMMDD" characters define the four digit year, 2 digit month, and 2 digit day which is common to all the MET times for the EDRs stored in that directory. Each of these directories is further subdivided into as many as three subdirectories, one for each component of the MASCS instrument, and an additional subdirectory for the housekeeping EDR:

<UVVS> – UVVS Subdirectory.
<VIRS> – VIRS Subdirectory.
<HK> – Housekeeping EDR subdirectory.

Each of these directories contains the EDR data files themselves (*.DAT) and, for each EDR 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.

6.2 Data Format Description

Data is stored in binary table format. A detached PDS label file will provide a detailed description of the structure of the binary table.

6.3 Label and Header Descriptions

The following are descriptions for the columns in the VIRS EDR and MASCS EDR binary table objects. A replica of the VIRS.FMT and MASCS_HK.FMT files can be found in the Appendix.

6.3.1 VIRS EDR Table Columns

The following are more detailed descriptions of the columns used in the VIRS EDR binary table object. They are numbered in the column order in which they appear in the table.

1. **SEQ_COUNTER**
```
Bytes: 2    Type: MSB Unsigned Integer
```

CCSDS packet sequence counter.

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.

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.

4. **SPACECRAFT_POSITION_VECTOR**
```
Bytes: 12   Type: IEEE_REAL
Num Items: 3      Item Bytes: 4
```

Derived vector in x,y,z giving spacecraft position in J2000 reference frame. Reference time will be SC_TIME + PACKET_SUBSECONDS + PERIOD * SPECTRUM_NUMBER.

5. **SUN_POSITION_VECTOR**
```
Bytes: 12   Type: IEEE_REAL
Num Items: 3      Item Bytes: 4
```

Derived vector in x,y,z giving sun position in J2000 reference frame. Reference time will be SC_TIME + PACKET_SUBSECONDS + PERIOD * SPECTRUM_NUMBER.

6. **TARGET_LATITUDE**
```
Bytes: 4    Type: IEEE_REAL
```

Derived latitude on Mercury corresponding to spectral observation. Reference time will be SC_TIME + PACKET_SUBSECONDS + PERIOD * SPECTRUM_NUMBER.

7. **TARGET_LONGITUDE**
```
Bytes: 4    Type: IEEE_REAL
```

Derived longitude on Mercury corresponding to spectral observation. Reference time will be SC_TIME + PACKET_SUBSECONDS + PERIOD * SPECTRUM_NUMBER.

8. **INT_TIME**
```
Bytes: 2    Type: MSB Unsigned Integer
```

Amount of time the array detectors will integrate photon counts. Unit is 50 milliseconds.

9. INT_COUNT
```
Bytes: 2    Type: MSB Unsigned Integer
```

Total amount of integrations that will be taken.

10. 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. Time between integrations = PERIOD – INT_TIME. Unit is 0.05 second.

11. DARK_FREQ
```
Bytes: 2    Type: MSB Unsigned Integer
```

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

12. 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. Conversion from raw counts (DN) to degrees Celsuis 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

13. 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. 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

14. 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. 0=Low, 1= High, 999=N/A value when VIS detector is enabled.

15. 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.

16. 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.

17. 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.

18. BINNING
```
Bytes: 2    Type: MSB Unsigned Integer
```

Number of pixels that were binned together in the data.

19. 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.

20. 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.

21. 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.

22. SPECTRUM_MET
```
Bytes: 4    Type: MSB Unsigned Integer
```

A calculated value intended to reflect mission elapsed time since launch (seconds) 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)

23. 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

24. SPECTRUM_DATA
```
Bytes: 1024 Type: MSB Integer
```

The uncompressed spectrum at full 16-bit resolution. Data are zero-padded at the end if necessary to a total of 1024 bytes.

6.3.2 MASCS_HK EDR Table Columns

The following are more detailed descriptions of the columns used in the MASCS EDR binary table object. They are numbered in the column order in which they appear in the table.

1. **SEQ_COUNTER**
   `Bytes: 2    Type: MSB Unsigned Integer`

CCSDS packet sequence counter.

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. Unit is in Mission Elapsed Time which is the number of seconds since launch.

3. **TYPE**
   `Bytes: 2    Type: MSB Unsigned Integer`

Designates whether row data is from a Short or Long housekeeping packet. This affects the resolution of the analog values, but not the size or format of the data. =0 short, =1 long.

4. **STATUS_INTERVAL**
   `Bytes: 2    Type: MSB Unsigned Integer`

Status interval in seconds. A more complete description of this field can be found in the MASCS User's Guide.

5. **MACRO_BLOCKS**
   `Bytes: 2    Type: MSB Unsigned Integer`

Number of Macro Blocks free.

6. **TLM_VOLUME**
   `Bytes: 2    Type: MSB Unsigned Integer`

Telemetry volume produced.

7. **WATCH_ADDR**
   `Bytes: 2    Type: MSB Unsigned Integer`

Address of watch data.

8. **WATCH_MEM**
   `Bytes: 2    Type: MSB Unsigned Integer`

Watch Memory. A more complete description of this field can be found in the MASCS User’s Guide.

9. **WATCH_DATA**
   `Bytes: 2    Type: MSB Unsigned Integer`

Contents of watch data. A more complete description of this field can be found in the MASCS User's Guide.

10. **SW_VERSION**
    `Bytes: 2    Type: MSB Unsigned Integer`

Software version number.

11. ALARM_ID
```
Bytes: 2    Type: MSB Unsigned Integer
```

Latest alarm ID.

12. ALARM_TYPE
```
Bytes: 2    Type: MSB Unsigned Integer
```

Latest alarm type. =0 persistent, =1 transient.

13. ALARM_COUNT
```
Bytes: 2    Type: MSB Unsigned Integer
```

Count of alarms.

14. CMD_EXEC
```
Bytes: 2    Type: MSB UnsignedInteger
```

Number of commands executed.

15. CMD_REJECT
```
Bytes: 2    Type: MSB Unsigned Integer
```

Number of commands rejected.

16. MAC_EXEC
```
Bytes: 2    Type: MSB Unsigned Integer
```

Number of macro commands executed.

17. MAC_REJECT
```
Bytes: 2    Type: MSB Unsigned Integer
```

Number of macro commands rejected.

18. MACRO_ID
```
Bytes: 2    Type: MSB Unsigned Integer
```

ID of most recent macro executed.

19. MACRO_LEARN
```
Bytes: 2    Type: MSB Unsigned Integer
```

Macro learn mode. =0 not learning, =1 learning. A more complete description of this field can be found in the MASCS User's Guide.

20. MON_RESPONSE
```
Bytes: 2    Type: MSB Unsigned Integer
```

Monitor response. =0 disabled, =1 enabled.

21. WRITE_ENABLE
```
Bytes: 2    Type: MSB Unsigned Integer
```

Memory write enable. =0 disabled, =1 enabled.

22. SHUTTER_POS_VALID
`Bytes: 2    Type: MSB Unsigned Integer`

Shutter position was monitored in the status interval. =0 false, =1 true.

23. SLIT_POS_VALID
`Bytes: 2    Type: MSB Unsigned Integer`

Slit position was monitored in the status interval. =0 false, =1 true.

24. VIRS_SCANNING
`Bytes: 2    Type: MSB Unsigned Integer`

VIRS scan on going. =0 false, =1 true.

25. UVVS_SCANNING
`Bytes: 2    Type: MSB Unsigned Integer`

UVVS scan on going. =0 false, =1 true.

26. GD_TABLE_GEN
`Bytes: 2    Type: MSB Unsigned Integer`

Grating drive table is being generated. =0 false, =1 true.

27. GD_PASS_THRU
`Bytes: 2    Type: MSB Unsigned Integer`

=1 DAC output value as written to the FPGA from the software will immediately be sent to the DAC.
=0 the DAC output value will be held in an FPGA buffer register until the next GDLCI interrupt.

28. NIR_ON
`Bytes: 2    Type: MSB Unsigned Integer`

Power enabled to the NIR electronics. =0 off, =1 on.

29. VIS_ON
`Bytes: 2    Type: MSB Unsigned Integer`

Power enabled to the VIS electronics. =0 off, =1 on.

