

Mars Reconnaissance Orbiter

# **CRISM DATA PRODUCT SOFTWARE INTERFACE SPECIFICATION**

## **Version 1.3.5**

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## DOCUMENT CHANGE LOG

Date	Description	Sections affected
12/15/03	Initial Draft	All
11/22/04	Calibration data records redefined based on instrument calibration results; data processing details (App. I) added; descriptions of macros updated; EDR and TRDR labels updated based on needs of data processing; housekeeping file updated for consistency with flight software	All
3/2/2005	Revisions upon recommendation of reviewers	All
9/14/2005	<p>Added distinguishing features of wavelength filters, exp, and frame rates for level 4 CDRs</p> <p>Distinguished MRO:WAV file for CDR and RDR</p> <p>Added metakernel list files, wavelength files to MRDRs and MTRDRs in figures and text</p> <p>Updated alarm limits</p> <p>Added 12 to 8 bit inverse table to level 6 CDRs</p> <p>Updated labels for level 4 and level 6 CDRs</p> <p>Updated summary parameters</p> <p>Added wavelength filter as keyword and included in EDRs and CDRs</p> <p>Added functional test to cases where macro <math>\neq</math> EDR</p> <p>Added image source to variable settings</p> <p>Fixed sphere lamp 1 and 2 confusion</p> <p>Changed gain_offset to pixel_proc in CDR filename</p> <p>Added compression_type = none, 8_bit to EDR labels</p> <p>Added MRO:SPHERE_TEMPERATURE to CDR labels</p> <p>Added MRO:FRAME_RATE to LDD list for EDR</p> <p>Added exp time parameter to CDR file name</p> <p>Added MRO:WAVELENGTH_FILTER to LDD for EDRs</p> <p>Made underscores in file names and product IDs consistent</p> <p>Renamed MTRDRs using convention for MRDRs; add required layers (observation ID, counter, column)</p> <p>Added column(s) to MRDR geometry image</p> <p>Made observation ID hexadecimal, and corrected its length in all example labels</p> <p>Reformatted MTRDR sample label to parallel MRDR</p> <p>Added SUBTYPE of product to MRDR and MTRDR name</p> <p>Updated graphics</p> <p>Made 1 label per image file</p> <p>Redefined MTRDRs along line of data archive SIS</p> <p>Added MRO:EXPOSURE_PARAMETER to LDD list, to CDR name, EDR and CDR labels</p> <p>Added correction for shutter position to sphere radiance</p>	All
5/3/2006	<p>split TP into different test patterns</p> <p>add VNIR and IR FPU electronics temperatures as keywords and included in CDR labels and table of CRISM-specific keywords</p> <p>added prefix bytes to TRDR label</p> <p>copy applicable changes to Data Archive SIS</p> <p>specify which value is used for sphere, spec housing temp, detector temp, FPE temp</p> <p>add VL (valid limit) 14-bit DN level 6 CDR</p> <p>revise MRO:activity CAT file</p> <p>add event log, instrument settings and data compressibility level 6 CDRs</p> <p>revise observation description</p> <p>make heater zone definitions consistent</p> <p>update definition of how bad pixels are filled</p> <p>update macros</p>	All

	<p>add example labels for MRDR, MTRDR wavelength files  add section on SPICE files  add section on browse files  add section on extras; move target list stuff to extras  update description of observation ID files  removed specific values of alarm limits and referenced appropriate CDR6  update calibration appendix  add compression_type = none, 8_bit to EDR keyword list  made observation_id and observation_number hexadecimal  update parameter formulations  create LDD keywords INVALID_PIXEL_COORDINATES,  REPLACED_PIXEL_COORDINATES and corresponding CAT file  modify SC CDR4 for sphere correction; add VNIR image in units of 14-bit  DN to use as a reference for the correction  add CDR6 BS for bias step  modify descriptions of DB, EB, and GH CDR6's  fixed CDR4 sample label sphere nomenclature  specify DDR geometry to 610, 2300 nm  add CDR for daily housekeeping  changed format of CDR4 images from IEEE_REAL to PC_REAL  defined 000 as inapplicable exposure time parameter  rename WV to WA for level-4 CDR  rename SR to SS for sphere radiance model  updated EDR, TRDR, DDR sample labels  deleted appendix a  added sample ADR label  Redefined definition of nonuniformity files  Eliminated CDR6 tables of CDR4s created inflight  Added ST CDR6s  Added ACT and PRE CDR6s and defined their distinct nomenclature  Refined definition of AS CDR6  Added BW CDR6  Added HV CDR6  Added PS CDR4  Added RW CDR4  Added RF CDR4  Renamed WV CDR4 to WA CDR4, to eliminate confusion with the WV  CDR6  Added SH CDR4  Added SL and VL CDR6s  Renamed SR CDR4 to SS  Added SW CDR6  Made the counter in the EDR or TRDR file name hexadecimal  Updated nomenclature of CDR4s to include additional identifiers  Added resampled TRDR, filetype "RTR"  Refined ADR definitions  Made the counter in the EDR or TRDR file name hexadecimal  Updated nomenclature of CDR4s to include additional identifiers  Added resampled TRDR, filetype "RTR"  Added ADR directory  Made DDRs band sequential</p>	
7/10/2006	<p>Renamed ACT and PRE CDR6s to BTF and ATF  Updated calibration description in Appendix I  Redefined last 3 layers of a DDR to exclude CRISM-derived data  Added missing commas in sample DDR label  Changed units of radiance to W/(m**2 micrometer sr)  Replaced local data dictionary keyword</p>	All

	MRO:FPE_ELECTRONICS_TEMPERATURE with MRO:FPE_TEMPERATURE	
10/1/2006	Added INVALID_PIXEL_LOCATION or to TRDR labels Added keywords specific to resampling and atmospheric corrections to TRDR label Added keywords specific to resampling and atmospheric corrections to LDD, and tables of CRISM-specific keywords Updated list of summary products Added keywords specific to resampling and atmospheric corrections to tables of CRISM-specific keywords Added definitions of RTRs Described and differentiated version 0 and 1 DDR Added EDR, TRDR, and MRDR browse product labels to appendix Describe SPICE kernels generated by CRISM Updated definition of DDR browse products Added DDR browse product labels to appendix	All
2/7/2007	Added AT and RT CDR4s and CT CDR6 describing wavelength-dependent atmospheric transmission, for post-calibration data processing Changed primary source of MRO:DETECTOR_TEMPERATURE from IR temperature sensor 2 to IR temperature sensor 1 Change of definition of wavelength filters on 11 Dec 2006 noted Changed units of elevation layer in DDR to kilometers Changed latitude range separating MRDR map tiles projected equirectangularly and polar stereographically Redefined calibrated data layer of MRDRs and MTRDRs to be I/F instead of radiance Redefined "HYD" IR browse product into three separate products based on first results from Mars	All
5/16/2007	Changed units of MOLA elevation in DDR description Fixed nomenclature of OTT tables in EXTRAS directory Updated descriptions of SB and NU CDRs	All
8/23/2007	Corrected character string in file names to designate EPFs Added definition of TOD observing mode Updated descriptions of SPICE kernels Added information on number of wavelengths to descriptions of EDRs generated by each observation type Defined separate backplane files for I/F and Lambert albedo versions of MRDR and MTRDR because they may not be filled identically Updated definitions of summary products, including replace D2400 with SINDEX and add BD920 Updated nomenclature of MRDRs to include tile number Deleted UR CDR6 and RA CDR4 which aren't being generated	All

## TBD ITEMS

Section	Description
All	Add appendix explaining usage of ADRs Update calibration description

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## ACRONYMS

A/D	Analog to Digital Converter
ADC	Analog to Digital Converter
ADR	Ancillary Data Record
APL	The Johns Hopkins University Applied Physics Laboratory
CAT	CRISM Analysis Tool
CRISM	Compact Reconnaissance Imaging Spectrometer for Mars
CDR	Calibration Data Record
CSV	Comma-Separated Value (a format for organizing tabular data in ASCII format)
CTX	Context Imager (on Mars Reconnaissance Orbiter)
DAC	Digital to Analog Converter
DDR	Derived Data Record
DPCM	Differential Pulse-Code Modulation (compression)
DPU	CRISM Data Processing Unit
EDR	Experiment Data Record
EPF	Emission Phase Function
FOV	Field-of-View
FPU	Focal Plane Unit
Gb	Gigabit ( $10^9$ bits)
GME	CRISM Gimbal Motor Electronics
HIRISE	High-Resolution Imaging Science Experiment (on Mars Reconnaissance Orbiter)
HOP	High-output Paraffin actuator; on CRISM a HOP deploys the cover
I/F	Intensity divided by flux, or the ratio of radiance to incident solar radiation
IR	Infrared
JHU/APL	The Johns Hopkins University Applied Physics Laboratory
JPL	Jet Propulsion Laboratory
LED	Light-emitting diode
LOS	Line-of Sight
Λs	Solar longitude; a measure of Mars' motion in its orbit, in degrees, since northern hemisphere vernal equinox
LUT	Look-up Table
LVDS	Low-Voltage Differential Signal
MOC	Mars Orbiter Camera (on Mars Global Surveyor)
MOLA	Mars Orbiter Laser Altimeter (on Mars Global Surveyor)
MRDR	Map-projected Reduced Data Record
MRO	Mars Reconnaissance Orbiter
MTRDR	Map-projected Targeted Reduced Data Record
MUX	Multiplexed or multiplexer
OMEGA	Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité (on Mars Express)
OSU	CRISM Optical Sensor Unit
PDS	Planetary Data System
RDR	Reduced Data Record
SIS	Software Interface Specification
SOC	Science Operations Center

SNR	Signal-to-noise ratio
SPICE	SPacecraft, Instrument, Camera, and Events; a set of data formats for spacecraft ephemeris, attitude, and instrument pointing
Tb	Terabit ( $10^{12}$ bits)
TBD	To Be Determined
TES	Thermal Emission Spectrometer (on Mars Global Surveyor)
THEMIS	Thermal Emission Imaging System (on Mars Odyssey)
TRDR	Targeted Reduced Data Record
VNIR	Visible / near-infrared

# 1. INTRODUCTION

## 1.1 Purpose and Scope

The purpose of this Data Product Software Interface Specification (SIS) is to provide users of the data products from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) with:

- a detailed description of the products
- a guide to interpreting and using their contents
- a description of how they were generated, including data sources and destinations
- a description of how raw data can be calibrated, including what archived data products are necessary and the procedures to use

Although this is beyond the scope of the strictest definition of the contents of a Planetary Data System (PDS) SIS, this approach is adopted because CRISM is a sophisticated instrument which will generate an extremely large data set that include multiple observing modes. The authors believe that detailed information is required for users to correctly utilize the data products described herein.

There are nine CRISM data products defined in this SIS document. These include:

- 1) Experiment Data Record (EDR) consisting of raw, uncalibrated CRISM spectra;
- 2) Derived Data Record (DDR) containing pointing and other ancillary information;
- 3) Targeted Reduced Data Record (TRDR), which is a radiometrically calibrated EDR;
- 4 and 5) two types of Calibration Data Records (CDRs), which are files used to generate radiance or radiance/solar irradiance (I/F) values in a TRDR from an EDR;
- 6) Ancillary Data Records (ADRs), which are files used to correct I/F values for atmospheric, photometric, or thermal effects, and which document the data set
- 7) Map-Projected Multispectral Reduced Data Record (MRDR);
- 8) Map-Projected Targeted Reduced Data Record (MTRDR); and
- 9) browse products for EDRs, DDRs, TRDRs, and MRDRs.

This SIS is intended to provide enough information to enable users to read and understand the data products. The users for whom this SIS is intended are the scientists who will analyze the data, including those associated with the Mars Reconnaissance Orbiter Project and those in the general planetary science community.

## 1.2 Contents

This Data Product SIS describes how data products generated by the CRISM are processed, formatted, labeled, and uniquely identified. The document details standards used in generating the products and software that may be used to access the product. Data product structure and organization is described in sufficient detail to enable a user to read the product. Finally, an example of each product label is provided.

The CRISM investigation team is also delivering, in parallel with flight data, a spectral library of analog materials that is useful to interpreting flight data. That is described in:

1. CRISM Spectral Library Software Interface Specification, S. Slavney, rev. 0, Nov. 24, 2003.

### **1.3 Applicable Documents and Constraints**

This Data Product SIS is responsive to the following Mars Reconnaissance Orbiter documents:

2. Mars Exploration Program Data Management Plan, R. E. Arvidson and S. Slavney, Rev. 2, Nov. 2, 2000.
3. Mars Reconnaissance Orbiter Project Data Archive Generation, Validation and Transfer Plan, R. E. Arvidson, S. Noland and S. Slavney, Jan. 26, 2006.
4. Mars Reconnaissance Orbiter (MRO) Compact Reconnaissance Imager and Spectrometer for Mars (CRISM) Experiment Operations Plan, S. L Murchie, version 1.5, September 29, 2003.
5. "Flight Operations Specification for the CRISM Science Operations Center (SOC)", S. L Murchie, version 1.0, November 22, 2003

This SIS is also consistent with the following Planetary Data System documents:

6. Planetary Data System Data Preparation Workbook, Version 3.1, Jet Propulsion Laboratory (JPL) D-7669, Part 1, February 1, 1995.
7. Planetary Data System Data Standards Reference, Version 3.6, JPL D-7669, Part 2, August 1, 2003.
8. Planetary Science Data Dictionary Document, JPL D-7116, Rev. E, August 28, 2002.

The reader is referred to the following documents for additional information:

9. Seidelmann, P. K., V. K. Abalakin, M. Bursa, M. E. Davies, C. de Bergh, J. H. Lieske, J. Oberst, J. L. Simon, E. M. Standish, P. Stooke, and P. C. Thomas, Report of the IAU/IAG working group on cartographic coordinates and rotational elements of the planets and satellites: 2000, *Celestial Mechanics and Dynamical Astronomy*, 82, 83-111, 2002.