30. VIS_HV_ON
`Bytes: 2    Type: MSB Unsigned Integer`

VIS_PMT High Voltage (HV) is on and the regulated output should be at about 900 V. =0 off, =1 on.

31. MUV_HV_ON
`Bytes: 2    Type: MSB Unsigned Integer`

MUV_PMT High Voltage (HV) is on and the regulated output should be at about 900 V. =0 off, =1 on.

32. FUV_HV_ON
`Bytes: 2    Type: MSB Unsigned Integer`

FUV_PMT High Voltage (HV) is on and the regulated output should be at about 1800 V. =0 off, =1 on.

33. HVPS_ON
```
Bytes: 2    Type: MSB Unsigned Integer
```

HVPS Oscillator has been started and the HVPS unregulated output should be at about 2500 V. =0 off, =1 on.

34. NIR_FF_LAMP_ON
```
Bytes: 2    Type: MSB Unsigned Integer
```

NIR Flat Field Lamp is powered. =0 off, =1 on.

35. VIS_FF_LAMP_ON
```
Bytes: 2    Type: MSB Unsigned Integer
```

VIS Flat Field Lamp is powered. =0 off, =1 on.

36. NIR_GAIN
```
Bytes: 2    Type: MSB Unsigned Integer
```

NIR Gain is configured to a low or 20X high setting. A more complete description of this field can be found in the MASCS User's Guide. =0 low, =1 high.

37. GD_ON
```
Bytes: 2    Type: MSB Unsigned Integer
```

Grating drive is on and ready to be controlled. =0 off, =1 on.

38. SPARE
```
Bytes: 2    Type: MSB Unsigned Integer
```

Unused spare column.

39. VIRS_SHUTTER_POS
```
Bytes: 2    Type: MSB Unsigned Integer
```

VIRS shutter is closed and occulting light out of the fiber optic cable. =0 open, =1 closed.

40. UVVS_SLIT_POS
```
Bytes: 2    Type: MSB Unsigned Integer
```

UVVS slit is in the Atmospheric position. =0 surface position. =1 atmospheric position.

41. GD_AT_INDEX
```
Bytes: 2    Type: MSB Unsigned Integer
```

Grating drive is positioned at the index position. A more complete description of this field can be found in the MASCS User's Guide. =0 false, =1 true.

42. VIRS_BUSY
```
Bytes: 2    Type: MSB Unsigned Integer
```

VIRS FPGA State Machines are currently accessing the VIRS detector memory. If true then during writes to VIRS memory the data will be thrown away and during reads the data returned will be 0FFFFh. =0 false, =1 true.

43. COVER_CMD_ERR

```
Bytes: 2    Type: MSB Unsigned Integer
```

Error flag: Exact sequence covered in Section 8.1.1 Contamination Cover Implementation (FPGA document) is violated. =0 no error, =1 error.

44. SHUTTER_CMD_ERR

```
Bytes: 2    Type: MSB Unsigned Integer
```

Error flag: CPU attempts to set any pair of A, B, or C drive enables to the slit stepper motor. Also set if the software does not clear all six slit bits between setting any set of two bits active. Will be cleared by the FPGA logic after any read of this register. =0 no error, =1 error.

45. SLIT_CMD_ERR

```
Bytes: 2    Type: MSB Unsigned Integer
```

Error flag: CPU attempts to set any pair of A, B, or C drive enables to the slit stepper motor. Also set if the software does not clear all six slit bits between setting any set of two bits active. Will be cleared by the FPGA logic after any read of this register. =0 no error, =1error

46. HV_CMD_SEQ_ERR

```
Bytes: 2    Type: MSB Unsigned Integer
```

UVVS HVPS command sequence error. =0 no error, =1 the UVVS High Voltage Control register has been sequenced improperly and the write to the register has been ignored.

47. NIR_LP

```
Bytes: 2    Type: MSB Unsigned Integer
```

AD7809 ADC in the NIR array electronics has gone into latchup protection mode(brief power down, power up sequence) due to a single event upset. =0 false, =1 true.

48. VIS_LP

```
Bytes: 2    Type: MSB Unsigned Integer
```

AD7809 ADC in the VIS array electronics has gone into latchup protection mode(brief power down, power up sequence) due to a single event upset. =0 false, =1 true.

49. RESET_CMD_ERR

```
Bytes: 2    Type: MSB Unsigned Integer
```

Reset Command Error flag. =1 if the software attempts to reset the FPGA through any method other than that described in Section 12.2 of the FPGA document. =0 no error, =1 error.

50. GD_MOVING

```
Bytes: 2    Type: MSB Unsigned Integer
```

Grating drive is making any movement. =0 not moving, =1 moving

51. SPARE_BITS_2

```
Bytes: 2    Type: MSB Unsigned Integer
```

Spare unused column.

52. UVVS_EOI

Bytes: 2   Type: MSB Unsigned Integer

During a GDLCI this signals the software to read the PMT count registers. They are stable and valid when the flag is true. Will be cleared automatically at the next GDLCI interrupt. =0 false, =1 true.

53. MOVE_GD_NOW
Bytes: 2   Type: MSB Unsigned Integer

During a GDLCI this signals the software that it is time to start moving the grating drive by changing the control step position. Will be cleared automatically at the next GDLCI interrupt. =0 false, =1 true.

54. TABLE_GENERATED
Bytes: 2   Type: MSB Unsigned Integer

Lookup table has been generated. The lookup table is only used internally by the Grating Drive control algorithm. A more complete description of this field can be found in the MASCS User's Guide. =0 false, =1 true.

55. GD_DIRECTION
Bytes: 2   Type: MSB Unsigned Integer

Initial direction for the grating drive rotation when given a 'find index' command. =0 counter-clockwise, =1 clockwise.

56. VIRS_IRQ
Bytes: 2   Type: MSB Unsigned Integer

IRQ2 is active, integration period is complete, and that all VIRS Data has been sampled and stored in the VIRS array memory. =0 false, =1 true.

57. GDLCI_IRQ
Bytes: 2   Type: MSB Unsigned Integer

IRQ1 is active. Occurs after the GDLCI register has reached its timeout period. =0 false, =1 true.

58. GD_POSITION
Bytes: 2   Type: MSB Unsigned Integer

Grating drive position reported from software. Values range from 0-2700 arc minutes.

59. CC_ENABLED
Bytes: 2   Type: MSB Unsigned Integer

Software enable set to open contamination cover. =0 disabled, =1 enabled.

60. FPGA_RESET_ENABLE
Bytes: 2   Type: MSB Unsigned Integer

Software enable to reset FPGA. =0 disabled, =1 enabled.

61. SBOS_ENABLE
Bytes: 2   Type: MSB Unsigned Integer

Software Bright Object Sensor (SBOS) is commanded to be active. =0 false, =1 true.

62. SBOS_TRIGGERED
```
Bytes: 2    Type: MSB Unsigned Integer
```

SBOS has been triggered. =0 false, =1 true.

63. SBOS_LEVEL
```
Bytes: 2    Type: MSB Unsigned Integer
```

SBOS sensor level (upper 8 bits of MUV PMT counts).

64. FPGA_2_5V
```
Bytes: 4    ype: IEEE Real
```

Digital Electronics Board FPGA 2.5 Volt Monitor. Value is derived from the Housekeeping DN value by the following formulas:

For the Short Housekeeping packet (8 bits):
FPGA_2_5V = 0.000366 * (DN*64)
For the Long Housekeeping packet (14 bits):
FPGA_2_5V = 0.000366 * DN.

65. HVPS_MON_SUM
```
Bytes: 4    type: IEEE Real
```

HVPS Test Monitor Sum. A more complete description of this field can be found in the MASCS User's Guide. Value is derived from the Housekeeping DN value by the following formulas:

For the Short Housekeeping packet (8 bits):
HVPS_MON_SUM = 0.000366 * (DN*64)
For the Long Housekeeping packet (14 bits):
HVPS_MON_SUM = 0.000366 * DN.

66. PLUS_5V
```
Bytes: 4    Type: IEEE Real
```

+5V Monitor. A more complete description of this field can be found in the MASCS User's Guide. Value is derived from the Housekeeping DN value by the following formulas:

For the Short Housekeeping packet (8 bits):
PLUS_5V = 0.0024805 * (DN*64)
For the Long Housekeeping packet (14 bits):
PLUS_5V = 0.0024805 * DN.