Finally, this SIS is meant to be consistent with the contract negotiated between the Mars Reconnaissance Orbiter Project and the CRISM Principal Investigator (PI) in which reduced data records and documentation are explicitly defined as deliverable products.

### **1.4 Relationships with Other Interfaces**

Data products described in this SIS are produced by the CRISM Science Operations Center (SOC). Changes to the SOC processing algorithms may cause changes to the data products and, thus, this SIS. The RDR products are dependent on the CRISM EDR products. As such, changes to the EDR product may affect the RDR products.

Changes in CRISM data products or this SIS may affect the design of the CRISM archive volumes.

## 2. DATA PRODUCT CHARACTERISTICS AND ENVIRONMENT

### 2.1 Instrument Overview

CRISM addresses the objectives of characterizing Martian aqueous mineralogy and crustal composition, seasonal variation in the surface and atmosphere, and identifying new targets of scientific interest using the three-pronged strategy described in Table 2-1.

**Table 2-1 CRISM Investigation Objectives and Implementation**

Objective	Implementation / Measurement Strategy	Observation / Planning Design
Find new targets of interest: aqueous deposits, crustal composition	Target observations using previous geologic studies and results from the Thermal Emission Spectrometer (TES), Thermal Emission Imaging System (THEMIS), Mars Orbiter Camera (MOC), etc.	Target list assembled from previous studies Screened / added to using targeting basemap
	Use Mars Express OMEGA data to find new targets lacking morphologic or thermal IR signatures	Derived products from OMEGA included in targeting basemap
	Find targets below OMEGA's resolution using near-global multispectral survey at key wavelengths	~70-channel, ~200-m/pixel multispectral survey to be conducted as early as possible in mission
Separate the surface and atmosphere Provide information on spatial/seasonal variations in aerosols, H <sub>2</sub> O, CO <sub>2</sub> , and ices	Observe emission phase function (EPF) at each targeted observation to quantify atmospheric effects	±60° EPF inherent to full and half resolution targeted observations
	Regularly acquire global grids of EPFs to monitor seasonal variations in surface and atmospheric properties	High time-resolution (atmospheric monitoring campaign) High spatial-resolution (seasonal change campaign)
	Sample compositional layering and seasonal change of polar ices	Key areas targeted with full and half resolution Monitor seasonal cap with multispectral windows
Measure surface targets with high spatial and spectral resolutions and high signal-to-noise ratio (SNR)	Measure thousands of targets at full spectral resolution and high spatial resolution	Full and half resolution targeted observations provide coverage at 6.55 nm/channel, 15-40 m/pixel (at nadir)
	Measure key regions of the surface at key wavelengths at higher resolutions than multispectral survey	Multispectral windows provide coverage of key regions of the planet at ~100 m/pixel, including seasonal polar caps to track seasonal changes
	Conduct inflight calibration of background and responsivity to provide radiometric accuracy	Radiometric calibration using integrating sphere Background and flat-field calibrations using shutter and focal plane lamps are integrated with each observation

### **2.1.1 Hardware overview.**

The CRISM system, design, and function are illustrated in Figure 2-2. CRISM consists of three boxes: the Optical Sensor Unit (OSU) which includes the optics, gimbal, focal planes, cryocoolers and radiators, and focal plane electronics; the Gimbal Motor Electronics (GME), which commands and powers the gimbal motor and encoder and analyzes data from the encoder in a feedback loop; and the Data Processing Unit (DPU), which accepts and processes commands from the spacecraft and accepts and processes data from the OSU and communicates it to the spacecraft. The CRISM OSU has a one-time deployable cover that protects the instrument optics from contamination. The cover will be opened following MRO's aerobraking into its science orbit.

The optical and sensor assembly in the OSU consists of a visible/near-infrared (VNIR) focal plane covering 362-1053 nm at 6.55 nm/channel and a cryogenically cooled infrared (IR) focal plane covering 1002-3920 nm at 6.55 nm/channel. Each field-of-view (FOV) is approximately 605 61.5- $\mu$ rad pixels wide. On each side of the VNIR FOV and one side of the IR FOV there are detector elements not illuminated through the spectrometer slit, that measure instrument and scattered light in the spectrometer cavity simultaneously with each scene measurement (Figure 2-3). A shutter can block the FOV to interleave full-field background measurements. The shutter can also be positioned to view a closed-loop controlled integrating sphere simultaneously by each focal plane, providing radiometric response and flat-field calibration. In addition, either of two redundant lamps can illuminate each focal plane directly to measure detector non-uniformity. Each focal plane has a dedicated electronics board that provides the required clock signals and bias voltages, and digitizes the video data from the focal plane. The digitized data is transmitted through the twist capsule to the DPU. The infrared focal plane is cooled to ~110K by one of three cryocoolers (selectable by the DPU).

The scanning subsystem consists of the Gimbal Motor Electronics (GME), a high-resolution angular encoder, and the gimbal drive motor. The GME contains the motor driver circuitry, and responds to a commanded profile from the DPU. Software in the DPU implements a control algorithm, utilizing feedback information from the 20-bit encoder to maintain closed-looped control. The system accurately follows a programmed scan pattern that is carefully designed to compensate for orbital motion and to accomplish the desired scan pattern across the Martian surface.

The DPU receives unregulated 28-32 volt power from MRO and provides regulated secondary power to CRISM, receives and processes commands from the MRO, controls the CRISM subsystems, and acquires and formats CRISM science and housekeeping data that is then sent to the spacecraft solid state recorder for downlink to earth.

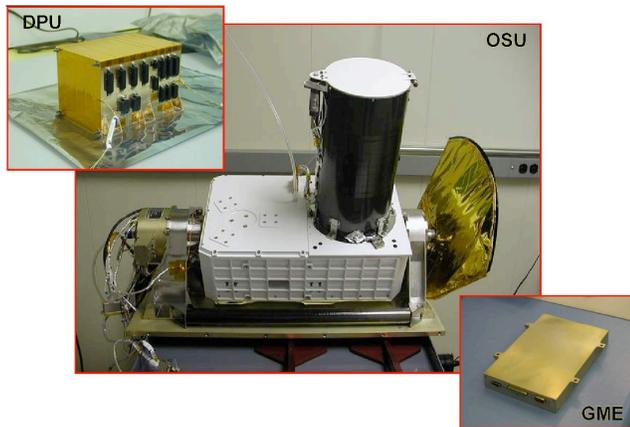


Figure 2-2a. Photographs of CRISM OSU, DPU, GME.

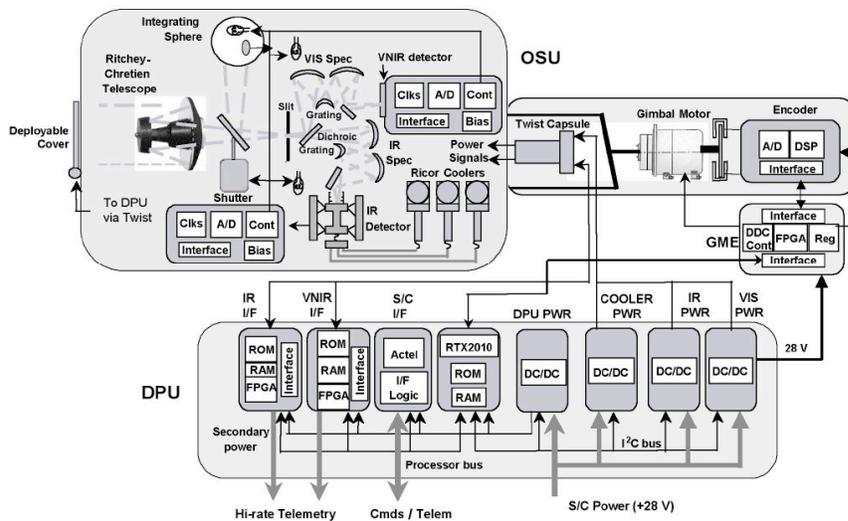


Figure 2-2b. CRISM block diagram.

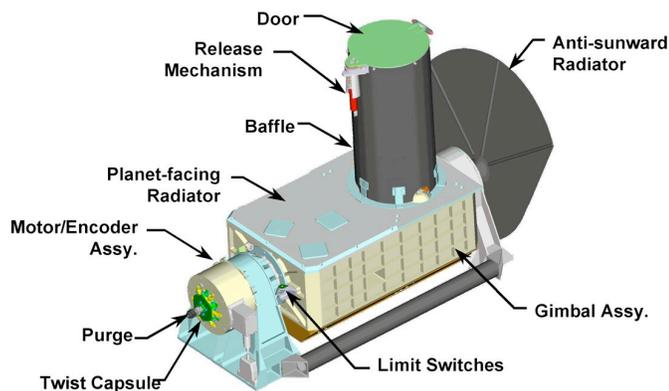


Figure 2-2c. CRISM Optical Sensor Unit (OSU) configuration.

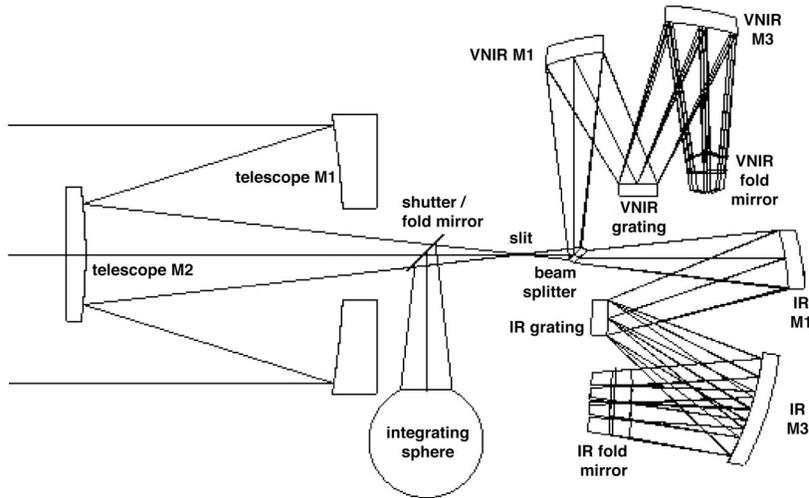


Figure 2-2d.  
CRISM optical  
diagram.

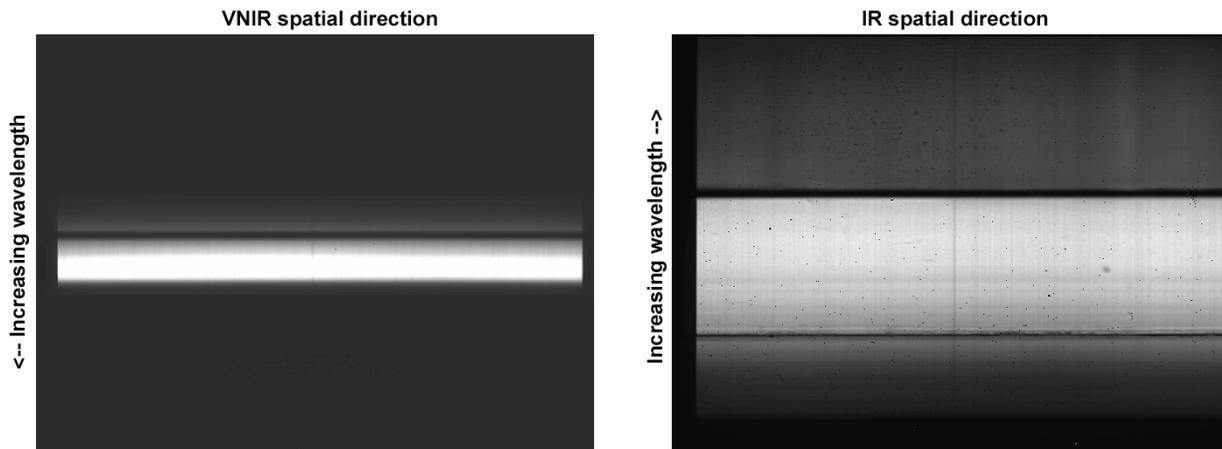


Figure 2-3. Sample VNIR and IR image frames (viewing internal integrating sphere).

### 2.1.2 Key variables in observing modes

Key variables ("configurations") in constructing observing scenarios include the following. All are selectable separately for the VNIR and IR detectors.

- Image source. Image data may be generated using digitized output from the detector, or using one of up to seven test patterns.
- Row selection. All detector rows having useful signal can be saved, or alternatively an arbitrary, commandable subset of rows can be saved. The number of rows with useful signal is 545, 107 in the VNIR and 438 in the IR. The nominal number of rows for multispectral mode was 73, 18 in the VNIR and 55 in the IR prior to 10 Dec 2006. On that date an extra channel was added to the VNIR for a total of 19. For each detector, there are four options of channel selection to choose from rapidly by command: hyperspectral (545 total channels), multispectral (73 total channels prior to 10 Dec 2006, 74 total channels on and after 10 Dec 2006), and two sets of

expanded multispectral (84 and 92 channels prior to 10 Dec 2006, 85 and 93 channels on and after 10 Dec 2006). An analogy is a car radio preset button. New options are set by uploading a data structure to the DPU.