67. MINUS_5V
```
Bytes: 4    Type: IEEE Real
```

-5 Volt Monitor. A more complete description of this field can be found in the MASCS User's Guide.Conversion from DN value is the same as that for PLUS_5V.

68. PLUS_12V
```
Bytes: 4    Type: IEEE Real
```

+12 Volt Monitor. A more complete description of this field can be found in the MASCS User's Guide. Conversion from DN value is the same as that for PLUS_5V.

69. MINUS_12V
```
Bytes: 4    Type: IEEE Real
```

-12 Volt Monitor. A more complete description of this field can be found in the MASCS User's Guide. Conversion from DN value is the same as that for PLUS_5V.

70. PLUS_5_CURRENT
`Bytes: 4    Type: IEEE Real`

+5 Volt Current. A more complete description of this field can be found in the MASCS User's Guide. Value is derived from the Housekeeping DN value by the following formulas:
For the Short Housekeeping packet (8 bits):
PLUS_5_CURRENT = 0.00024414 * (DN*64)
For the Long Housekeeping packet (14 bits):
PLUS_5_CURRENT = 0.00024414 * DN.

71. MINUS_5_CURRENT
`Bytes: 4    Type: IEEE Real`

-5 Volt Current. A more complete description of this field can be found in the MASCS User's Guide. Conversion from DN value is the same as that for PLUS_5_CURRENT.

72. PLUS_12_CURRENT
`Bytes: 4    Type: IEEE Real`

+12 Volt Current. A more complete description of this field can be found in the MASCS User's Guide. Conversion from DN value is the same as that for PLUS_5_CURRENT.

73. MINUS_12_CURRENT
`Bytes: 4    Type: IEEE Real`

-12 Volt Current. A more complete description of this field can be found in the MASCS User's Guide. Conversion from DN value is the same as that for PLUS_5_CURRENT.

74. PLUS_28_CURRENT
`Bytes: 4    Type: IEEE Real`

+28 Volt Current. A more complete description of this field can be found in the MASCS User's Guide. Conversion from DN value is the same as that for PLUS_5_CURRENT.

75. SWITCHED_28_CUR
`Bytes: 4    Type: IEEE Real`

Switched +28V current monitor. A more complete description of this field can be found in the MASCS User's Guide. Conversion from DN value is the same as that for PLUS_5_CURRENT.

76. UNREG_HV_MON
`Bytes: 4    Type: IEEE Real`

Unregulated PMT High Voltage monitor. A more complete description of this field can be found in the MASCS User's Guide. Conversion from DN value is the same as that for HVPS_MON_SUM.

77. VIS_HV_MON
`Bytes: 4    Type: IEEE Real`

VIS PMT High Voltage Monitor. A more complete description of this field can be found in the MASCS User's Guide. Value is derived from the Housekeeping DN value by the following formulas:

For the Short Housekeeping packet (8 bits):

VIS_HV_MON = 0.366 * (DN*64)

For the Long Housekeeping packet (14 bits):

VIS_HV_MON = 0.366 * DN

78. MUV_HV_MON
```
Bytes: 4    Type: IEEE Real
```

MUV High Voltage Monitor. A more complete description of this field can be found in the MASCS User's Guide. Conversion from DN value is the same as that for VIS_HV_MON.

79. FUV_HV_MON
```
Bytes: 4    Type: IEEE Real
```

FUV High Voltage Monitor. A more complete description of this field can be found in the MASCS User's Guide. Conversion from DN value is the same as that for VIS_HV_MON.

80. DEB_TEMP
```
Bytes: 4    Type: IEEE Real
```

Digital Electronics Board Temperature. A more complete description of this field can be found in the MASCS User's Guide. Value is converted from DN telemetry value by the following formulas:

From the short housekeeping packet (12 bit data):

$$DEB\_TEMP = -1.67826 - 0.0061(DN*4) - 2.703*10^{-8}(DN*4)^2 + 3.8131*10^{-11}(DN*4)^3 + 8.9793*10^{-15}(DN*4)^4 - 3.4338*10^{-18}(DN*4)^5$$

From the long housekeeping packet (14 bit data):

$$DEB\_TEMP = -1.67826 - 0.0061(DN) - 2.703*10^{-8}(DN)^2 + 3.8131*10^{-11}(DN)^3 + 8.9793*10^{-15}(DN)^4 - 3.4338*10^{-18}(DN)^5$$".

81. VIS_PMT_TEMP
```
Bytes: 4    Type: IEEE Real
```

VIS_PMT Temperature. A more complete description of this field can be found in the MASCS User's Guide. Conversion from DN value is the same as that for DEB_TEMP.

82. MUV_PMT_TEMP
```
Bytes: 4    Type: IEEE Real
```

MUV_PMT Temperature. A more complete description of this field can be found in the MASCS User's Guide. Conversion from DN value is the same as that for DEB_TEMP.

83. FUV_PMT_TEMP
```
Bytes: 4    Type: IEEE Real
```

FUV_PMT Temperature. A more complete description of this field can be found in the MASCS User's Guide. Conversion from DN value is the same as that for DEB_TEMP.

84. HVPS_LV_TEMP
```
Bytes: 4    Type: IEEE Real
```

High Voltage Power Supply Low Voltage Temperature. A more complete description of this field can be found in the MASCS User's Guide. Conversion from DN value is the same as that for DEB_TEMP.

85. HVPS_HV_TEMP
```
Bytes: 4    Type: IEEE Real
```

High Voltage Power Supply High Voltage Temperature. A more complete description of this field can be found in the MASCS User's Guide. Conversion from DN value is the same as that for DEB_TEMP.

86. UVVS_GRATING_TEMP
```
Bytes: 4    Type: IEEE Real
```

UVVS Grating Drive temperature. A more complete description of this field can be found in the MASCS User's Guide. Conversion from DN value is the same as that for DEB_TEMP.

87. VIS_ARRAY_TEMP_1
```
Bytes: 4    Type: IEEE Real
```

VIS Array Temperature #1. A more complete description of this field can be found in the MASCS User's Guide. Conversion from DN value is the same as that for DEB_TEMP.

88. VIS_ARRAY_TEMP_2
```
Bytes: 4    Type: IEEE Real
```

VIS Array Temperature #2. A more complete description of this field can be found in the MASCS User's Guide. Conversion from DN value is the same as that for DEB_TEMP.

89. NIR_ARRAY_EXT_TEMP
```
Bytes: 4    Type: IEEE Real
```

NIR Array External Temperature. A more complete description of this field can be found in the MASCS User's Guide. Conversion from DN value is the same as that for DEB_TEMP.

90. NIR_ARRAY_INT_TEMP
```
Bytes: 4    Type: IEEE Real
```

NIR Array Internal Temperature. A more complete description of this field can be found in the MASCS User's Guide. Value is converted from DN telemetry value by the following formulas:

From the short housekeeping packet (12 bit data):

$$\mathrm{NIR\_ARRAY\_INT\_TEMP} = -22.2879012 - 702.301101*10^{-5}(DN*4) + 339.958815*10^{-9}(DN*4)^2 + 173.862825*10^{-12}(DN*4)^3 - 9.72043502*10^{-15}(DN*4)^4 - 8.891005*10^{-18}(DN*4)^5$$

From the long housekeeping packet (14 bit data):

$$\mathrm{NIR\_ARRAY\_INT\_TEMP} = -22.2879012 - 702.301101*10^{-5}(DN) + 339.958815*10^{-9}(DN)^2 + 173.862825*10^{-12}(DN)^3 - 9.72043502*10^{-15}(DN)^4 - 8.891005*10^{-18}(DN)^5$$

91. BOB _TEMP
```
Bytes: 4    Type: IEEE Real
```

Break out Board Temperature. A more complete description of this field can be found in the MASCS User's Guide. Conversion from DN value is the same as that for DEB_TEMP.

92. VIRS_GRATING_TEMP
```
Bytes: 4    Type: IEEE Real
```

VIRS Grating Temperature. A more complete description of this field can be found in the MASCS User's Guide. Conversion from DN value is the same as that for DEB_TEMP.

93. COVER_TEMP
`Bytes: 4    Type: IEEE Real`

Contamination Cover Temperature. A more complete description of this field can be found in the MASCS User's Guide. Conversion from DN value is the same as that for DEB_TEMP.

94. LVPS _TEMP
`Bytes: 4    Type: IEEE Real`

Low Voltage Power Supply Temperature. A more complete description of this field can be found in the MASCS User's Guide. Value is converted from DN telemetry value by using the following formulas:
For the short housekeeping packet (12 bits):
LVPS_TEMP = 25 + ((A/B)-10000) / 78.5 where
A = 3333.333*((DN*4*0.000366/3)+1)
B = 1 - (((DN*4*0.0003666/3)+1)/3)
For the long housekeeping packet (14 bits):
LVPS_TEMP = 25 + ((A/B)-10000) / 78.5 where
A = 3333.333*((DN*0.000366/3)+1)
B = 1 - (((DN*0.0003666/3)+1)/3)

95. SPARE_BITS
`Bytes: 2    Type: MSB Unsigned Integer`

Spare unused column.

7. Archive Release Schedule to PDS

The MESSENGER MASCS EDR archive will be transferred from the SOC to the Planetary Data System Geosciences and Atmospheres Nodes using whatever electronic media transfers are appropriate. Both Nodes have agreed to store the MASCS EDR Archive volume containing both UVVS and VIRS EDRs (UVVS is detailed in a separate UVVS EDR SIS). The details of transfer are specified in section 5.3.3.The transfer will take place according to the schedule in the MESSENGER Data Management and Archiving Plan.

Table B-1. Schedule of Data Releases by Mission Phase – REMOVED – refer to schedule in MESSENGER Data Management and Archiving Plan.

8. Appendices

APPENDIX - VIRS.FMT FILE

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

OBJECT         = COLUMN
   NAME           = SPACECRAFT_POSITION_VECTOR
   COLUMN_NUMBER  = 4
   BYTES          = 12
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 9
   ITEMS          = 3
   ITEM_BYTES     = 4
   DESCRIPTION    = "Derived vector in x,y,z giving spacecraft position in
   J2000 reference frame. Reference time will be SC_TIME plus PACKET_SUBSECONDS
   plus PERIOD * SPECTRUM_NUMBER."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = SUN_POSITION_VECTOR
   COLUMN_NUMBER  = 5
   BYTES          = 12
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 21
   ITEMS          = 3
   ITEM_BYTES     = 4
   DESCRIPTION    = "Derived vector in x,y,z giving sun position in J2000
   reference frame. Reference time will be SC_TIME plus PACKET_SUBSECONDS
   plus PERIOD * SPECTRUM_NUMBER."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = TARGET_LATITUDE
   COLUMN_NUMBER  = 6
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
```

```
   START_BYTE     = 33
   DESCRIPTION    = "Derived latitude on Mercury corresponding to spectral
   observation. Reference time will be SC_TIME plus PACKET_SUBSECONDS
   plus PERIOD * SPECTRUM_NUMBER."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = TARGET_LONGITUDE
   COLUMN_NUMBER  = 7
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 37
   DESCRIPTION    = "Derived longitude on Mercury corresponding to spectral
   observation. Reference time will be SC_TIME plus PACKET_SUBSECONDS
   plus PERIOD * SPECTRUM_NUMBER."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = INT_TIME
   COLUMN_NUMBER  = 8
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 41
   DESCRIPTION    = "Amount of time the array detectors will integrate photon
   counts.  Unit is 50 milliseconds."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = INT_COUNT
   COLUMN_NUMBER  = 9
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 43
   DESCRIPTION    = "Total amount of integrations that will be taken."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = PERIOD
   COLUMN_NUMBER  = 10
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 45
   DESCRIPTION    = "Interval time after which another integration will be
   started.  Integrations are started at the top of every period.  Time
   between integrations = PERIOD - INT_TIME.  Unit is 0.05 second."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = DARK_FREQ
   COLUMN_NUMBER  = 11
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 47
   DESCRIPTION    = "Dark counts will be collected every X integrations during
   a VIRS observation."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = TEMP_1
   COLUMN_NUMBER  = 12
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 49
   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.
   Conversion from raw counts (DN) to degrees Celsuis 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
"
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = TEMP_2
```

```
   COLUMN_NUMBER  = 13
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 53
   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. 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
   "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = NIR_GAIN
   COLUMN_NUMBER  = 14
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 57
   DESCRIPTION    = "Gain of NIR array detector. A more complete description
   of this field can be found in the MASCS User's Guide.0=Low, 1=High,
   999= N/A value when VIS dector is enabled.
   "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = OTHER_CHANNEL_ON
   COLUMN_NUMBER  = 15
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 59
   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."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = NIR_LAMP_ON
   COLUMN_NUMBER  = 16
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 61
   DESCRIPTION    = "NIR flat field lamp is powered on or off. A value of 0
   is off, a value of 1 is on."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = VIS_LAMP_ON
   COLUMN_NUMBER  = 17
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 63
   DESCRIPTION    = "VIS flat field lamp is powered on or off. A value of 0
   is off, a value of 1 is on."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = BINNING
   COLUMN_NUMBER  = 18
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 65
   DESCRIPTION    = "Number of pixels that were binned together in the data."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = START_PIXEL
   COLUMN_NUMBER  = 19
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 67
   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."
```

```
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = END_PIXEL
   COLUMN_NUMBER  = 20
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 69
   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."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPECTRUM_NUMBER
   COLUMN_NUMBER  = 21
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 71
   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."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPECTRUM_MET
   COLUMN_NUMBER  = 22
   BYTES          = 4
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 73
   DESCRIPTION    = "A calculated value intended to reflect mission elapsed
   time since launch (seconds) 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)
   "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPECTRUM_SUBSECONDS
   COLUMN_NUMBER  = 23
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 77
   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
   "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPECTRUM_DATA
   COLUMN_NUMBER  = 24
   BYTES          = 1024
   DATA_TYPE      = MSB_INTEGER
   START_BYTE     = 79
   ITEMS          = 512
   ITEM_BYTES     = 2
   DESCRIPTION    = "The uncompressed spectrum at full 16-bit resolution.
   Data are zero-padded at the end if necessary to a total of 1024 bytes."
END_OBJECT    = COLUMN
```

APPENDIX - MASCS_HK.FMT FILE

```
OBJECT        = COLUMN
   NAME           = SEQ_COUNTER
   COLUMN_NUMBER  = 1
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
```

```
   START_BYTE     = 1
   DESCRIPTION    = "CCSDS packet sequence counter."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SC_TIME
   COLUMN_NUMBER  = 2
   BYTES          = 4
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 3
   UNIT           = "SECONDS"
   DESCRIPTION    = "Spacecraft time in integer seconds that is transmitted
   to MESSENGER subsystems by the Integrated Electronics Module. Unit is in
   mission elapsed time which is the number of seconds since launch.
   "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = TYPE
   COLUMN_NUMBER  = 3
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 7
   DESCRIPTION    = "Designates whether row data is from a Short or Long
   housekeeping packet. This affects the resolution of the analog values,
   but not the size or format of the data. =0 short, =1 long"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = STATUS_INTERVAL
   COLUMN_NUMBER  = 4
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 9
   DESCRIPTION    = "Status Interval in seconds. A more complete description
   of this field can be found in the MASCS User's Guide."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = MACRO_BLOCKS
   COLUMN_NUMBER  = 5
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 11
   DESCRIPTION    = "Number of Macro Blocks free."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = TLM_VOLUME
   COLUMN_NUMBER  = 6
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 13
   DESCRIPTION    = "Telemetry volume produced."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = WATCH_ADDR
   COLUMN_NUMBER  = 7
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 15
   DESCRIPTION    = "Address of watch data."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = WATCH_MEM
   COLUMN_NUMBER  = 8
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 17
   DESCRIPTION    = "Watch memory. A more complete description of this field
   can be found in the MASCS User's Guide."
END_OBJECT    = COLUMN
```