- Pixel binning . Pixels can be saved unbinned or binned 2x, 5x, or 10x in the spatial direction. No pixel binning in the spectral direction is supported.
- Compression. All CRISM data are read off the detector in 14-bit format and are compressed real-time in hardware. Compression options, in succession, are:
  - Subtraction of an offset, on a line by line basis. Offsets are set by uploading a data structure to the DPU.
  - Multiplication by a gain, on a line by line basis, with the output in 12-bit format. Gains are set by uploading a data structure to the DPU. (Raw 12-bit data are stored onground in data products as 16-bit numbers.)
  - Optionally, conversion from 12 to 8 bits using one of eight look-up tables (LUTs) specified on a line by line basis. These choices are set by uploading a data structure to the DPU.
  - Optionally, lossless Fast + differential pulse-code modulation (DPCM) compression
- Pointing. CRISM has two basic gimballed pointing configurations and two basic superimposed scan patterns. Pointing can be (1) fixed (nadir-pointed in the primary science orbit) or (2) dynamic, tracking a target point on the surface of Mars and taking out ground track motion. Two types of superimposed scans are supported: (1) a short, 4-second duration fixed-rate ("EPF-type") scan which superimposes a constant angular velocity scan on either of the basic pointing profiles, or (2) a long, minutes-duration fixed-rate ("target swath-type") scan.
- Frame rate . Frame rates of 1, 3.75, 5, 15, and 30 Hz are supported. The 1 Hz frame rate is used for hyperspectral measurements of the onboard integrating sphere, because the long exposures possible at 1 Hz are needed for appreciable SNR at the shortest wavelengths. 3.75 Hz is used for hyperspectral measurements of Mars; this is the highest frame rate at which the DPU electronics support onboard compression options over the range of wavelengths imaged onto the detectors with useful SNR. 15 and 30 Hz frame rates are used for nadir-pointed multispectral measurements that return only selected wavelengths. The 5 Hz frame rate is not planned for use in flight, because at that rate the electronics do not support compression of a hyperspectral wavelength selection, and it would produce excessive along-track smear in a nadir-pointed observation.
- Integration time. Integration times are in increments of 1/480th of the inverse of the frame rate. At 1 Hz, for example, available integration times are 1/480th sec, 2/480th sec...480/480th , and at 15 Hz, 1/7200th sec, 2/7200th sec...480/7200th sec.
- Calibration lamps. 4095 levels are commandable in each of two lamps at each focal plane, and in two lamps in the integrating sphere. All settings are open-loop, meaning that current is commanded directly. For the integrating sphere only, closed loop control is available at 4095 settings. For closed loop control, the setting refers to output from a photodiode viewing the interior of the integrating sphere; current is adjusted dynamically to attain the commanded photodiode output. Note: lamps reach maximum current at open- or closed-loop settings <4095.
- Shutter position. Open, closed, or viewing the integrating sphere. The shutter is actually commandable directly to position 0 through 32. In software, open=3, sphere=17, closed=32.

NOTE: during integration and testing, it was discovered that at positions  $\leq 2$  the hinge end of the shutter is directly illuminated and creates scattered light. Position 3 does not cause this effect, but the other end of the shutter slightly vignettes incoming light.

### **2.1.3 Summary of orbital observing modes**

During the primary science orbit, CRISM uses several basic observing scenarios as described in Table 2-4. In targeted mode (Figure 2-5), as a target is over flown it is covered by a slow, continuous scan of the field-of-view, taking out most ground track motion. During this operation, the instrument gimbal covers angles  $\pm 35^\circ$ . This central scan is bracketed by five incoming and five outgoing  $\pm 0.3^\circ$  scans centered on the center point of the target, at  $5^\circ$  increments in gimbal position over the range of  $40^\circ$ - $60^\circ$  in gimbal angle. The total of eleven scans provides an 11-angle emission phase function<sup>1</sup> (EPF) that contains information needed for photometric and atmospheric correction of the central targeted scan. The goal is to cover >1000 targets in this manner.

In atmospheric EPF mode, the central scan is replaced by a  $\pm 0.3^\circ$  scan covering a geographically restricted region. The main purpose is recovery of an EPF. Atmospheric mode is used every  $\sim 9^\circ$  of solar longitude (Ls; a measure of Martian season, where  $0^\circ$  is northern hemisphere vernal equinox) to acquire a low spatial density global grid of EPFs to track seasonal variations in surface and atmospheric properties. The grid is covered in 1 solar day. Every  $\sim 36^\circ$  of Ls, a cluster of grids is taken on non-contiguous days to provide a higher spatial density grid to monitor seasonal change in surface material spectral properties. The grids are to be overlain on a best-effort basis; repeat coverage to  $\pm 25$  km can be accomplished from careful selection of the orbits along which the EPFs are taken.

In multispectral mode, the instrument is fixed pointing at nadir, and selected wavelengths are measured at spatial resolution that is reduced by binning pixels in the spatial direction, to manage data volume. This mode of operation is intended to search for new targets of interest and to provide moderate spatial and spectral resolution mapping of surface composition. Two modes of multispectral operation are supported:  $\sim 200$  m/pixel "multispectral survey" mode which is designed to accomplish coverage rapidly, and  $\sim 100$  m/pixel "multispectral window" mode which is intended for higher spatial resolution in key areas.

In optical depth tracking mode mode, the instrument is fixed pointing at nadir, and a short burst of data is taken periodically with CRISM's full wavelength selection, but at spatial resolution that is reduced by binning pixels in the spatial direction to manage data volume. This mode of operation is intended to supplement EPFs with high spatial density measurements with full hyperspectral capability.

In addition, radiometric calibrations using the onboard integrated sphere and measurements of detector bias are taken at least daily.

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<sup>1</sup> An emission phase function is a set of observations of a location on the Martian surface at near-constant solar incidence angle but variable emission angle (and thus phase angle). Because the atmospheric path length varies while illumination is held constant, an EPF enables simultaneous solution for atmospheric and surface components to radiance using estimated surface and atmospheric wavelength-dependent scattering functions. The EPF geometries envelope that of the central scan, so the estimated atmospheric and surface components of its measured radiance can be separated.

On a monthly basis, the flat-field response is assessed by imaging bland regions of Mars, and the redundant lamps in the sphere and at the focal plane are intercalibrated.

**Table 2-4. CRISM Observing Modes During Primary Science Orbit**

Mode	Pointing	Description	Desired Coverage
Targeted	Tracking as shown, once per target	Full resolution Spatial pixels unbinned for target - 18 m/pixel @300 km, 10x binned for EPF	1000's of targets
		Half resolution short Spatial pixels 2x binned for target - 36 m/pixel @300 km, 10x binned for EPF; same swath length as above	
		Half resolution long Spatial pixels 2x binned for target - 36 m/pixel @300 km, 10x binned for EPF; twice swath length as above	
Atmospheric	Tracking as shown but only center of target measured	EPFs Spatial pixels 10x binned (~200 m/pixel @300 km)	9° lon. x 22° lat. grid every ~36° of Ls (3 non-contiguous days of EPFs)
	Nadir-pointed	Tracking Optical Depth (TODs) Spatial pixels 10x binned (~200 m/pixel @300 km)	Between other scheduled observations
Multispectral	Nadir-pointed	Multispectral survey Selected channels, spatial pixels 10x binned (~200 m/pixel @300 km)	≥80% of Mars
		Multispectral windows Selected channels, spatial pixels 5x binned (~100 m/pixel @300 km)	Select areas plus sampling of seasonal variation at polar cap
Radiometric Calibration	-	Observations of onboard integrating sphere	Daily
Bias Calibration	-	Dark observations at multiple exposure times	Daily
Flat-Field Calibration	Nadir-pointed	Observations of bland regions of Mars	Every month
Lamp inter-calibration	-	Full resolution observations of onboard integrating sphere and lamps, alternating sides	Every month