```
OBJECT         = COLUMN
   NAME           = WATCH_DATA
   COLUMN_NUMBER  = 9
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 19
   DESCRIPTION    = "Contents of watch data. A more complete description of
   this field can be found in the MASCS User's Guide."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = SW_VERSION
   COLUMN_NUMBER  = 10
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 21
   DESCRIPTION    = "Software version number."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = ALARM_ID
   COLUMN_NUMBER  = 11
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 23
   DESCRIPTION    = "Latest alarm ID."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = ALARM_TYPE
   COLUMN_NUMBER  = 12
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 25
   DESCRIPTION    = "Latest alarm type. =0 persistent, =1 transient."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = ALARM_COUNT
   COLUMN_NUMBER  = 13
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 27
   DESCRIPTION    = "Count of alarms."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = CMD_EXEC
   COLUMN_NUMBER  = 14
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 29
   DESCRIPTION    = "Number of commands executed."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = CMD_REJECT
   COLUMN_NUMBER  = 15
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 31
   DESCRIPTION    = "Number of commands rejected."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = MAC_EXEC
   COLUMN_NUMBER  = 16
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 33
   DESCRIPTION    = "Number of macro commands executed."
END_OBJECT     = COLUMN
```

```
OBJECT        = COLUMN
   NAME           = MAC_REJECT
   COLUMN_NUMBER  = 17
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 35
   DESCRIPTION    = "Number of macro commands rejected."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = MACRO_ID
   COLUMN_NUMBER  = 18
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 37
   DESCRIPTION    = "ID of most recent macro executed."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = MACRO_LEARN
   COLUMN_NUMBER  = 19
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 39
   DESCRIPTION    = "Macro learn mode. =0 not learning, =1 learning. A more
   complete description of this field can be found in the MASCS User's Guide."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = MON_RESPONSE
   COLUMN_NUMBER  = 20
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 41
   DESCRIPTION    = "Monitor response. =0 disabled, =1 enabled."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = WRITE_ENABLE
   COLUMN_NUMBER  = 21
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 43
   DESCRIPTION    = "Memory write enable. =0 disabled, =1 enabled"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SHUTTER_POS_VALID
   COLUMN_NUMBER  = 22
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 45
   DESCRIPTION    = "Shutter position was monitored in the
   status interval. =0 false, =1 true."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SLIT_POS_VALID
   COLUMN_NUMBER  = 23
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 47
   DESCRIPTION    = "Slit position was monitored in the status interval.
      =0 false, =1 true"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = VIRS_SCANNING
   COLUMN_NUMBER  = 24
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 49
   DESCRIPTION    = "VIRS scan on going. =0 false, =1 true."
END_OBJECT    = COLUMN
```

```
OBJECT         = COLUMN
   NAME           = UVVS_SCANNING
   COLUMN_NUMBER  = 25
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 51
   DESCRIPTION    = "UVVS scan on going. =0 false, =1 true."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = GD_TABLE_GEN
   COLUMN_NUMBER  = 26
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 53
   DESCRIPTION     = "Grating drive table is being generated.
      =0 false, =1 true"
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = GD_PASS_THRU
   COLUMN_NUMBER  = 27
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 55
   DESCRIPTION    = "=1 DAC output value as written to the FPGA from the
   software will immediately be sent to the DAC.
   =0 the DAC output value will be held in an FPGA buffer register until the
   next GDLCI interrupt."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = NIR_ON
   COLUMN_NUMBER  = 28
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 57
   DESCRIPTION    = "Power enabled to the NIR electronics.
            =0 off, =1 on"
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = VIS_ON
   COLUMN_NUMBER  = 29
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 59
   DESCRIPTION    = "Power enabled to the VIS electronics.
             =0 off, =1 on"
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = VIS_HV_ON
   COLUMN_NUMBER  = 30
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 61
   DESCRIPTION    = "VIS_PMT High Voltage (HV) is on and the regulated output
   should be at about 900 V. =0 off, =1 on"
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = MUV_HV_ON
   COLUMN_NUMBER  = 31
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 63
   DESCRIPTION     = "MUV_PMT High Voltage (HV) is on and the regulated
   output should be at about 900 V. =0 off, =1 on"
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = FUV_HV_ON
```

```
   COLUMN_NUMBER  = 32
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 65
   DESCRIPTION    = "FUV_PMT High Voltage (HV) is on and the regulated
   output should be at about 1800 V. =0 off, =1 on"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = HVPS_ON
   COLUMN_NUMBER  = 33
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 67
   DESCRIPTION     = "HVPS Oscillator has been started and the HVPS
   unregulated output should be about 2500 V. =0 on, =1 off"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = NIR_FF_LAMP_ON
   COLUMN_NUMBER  = 34
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 69
   DESCRIPTION    = "NIR Flat Field Lamp is powered. = 0 off, = 1 on"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = VIS_FF_LAMP_ON
   COLUMN_NUMBER  = 35
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 71
   DESCRIPTION    = "VIS Flat Field Lamp is powered. =0 off, =1 on"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = NIR_GAIN
   COLUMN_NUMBER  = 36
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 73
   DESCRIPTION    = "NIR Gain is configured to a low or 20X high setting.
   A more complete description of this field can be found in the MASCS User's
   Guide. =0 low, =1 high "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = GD_ON
   COLUMN_NUMBER  = 37
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 75
   DESCRIPTION    = "Grating drive is on and ready to be controlled.
       =0 off, =1 on"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPARE
   COLUMN_NUMBER  = 38
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 77
   DESCRIPTION    = "Unused spare column."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = VIRS_SHUTTER_POS
   COLUMN_NUMBER  = 39
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 79
   DESCRIPTION    = "VIRS shutter is closed and occulting light out of the
      fiber optic cable. =0 open, =1 closed"
```

```
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = UVVS_SLIT_POS
   COLUMN_NUMBER  = 40
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 81
   DESCRIPTION    = "UVVS slit is in the Atmospheric position
   =0 surface position. =1 atmospheric position."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = GD_AT_INDEX
   COLUMN_NUMBER  = 41
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 83
   DESCRIPTION    = "Grating drive is positioned at the index position. A
   more complete description of this field can be found in the MASCS
   User's Guide. =0 false, =1 true"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = VIRS_BUSY
   COLUMN_NUMBER  = 42
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 85
   DESCRIPTION    = "VIRS FPGA State Machines are currently accessing the
   VIRS detector memory. If true then during writes to VIRS memory the data
   will be thrown away and during reads the data returned will be 0FFFFh.
   =0 false. =1 true"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = COVER_CMD_ERR
   COLUMN_NUMBER  = 43
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 87
   DESCRIPTION    = "Error flag: Exact sequence covered in Section
   8.1.1 Contamination Cover Implementation (FPGA document) is violated.
   =0 no error, =1 error"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SHUTTER_CMD_ERR
   COLUMN_NUMBER  = 44
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 89
   DESCRIPTION     = "Error flag: CPU attempts to set any pair of A, B, or
   C drive enables to the slit stepper motor. Also set if the software does
   not clear all six slit bits between setting any set of two bits active.
   Will be cleared by the FPGA logic after any read of this register.
   =0 no error, =1 error"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SLIT_CMD_ERR
   COLUMN_NUMBER  = 45
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 91
   DESCRIPTION     = "Error flag: CPU attempts to set any pair of A, B, or
   C drive enables to the slit stepper motor. Also set if the software does
   not clear all six slit bits between setting any set of two bits active.
   Will be cleared by the FPGA logic after any read of this register.
   =0 no error, =1 error"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = HV_CMD_SEQ_ERR
```

```
   COLUMN_NUMBER  = 46
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 93
   DESCRIPTION    = "UVVS HVPS command sequence error. =0 no error,
   =1 the UVVS High Voltage Control register has been sequenced
   improperly and the write to the register has been ignored."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = NIR_LP
   COLUMN_NUMBER  = 47
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 95
   DESCRIPTION    = "AD7809 ADC in the NIR array electronics has gone into
   latchup protection mode(brief power down, power up sequence) due to a
   single event upset. =0 false, =1 true"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = VIS_LP
   COLUMN_NUMBER  = 48
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 97
   DESCRIPTION    = "AD7809 ADC in the VIS array electronics has gone into
   latchup protection mode(brief power down, power up sequence) due to a
   single event upset. =0 false, =1 true"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = RESET_CMD_ERR
   COLUMN_NUMBER  = 49
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 99
   DESCRIPTION    = "Reset Command Error flag. =1 if the software attempts to
   reset the FPGA through any method other than that described in
   Section 12.2 of the FPGA document. =0 no error, =1 error"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = GD_MOVING
   COLUMN_NUMBER  = 50
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 101
   DESCRIPTION    = "Grating drive is making any movement.
   =0 not moving, =1 moving"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPARE_BITS_2
   COLUMN_NUMBER  = 51
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 103
   DESCRIPTION    = "Spare unused column"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = UVVS_EOI
   COLUMN_NUMBER  = 52
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 105
   DESCRIPTION    = "During a GDLCI this signals the software to read the PMT
   count registers. They are stable and valid when the flag is true. Will
   be cleared automatically at the next GDLCI interrupt. =0 false, =1 true"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = MOVE_GD_NOW
```

```
   COLUMN_NUMBER  = 53
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 107
   DESCRIPTION    = "During a GDLCI this signals the software that it is time
   to start moving the grating drive by changing the control step
   position. Will be cleared automatically at the next GDLCI interrupt.
   =0 false, =1 true"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = TABLE_GENERATED
   COLUMN_NUMBER  = 54
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 109
   DESCRIPTION    = "Lookup table has been generated. The lookup table is only
   used internally by the Grating Drive control algorithm. A more complete
   description of this field can be found in the MASCS User's Guide.
   =0 false, =1 true"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = GD_DIRECTION
   COLUMN_NUMBER  = 55
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 111
   DESCRIPTION    = "Initial direction for the grating drive rotation when
       given a 'find index' command. =0 counter-clockwise =1 clockwise"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = VIRS_IRQ
   COLUMN_NUMBER  = 56
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 113
   DESCRIPTION    = "IRQ2 is active, integration
   period is complete, and that all VIRS Data has been sampled and stored in
   the VIRS array memory. =0 false, =1 true"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = GDLCI_IRQ
   COLUMN_NUMBER  = 57
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 115
   DESCRIPTION    = "IRQ1 is active. Occurs after the GDLCI register has
   reached its timeout period. =0 false, =1 true"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = GD_POSITION
   COLUMN_NUMBER  = 58
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 117
   DESCRIPTION    = "Grating drive position reported from software. Values
   range from 0-2700 arc minutes."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = CC_ENABLED
   COLUMN_NUMBER  = 59
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 119
   DESCRIPTION    = "Software enable set to open contamination cover.
         =0 disabled, =1 enabled"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
```

```
   NAME           = FPGA_RESET_ENABLE
   COLUMN_NUMBER  = 60
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 121
   DESCRIPTION    = "Software enable to reset FPGA. =0 disabled, =1 enabled"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SBOS_ENABLE
   COLUMN_NUMBER  = 61
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 123
   DESCRIPTION    = "Software Bright Object Sensor (SBOS) is commanded to be
   active. =0 false, =1 true"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SBOS_TRIGGERED
   COLUMN_NUMBER  = 62
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 125
   DESCRIPTION    = "SBOS has been triggered. =0 false, =1 true"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SBOS_LEVEL
   COLUMN_NUMBER  = 63
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 127
   DESCRIPTION    = "SBOS sensor level (upper 8 bits of MUV PMT counts)"
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = FPGA_2_5V
   COLUMN_NUMBER  = 64
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 129
   UNIT           = "VOLT"
   DESCRIPTION    = "Digital Electronics Board FPGA 2.5 Volt Monitor. Value is
    derived from the Housekeeping DN value by the following formulas:
    For the Short Housekeeping packet (8 bits):
       FPGA_2_5V = 0.000366 * (DN*64)
    For the Long Housekeeping packet (14 bits):
       FPGA_2_5V = 0.000366 * DN
    "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = HVPS_MON_SUM
   COLUMN_NUMBER  = 65
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 133
   UNIT           = "VOLT"
   DESCRIPTION    = "HVPS Test Monitor Sum. A more complete description of
   this field can be found in the MASCS User's Guide. Value is derived from the
    Housekeeping DN value by the following formulas:
    For the Short Housekeeping packet (8 bits):
       HVPS_MON_SUM = 0.000366 * (DN*64)
    For the Long Housekeeping packet (14 bits):
       HVPS_MON_SUM = 0.000366 * DN
    "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = PLUS_5V
   COLUMN_NUMBER  = 66
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
```

```
   START_BYTE     = 137
   UNIT           = "VOLT"
   DESCRIPTION    = "+5V Monitor. A more complete description of
   this field can be found in the MASCS User's Guide. Value is derived from
   the Housekeeping DN value by the following formulas:
    For the Short Housekeeping packet (8 bits):
       PLUS_5V = 0.0024805 * (DN*64)
    For the Long Housekeeping packet (14 bits):
       PLUS_5V = 0.0024805 * DN
    "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = MINUS_5V
   COLUMN_NUMBER  = 67
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 141
   UNIT           = "VOLT"
   DESCRIPTION    = "-5 Volt Monitor. A more complete description of
   this field can be found in the MASCS User's Guide. Conversion from DN
   value is the same as that for PLUS_5V."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = PLUS_12V
   COLUMN_NUMBER  = 68
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 145
   UNIT           = "VOLT"
   DESCRIPTION    = "+12 Volt Monitor. A more complete description of
   this field can be found in the MASCS User's Guide. Conversion from DN
   value is the same as that for PLUS_5V."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = MINUS_12V
   COLUMN_NUMBER  = 69
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 149
   UNIT           = "VOLT"
   DESCRIPTION    = "-12 Volt Monitor. A more complete description of
   this field can be found in the MASCS User's Guide. Conversion from DN
   value is the same as that for PLUS_5V."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = PLUS_5_CURRENT
   COLUMN_NUMBER  = 70
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 153
   UNIT           = "AMP"
   DESCRIPTION    = "+5 Volt Current. A more complete description of
   this field can be found in the MASCS User's Guide. Value is derived from
   the Housekeeping DN value by the following formulas:
    For the Short Housekeeping packet (8 bits):
       PLUS_5_CURRENT = 0.00024414 * (DN*64)
    For the Long Housekeeping packet (14 bits):
       PLUS_5_CURRENT = 0.00024414 * DN
    "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = MINUS_5_CURRENT
   COLUMN_NUMBER  = 71
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 157
   UNIT           = "AMP"
   DESCRIPTION    = "-5 Volt Current. A more complete description of
   this field can be found in the MASCS User's Guide. Conversion from DN
```

```
   value is the same as that for PLUS_5_CURRENT."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = PLUS_12_CURRENT
   COLUMN_NUMBER  = 72
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 161
   UNIT           = "AMP"
   DESCRIPTION    = "+12 Volt Current. A more complete description of
   this field can be found in the MASCS User's Guide. Conversion from DN
   value is the same as that for PLUS_5_CURRENT."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = MINUS_12_CURRENT
   COLUMN_NUMBER  = 73
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 165
   UNIT           = "AMP"
   DESCRIPTION    = "-12 Volt Current. A more complete description of
   this field can be found in the MASCS User's Guide. Conversion from DN
   value is the same as that for PLUS_5_CURRENT."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = PLUS_28_CURRENT
   COLUMN_NUMBER  = 74
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 169
   UNIT           = "AMP"
   DESCRIPTION    = "+28 Volt Current. A more complete description of
   this field can be found in the MASCS User's Guide. Conversion from DN
   value is the same as that for PLUS_5_CURRENT."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SWITCHED_28_CUR
   COLUMN_NUMBER  = 75
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 173
   UNIT           = "AMP"
   DESCRIPTION    = "Switched +28V current Monitor. A more complete
   description of this field can be found in the MASCS User's Guide.
   Conversion from DN value is the same as that for PLUS_5_CURRENT."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = UNREG_HV_MON
   COLUMN_NUMBER  = 76
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 177
   UNIT           = "VOLT"
   DESCRIPTION    = "Unregulated PMT High Voltage Monitor. A more complete
   description of this field can be found in the MASCS User's Guide.
   Conversion from DN value is the same as that for HVPS_MON_SUM."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = VIS_HV_MON
   COLUMN_NUMBER  = 77
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 181
   UNIT           = "VOLT"
   DESCRIPTION    = "VIS PMT High Voltage Monitor. A more complete
   description of this field can be found in the MASCS User's Guide. Value
   is derived from the Housekeeping DN value by the following formulas:
     For the Short Housekeeping packet (8 bits):
```