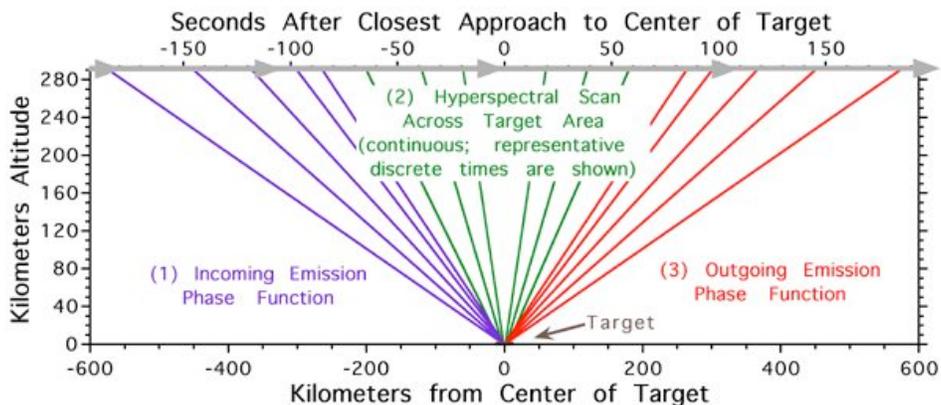


Figure 2-5. Elements to a CRISM targeted observation.

### 2.1.4 Details of observing modes

Commanding of CRISM uses onboard macros, sequences of commands that configure the instrument for a particular operation, acquire data, and then return the instrument to a reference configuration. Up to 255 macros are stored onboard, and the data acquired by part or all of one macro is the fundamental data unit that populates a single EDR.

CRISM science observations use nine basic sequences of macros that translate into different sequences of EDRs (Table 2-6). All of the sequences use an onboard target list for autonomous pointing and time of observations by the spacecraft guidance and controls system. A target ID<sup>2</sup> is used to uniquely identify a target on this list.

#### 2.1.4.1 Targeted measurements and EPF measurements

Four of the macro sequences are intended for execution while the gimbal is tracking a target, and superimposing 11 slow scans: Full resolution targeted observation, half resolution (long or short) targeted observation, and atmospheric survey EPF. All follow the same basic outline. The gimbal is first set to +60° to begin the scan, which then starts at the commanded time. During approach to the target, the scan profile is designed to slowly sweep the optical line-of-sight (LOS) back and forth across the target. Thus, instead of holding the target still within the FOV, short ±0.3° scans are superimposed (part 1 in Figure 2-5). These short scans are called EPF scans. During target over-flight (+35° to -35° gimbal angle; part 2 in Figure 2-5), the gimbal takes a much longer sweep across the target. It is this long central scan that differentiates the classes of observations. The incoming EPF sequence is repeated outgoing, except in reverse order (part 3 in Figure 2-5). Four "dark" measurements of instrument background are taken, marking the start and end of each group of EPF scans, effectively bracketing the incoming and outgoing EPF scans and the central scan.

<sup>2</sup> MRO autonomously determines spacecraft attitude and time to execute a CRISM observation. The inputs include latitude, longitude, and elevation of the target and the command macro sequence and gimbal profile to signal to CRISM to execute. Each observation is given a unique tag or "target ID" to identify it. On MRO this nomenclature is diagnostic of a particular mode of targeting so it is preserved in this SIS. However in PDS data product labels it is replaced by the term "observation ID" and is equivalent to it.

The character of the central scan is what differentiates the four types of gimballed science observations:

A full resolution targeted measurement utilizes CRISM's full resolution capabilities, at the expense of a relatively large data volume. The gimbal is first moved to the starting position of the central scan, which depends on the scan's length. However, it is not the scan length that is the independent variable, but rather the desired speed of the central scan and the time available for execution. Taken together these dictate length of the scan and the initial gimbal position. For full resolution observations, the central scan is executed such that the LOS scans at a rate of 1 pixel (approximated as 60  $\mu$ rad) per integration time, and crosses the target at mid-scan. The number of integrations is selected to mostly occupy the range of gimbal angles between  $\pm 35^\circ$ . Depending on the altitude above a particular target, one of several choices of macros is used to mostly occupy but not overfill this gimbal range, and the corresponding gimbal setup macro is used. The data are taken without spatial pixel binning, and the dark and lamp data are correspondingly taken without pixel binning. However to conserve data volume, the EPF scans are taken with 10x pixel binning; the gimbal scan rate for the EPFs yields approximately square pixels projected onto the surface.

A half resolution long targeted measurement covers a larger area, but at half the spatial resolution. It is intended for targets for which areal coverage is more important than the highest possible resolution. The gimbal is again moved to the starting position of the central scan, which for a given scan duration is about twice the angular offset as the full resolution targeted measurement. The LOS is scanned at a rate of 2 pixels (120  $\mu$ rad) per integration time, and sufficient integrations are executed to mostly occupy the range of gimbal angles between  $\pm 35^\circ$ . Depending on the altitude above a particular target, one of several choices of macros is used to mostly occupy but not overfill this gimbal range, and the corresponding gimbal setup macro is used. The duration of the scan is the same as for a full resolution targeted measurement taken from the same altitude. The data are taken with 2x spatial pixel binning; the higher scan rate yields approximately square pixel footprints projected onto the planet surface. The area covered by the central scan is approximately twice that as for a full resolution targeted measurement. The dark data are correspondingly taken with 2x pixel binning. However to conserve data volume, the EPF scans are taken with 10x pixel binning; the gimbal scan rate yields approximately square pixels projected onto the surface.

A half resolution short targeted measurement is a lower data volume alternative to the two types of targeted observations just described, intended to provide flexibility in covering more targets. The gimbal is first moved to the starting position of the central scan, which in this case is chosen so the scan only occupies about half the range of gimbal angles between  $\pm 35^\circ$ . Then the LOS is scanned at a rate of 2 pixels (120  $\mu$ rad) per integration time, and sufficient integrations are executed to occupy approximately half the range of gimbal angles between  $\pm 35^\circ$ . Depending on the altitude above a particular target, one of several choices of macros is used, and the corresponding gimbal setup macro is used. The duration of data collection over the central scan is half that of a full resolution targeted measurement taken from the same altitude. The data are taken with 2x spatial pixel binning; the higher scan rate yields approximately square pixel footprints projected onto the planet surface. The area covered by the central scan is approximately the same as that as for a full resolution targeted measurement. The dark data are correspondingly taken with 2x pixel binning. However to conserve data volume, the EPF scans

are taken with 10x pixel binning; the gimbal scan rate yield approximately square pixels projected onto the surface.