```
        VIS_HV_MON = 0.366 * (DN*64)
      For the Long Housekeeping packet (14 bits):
        VIS_HV_MON = 0.366 * DN
     "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME            = MUV_HV_MON
   COLUMN_NUMBER  = 78
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 185
   UNIT           = "VOLT"
   DESCRIPTION    = "MUV High Voltage Monitor. A more complete description of
   this field can be found in the MASCS User's Guide. Conversion from DN
   value is the same as that for VIS_HV_MON."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME            = FUV_HV_MON
   COLUMN_NUMBER  = 79
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 189
   UNIT           = "VOLT"
   DESCRIPTION    = "FUV High Voltage  Monitor. A more complete description
   of this field can be found in the MASCS User's Guide. Conversion from DN
   value is the same as that for VIS_HV_MON."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME            = DEB_TEMP
   COLUMN_NUMBER  = 80
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 193
   UNIT           = "CELSIUS"
   DESCRIPTION    = "Digital Electronics Board Temperature. A more complete
   description of this field can be found in the MASCS User's Guide. Value is
   converted from DN telemetry value by the following formulas:
    From the short housekeeping packet (12 bit data):
      DEB_TEMP = -1.67826 - 0.0061(DN*4) - 2.703*10^(-8)(DN*4)^2 +
      3.8131*10^(-11)(DN*4)^3 + 8.9793*10^(-15)(DN*4)^4 -
      3.4338*10^(-18)(DN*4)^5
    From the long housekeeping packet (14 bit data):
      DEB_TEMP = -1.67826 - 0.0061(DN) - 2.703*10^(-8)(DN)^2 +
      3.8131*10^(-11)(DN)^3 + 8.9793*10^(-15)(DN)^4 - 3.4338*10^(-18)(DN)^5
     "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME            = VIS_PMT_TEMP
   COLUMN_NUMBER  = 81
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 197
   UNIT           = "CELSIUS"
   DESCRIPTION    = "VIS_PMT Temperature. A more complete description of
   this field can be found in the MASCS User's Guide. Conversion from DN
   value is the same as that for DEB_TEMP."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME            = MUV_PMT_TEMP
   COLUMN_NUMBER  = 82
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 201
   UNIT           = "CELSIUS"
   DESCRIPTION    = "MUV_PMT Temperature. A more complete description of
   this field can be found in the MASCS User's Guide. Conversion from DN
   value is the same as that for DEB_TEMP."
END_OBJECT    = COLUMN
```

```
OBJECT         = COLUMN
   NAME           = FUV_PMT_TEMP
   COLUMN_NUMBER  = 83
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 205
   UNIT           = "CELSIUS"
   DESCRIPTION    = "FUV_PMT Temperature. A more complete description of
   this field can be found in the MASCS User's Guide. Conversion from DN
   value is the same as that for DEB_TEMP."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = HVPS_LV_TEMP
   COLUMN_NUMBER  = 84
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 209
   UNIT           = "CELSIUS"
   DESCRIPTION    = "High Voltage Power Supply Low Voltage Temperature. A
   more complete description of this field can be found in the MASCS User's
   Guide. Conversion from DN value is the same as that for DEB_TEMP."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = HVPS_HV_TEMP
   COLUMN_NUMBER  = 85
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 213
   UNIT           = "CELSIUS"
   DESCRIPTION    = "High Voltage Power Supply High Voltage Temperature. A
   more complete description of this field can be found in the MASCS User's
   Guide. Conversion from DN value is the same as that for DEB_TEMP."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = UVVS_GRATING_TEMP
   COLUMN_NUMBER  = 86
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 217
   UNIT           = "CELSIUS"
   DESCRIPTION    = "UVVS Grating Drive Temperature. A more complete
   description of this field can be found in the MASCS User's Guide.
   Conversion from DN value is the same as that for DEB_TEMP."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = VIS_ARRAY_TEMP_1
   COLUMN_NUMBER  = 87
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 221
   UNIT           = "CELSIUS"
   DESCRIPTION    = "VIS Array Temperature #1. A more complete description of
   this field can be found in the MASCS User's Guide.
   Conversion from DN value is the same as that for DEB_TEMP."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = VIS_ARRAY_TEMP_2
   COLUMN_NUMBER  = 88
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 225
   UNIT           = "CELSIUS"
   DESCRIPTION    = "VIS Array Temperature #2. A more complete description of
   this field can be found in the MASCS User's Guide.
   Conversion from DN value is the same as that for DEB_TEMP."
END_OBJECT     = COLUMN

OBJECT         = COLUMN
   NAME           = NIR_ARRAY_EXT_TEMP
```

```
   COLUMN_NUMBER  = 89
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 229
   UNIT           = "CELSIUS"
   DESCRIPTION    = "NIR Array External Temperature. A more complete
   description of this field can be found in the MASCS User's Guide.
   Conversion from DN value is the same as that for DEB_TEMP."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = NIR_ARRAY_INT_TEMP
   COLUMN_NUMBER  = 90
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 233
   UNIT           = "CELSIUS"
   DESCRIPTION    = "NIR Array Internal Temperature. A more complete
   description of this field can be found in the MASCS User's Guide. Value is
   converted from DN telemetry value by the following formulas:
    From the short housekeeping packet (12 bit data):
      NIR_ARRAY_INT_TEMP = -22.2879012 - 702.301101*10^(-5)(DN*4)
      + 339.958815*10^(-9)(DN*4)^2 + 173.862825*10^(-12)(DN*4)^3
      - 9.72043502*10^(-15)(DN*4)^4 - 8.891005*10^(-18)(DN*4)^5
    From the long housekeeping packet (14 bit data):
      NIR_ARRAY_INT_TEMP = -22.2879012 - 702.301101*10^(-5)(DN)
      + 339.958815*10^(-9)(DN)^2 + 173.862825*10^(-12)(DN)^3
      - 9.72043502*10^(-15)(DN)^4 - 8.891005*10^(-18)(DN)^5
      "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = BOB_TEMP
   COLUMN_NUMBER  = 91
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 237
   UNIT           = "CELSIUS"
   DESCRIPTION    = "Break out Board Temperature. A more complete description
   of this field can be found in the MASCS User's Guide.
   Conversion from DN value is the same as that for DEB_TEMP."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = VIRS_GRATING_TEMP
   COLUMN_NUMBER  = 92
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 241
   UNIT           = "CELSIUS"
   DESCRIPTION    = "VIRS Grating Temperature. A more complete description
   of this field can be found in the MASCS User's Guide.
   Conversion from DN value is the same as that for DEB_TEMP."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = COVER_TEMP
   COLUMN_NUMBER  = 93
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 245
   UNIT           = "CELSIUS"
   DESCRIPTION    = "Contamination Cover Temperature. A more complete
   description of this field can be found in the MASCS User's Guide.
   Conversion from DN value is the same as that for DEB_TEMP."
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = LVPS_TEMP
   COLUMN_NUMBER  = 94
   BYTES          = 4
   DATA_TYPE      = IEEE_REAL
   START_BYTE     = 249
   UNIT           = "CELSIUS"
```

```
   DESCRIPTION    = "Low Voltage Power Supply Temperature. A more complete
   description of this field can be found in the MASCS User's Guide. Value is
   converted from DN telemetry value by using the following formulas:
    For the short housekeeping packet (12 bits):
    LVPS_TEMP = 25 + ((A/B)-10000) / 78.5 where
       A = 3333.333*((DN*4*0.000366/3)+1)
       B = 1 - (((DN*4*0.0003666/3)+1)/3)
    For the long housekeeping packet (14 bits):
    LVPS_TEMP = 25 + ((A/B)-10000) / 78.5 where
       A = 3333.333*((DN*0.000366/3)+1)
       B = 1 - (((DN*0.0003666/3)+1)/3)
    "
END_OBJECT    = COLUMN