In an EPF measurement, the central scan is replaced with another EPF scan. The EPFs and dark data are all taken with 10x pixel binning. An EPF measurement is intended to characterize the atmosphere or the average surface properties of a kilometers-sized area, as a part of tracking seasonal changes.

#### **2.1.4.2 *Multispectral survey, multispectral windows, and TODs***

The multispectral survey is intended to map large areas Mars Odyssey/THEMIS-IR scale of resolution, for two purposes: (a) to find sites for targeted measurements, or (b) to characterize composition over large, contiguous areas. This type of observation does not use a scan profile, but is nadir-pointed and measures selected wavelengths at elevated frame rates. The basic configuration is a repeating sequence of alternating Mars-viewing and background measurement macros. The Mars-viewing periods are constrained to be in blocks of 3 minutes so that adequate interpolation of background is possible. CRISM spends most of its observing time in this mode\.

For the minimum 26-Tb downlink MRO mission, the downlink volume allocated to CRISM (7.8 Tb) requires that most of the multispectral survey be converted onboard to 8-bit format. Pre-launch simulations show that when the data are in 12-bit format, noise is seldom <1 DN. *Excluding* ices, translating this value to 8 bits entails quantization at up to 5 times the noise level, resulting in effective degradation of SNR. The variety of LUTs used to convert from 12 to 8 bits (Figure 2-7) is meant to provide a least-loss choice for any given wavelength. This loss is accepted as the consequence of achieving near-global coverage of non-ice surfaces at key wavelengths if the mission downlink is at the low end of its possible range. However the dynamic range of surface materials *including* ices is so large that fitting all of the data into an 8-bit dynamic range would entail losses in effective SNR of up to >10. Instead, polar regions will be mapped losslessly, avoiding this loss at the expense of downlink volume. Losslessly compressed multispectral observations are called the polar multispectral survey. In the event of a larger CRISM downlink allocation than 7.8 Tb, the highest priority is upgrading most or all of the lossy-compressed multispectral survey to polar multispectral survey.

Multispectral survey data and accompanying background and lamp calibrations are taken in 10x pixel binning mode, with ~72 channels selected. Dark, lamp, and Mars data are all taken at 15 Hz, yielding 200-m effective pixels projected on Mars.

Multispectral windows resemble the above multispectral survey, except that they are taken at 30 Hz with 5x pixel binning, yielding 100-m effective pixels projected on Mars. These data are always taken in 12-bit format. Multispectral windows have 3 basic uses:

- Polar monitoring. Selected parts of the polar region are observed several times around specific periods of Ls to monitor seasonal changes in the polar cap.
- Ridealongs . If a High-Resolution Imaging Science Experiment (HiRISE) or Context Imager (CTX) measurement is not coordinated with a CRISM targeted measurement, then a 15-second duration multispectral window with a preceding dark measurements and following lamp measurement may be executed, with the window centered on the center of the HiRISE or CTX target. This assures that science observations by either of those instruments are accompanied by at least a minimal CRISM observation.

- Depending on downlink availability, multispectral windows can be used in place of the multispectral survey for mapping selected regions of the planet. Because of lower SNR than in survey mode, this is only recommended for resolution of 100-m scale spatial heterogeneity, not for detection of weak bands.

Tracking optical depth measurements (TODs) resemble the multispectral survey, except that they are taken with all wavelengths in brief bursts every approximately 48 seconds, yielding 10 x 10 km footprints every 2° of latitude. These data are always taken in 12-bit format. TODs are designed to fill time between other observations to maintain a high spatial density of sampling of atmospheric properties.

#### **2.1.4.3 Other calibrations**

Radiometric calibration is performed at least daily. A radiometric calibration consists of a set of sphere measurements (with the sphere operated closed-loop) with bracketing measurements of the ambient background with the shutter viewing the darkened sphere. These data are used to recover radiometric responsivity.

Bias calibration is performed at least daily. A bias calibration consists of a set of shutter-closed measurements at each frame rate, at 4-5 integration times per frame rate. These data are used to recover detector bias, i.e., the offset image with zero scene radiance or thermal background.

Flat-field calibration is performed at months. A flat-field calibration consists of a set of of a bland region of Mars with bracketing background measurements. These data are used to recover non-uniformity of the VNIR detector. (The integrating sphere provides sufficient signal for this to be measured in the IR, but in the VNIR, at wavelengths <600 nm there is insufficient signal at a single detector element to determine non-uniformity at the desired accuracy of 0.001.)

A calibration source intercalibration is performed monthly to track long-term changes in system response. The sphere bulb controlled by the VNIR electronics is the primary radiometric reference for CRISM. The IR-controlled bulb is measured only monthly to monitor output of the VNIR-controlled bulb for long-term changes.

**Table 2-6. Translation of different observation classes into EDRs.**

<b>Full resolution targeted observation (3.75 Hz)</b>	<b>Half resolution (long or short) targeted observation (3.75 Hz)</b>	<b>Atmospheric survey EPF (3.75 Hz)</b>
full spatial resolution background measurement with shutter closed	half spatial resolution background measurement with shutter closed	reduced spatial resolution (10x-pixel-binned) background measurement with shutter closed
reduced spatial resolution (10x-pixel-binned) measurement of Mars for EPF (5 times)	reduced spatial resolution (10x-pixel-binned) measurement of Mars for EPF (5 times)	reduced spatial resolution (10x-pixel-binned) measurement of Mars for EPF (5 times)
full spatial resolution background measurement with shutter closed	half spatial resolution background measurement with shutter closed	reduced spatial resolution (10x-pixel-binned) background measurement with shutter closed
full spatial resolution measurement of Mars	half spatial resolution measurement of Mars	reduced spatial resolution (10x-pixel-binned) measurement of Mars for EPF
full spatial resolution background measurement with shutter closed	half spatial resolution background measurement with shutter closed	reduced spatial resolution (10x-pixel-binned) background measurement with shutter closed
reduced spatial resolution (10x-pixel-binned) measurement of Mars for EPF (5 times)	reduced spatial resolution (10x-pixel-binned) measurement of Mars for EPF (5 times)	reduced spatial resolution (10x-pixel-binned) measurement of Mars for EPF (5 times)
full spatial resolution background measurement with shutter closed	half spatial resolution background measurement with shutter closed	reduced spatial resolution (10x-pixel-binned) background measurement with shutter closed