OBJECT        = COLUMN
   NAME           = SPARE_BITS
   COLUMN_NUMBER  = 95
   BYTES          = 2
   DATA_TYPE      = MSB_UNSIGNED_INTEGER
   START_BYTE     = 253
   DESCRIPTION    = "Spare unused column."
END_OBJECT    = COLUMN
```

APPENDIX - SPICE Kernel Files Used In Messenger Data Products

The following SPICE kernel files will be used to compute the UTC time and any geometric quantities found in the PDS labels. Kernel files will be generated throughout the mission with a filenaming convention specified by the MESSENGER project.

***.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 - CODMAC

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 such a 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 - 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
DEB	Digital Electronics Board
DN	digital 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 Electrial 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	MErcury, 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 - MASCS Instrument Overview

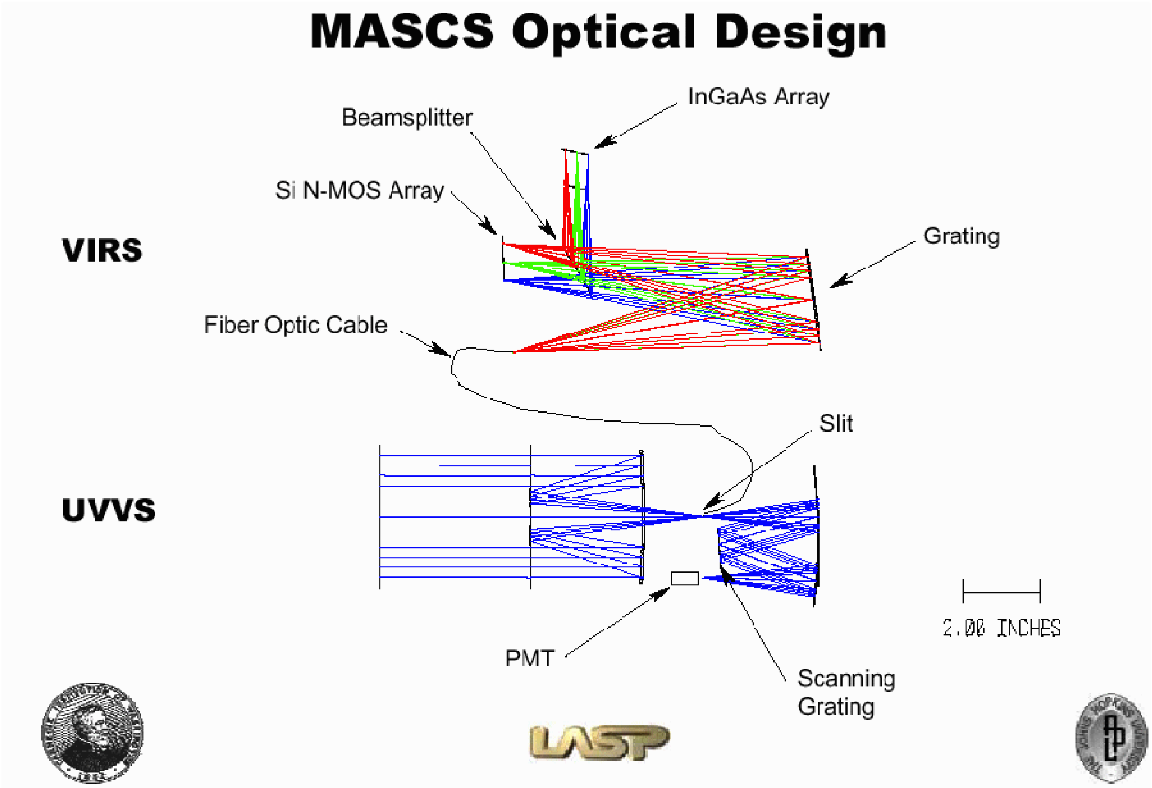
Visible and Infrared Spectrograph measures the visible and infrared surface reflectance. It is a concave grating spectrograph equipped with Si an InGaAs photodiode arrays.(see Figure below).

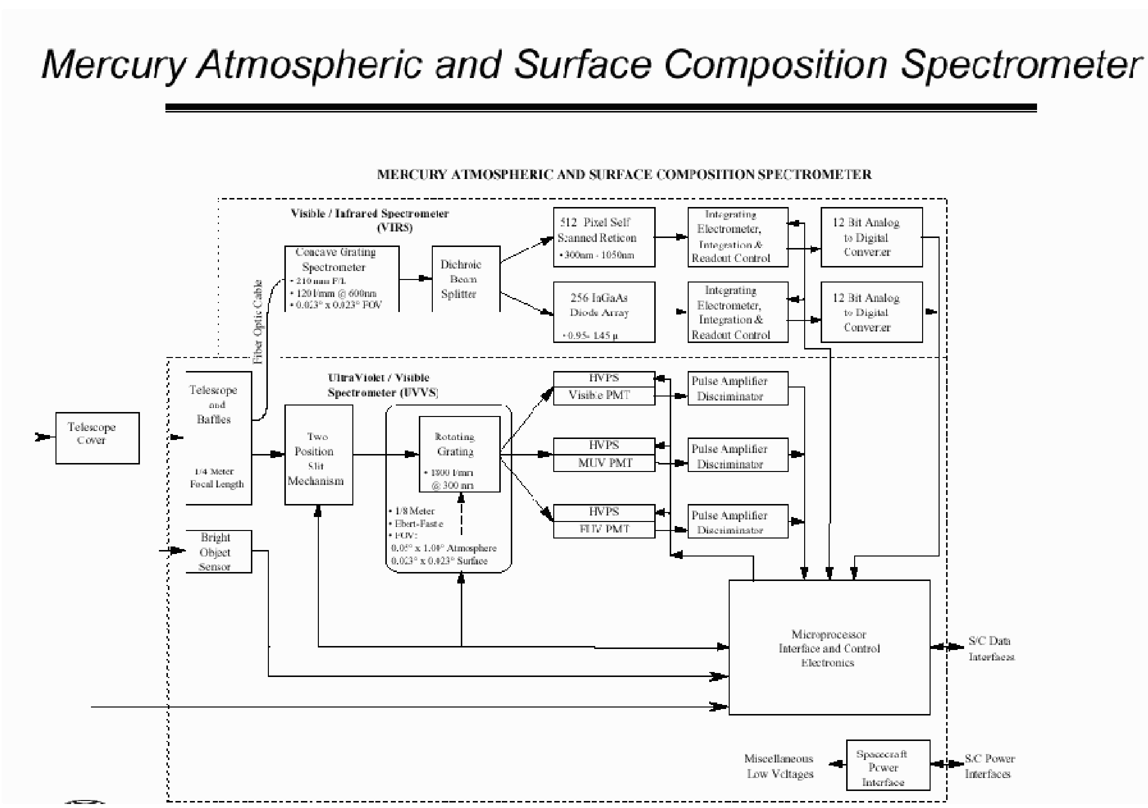
Ultraviolet and Visible Spectrometer

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

Visible and infrared Spectrograph

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


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


Mercury Atmospheric and Surface Composition Spectrometer
MERCURY ATMOSPHERIC AND SURFACE COMPOSITION SPECTROMETER
Visible / Infrared Spectrometer (VIRS)
Concave Grating Spectrometer
• 210 mm F/L
• 120 l/mm @ 600nm
• 0.023° x 0.023° FOV
Dichroic Beam Splitter
512 Pixel Self Scanned Reticon
• 300nm - 1050nm
256 InGaAs Diode Array
• 0.95- 1.45 μ
Integrating Electrometer, Integration & Readout Control
12 Bit Analog to Digital Converter
Fiber Optic Cable
Telescope Cover
Telescope and Baffles
1/4 Meter Focal Length
UltraViolet / Visible Spectrometer (UVVS)
Two Position Slit Mechanism
Rotating Grating
• 1800 l/mm @ 300 nm
• 1/8 Meter
• Ebert-Fastie
• FOV:
0.05° x 1.0° Atmosphere
0.023° x 0.023° Surface
HVPS
Visible PMT
MUV PMT
FUV PMT
Pulse Amplifier Discriminator
Bright Object Sensor
Microprocessor Interface and Control Electronics
S/C Data Interfaces
Miscellaneous Low Voltages
Spacecraft Power Interface
S/C Power Interfaces