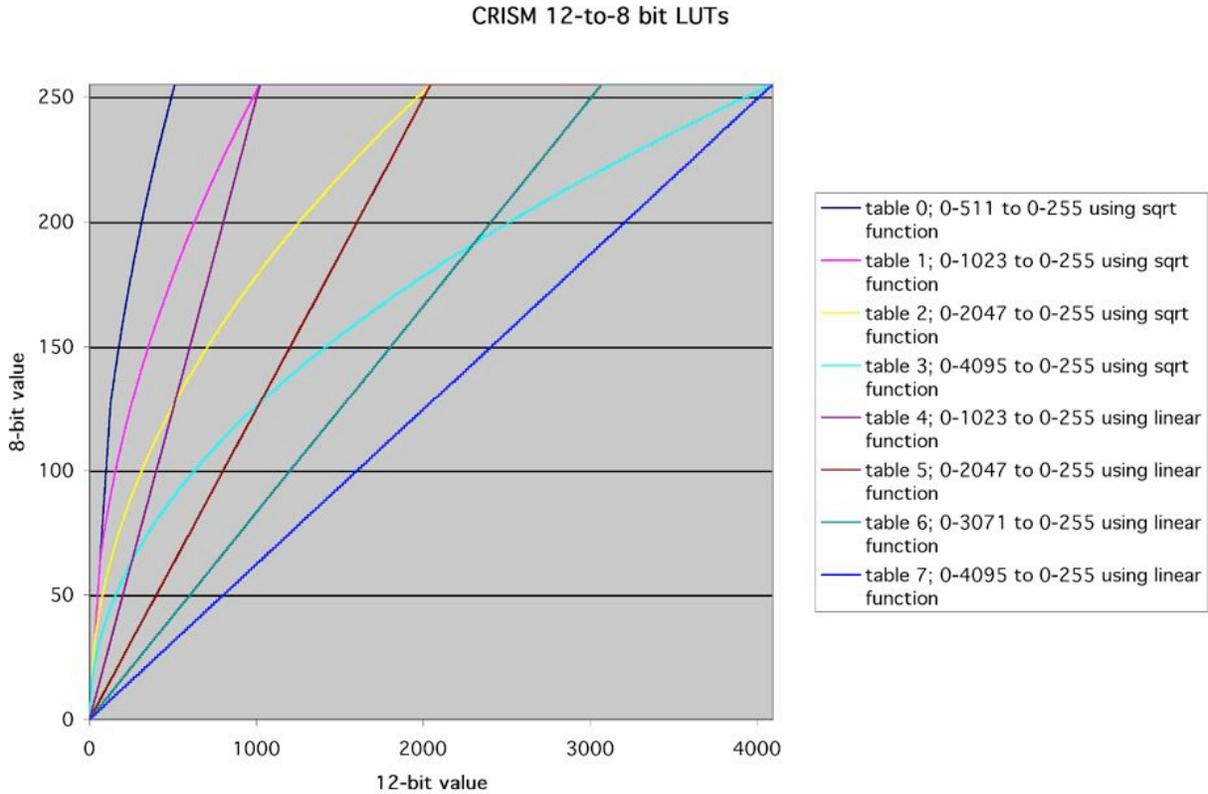
<b>Tracking optical depth observation (3.75 Hz)</b>
reduced spatial resolution (10x-pixel-binned) background measurement with shutter closed
reduced spatial resolution (10x-pixel-binned) measurement of Mars (4 times)
<i>(repeat last 2 sequences n times)</i>
reduced spatial resolution (10x-pixel-binned) background measurement with shutter closed
full spatial resolution background measurement with shutter closed

Multispectral survey (15 Hz)	Multispectral window (30 Hz)
reduced spatial resolution (10x-pixel-binned) background measurement with shutter closed	reduced spatial resolution (5x-pixel-binned) background measurement, shutter closed
reduced spatial resolution (10x-pixel-binned) measurement of Mars	reduced spatial resolution (5x-pixel-binned) measurement of Mars
<i>(repeat last 2 sequences n times)</i>	<i>(repeat last 2 sequences n times)</i>
reduced spatial resolution (10x-pixel-binned) background measurement with shutter closed	reduced spatial resolution (5x-pixel-binned) background measurement, shutter closed

Radiometric Calibration	
full spatial resolution background measurement of the internal integrating sphere before it is powered on (VNIR 1 Hz, IR 1 Hz)	reduced spatial resolution (10x-binned) background measurement of the internal integrating sphere before it is powered on (VNIR 1 Hz, IR 15 Hz)
full spatial resolution measurement of the internal integrating sphere illuminated under closed-loop control using primary lamp (VNIR 1 Hz, IR 1 Hz)	reduced spatial resolution (10x-binned) measurement of the internal integrating sphere illuminated under closed-loop control using primary lamp (VNIR 1 Hz, IR 15 Hz)
full spatial resolution background measurement of the internal integrating sphere after it is powered on (VNIR 1 Hz, IR 1 Hz)	reduced spatial resolution (10x-binned) background measurement of the internal integrating sphere after it is powered on (VNIR 1 Hz, IR 15 Hz)
full spatial resolution background measurement of the internal integrating sphere before it is powered on (VNIR 1 Hz, IR 3.75 Hz)	reduced spatial resolution (5x-binned) background measurement of the internal integrating sphere before it is powered on (VNIR 1 Hz, IR 30 Hz)
full spatial resolution measurement of the internal integrating sphere illuminated under closed-loop control using primary lamp (VNIR 1 Hz, IR 3.75 Hz)	reduced spatial resolution (5x-binned) measurement of the internal integrating sphere illuminated under closed-loop control using primary lamp (VNIR 1 Hz, IR 30 Hz)
full spatial resolution background measurement of the internal integrating sphere after it is powered on (VNIR 1 Hz, IR 3.75 Hz)	reduced spatial resolution (5x-binned) background measurement of the internal integrating sphere after it is powered on (VNIR 1 Hz, IR 30 Hz)

Flat-field Calibration	
full spatial resolution background measurement with shutter closed, 1 Hz	reduced spatial resolution (10x-binned) background measurement with shutter closed, 15 Hz
full spatial resolution measurement of bland scene on Mars, 1 Hz	reduced spatial resolution (10x-binned) measurement of bland scene on Mars, 15 Hz
full spatial resolution background measurement with shutter closed, 1 Hz	reduced spatial resolution (10x-binned) background measurement with shutter closed, 15 Hz
full spatial resolution background measurement with shutter closed, 3.75 Hz	reduced spatial resolution (5x-binned) background measurement with shutter closed, 30 Hz
full spatial resolution measurement of bland scene on Mars, 3.75 Hz	reduced spatial resolution (5x-binned) measurement of bland scene on Mars, 30 Hz
full spatial resolution background measurement with shutter closed, 3.75 Hz	reduced spatial resolution (5x-binned) background measurement with shutter closed, 30 Hz

Bias Calibration (IR only)
full spatial resolution background measurement with shutter closed, series of integration times, 1 Hz
full spatial resolution background measurement with shutter closed, series of integration times, 3.75 Hz
reduced spatial resolution (10x-binned) background measurement with shutter closed, series of integration times, 15 Hz
reduced spatial resolution (5x-binned) background measurement with shutter closed, series of integration times, 30 Hz



**Figure 2-7. Translation of 12-bit DNs into 8-bit DNs using LUTs.**

## 2.2 Data Product Overview

The CRISM data stream downlinked by the spacecraft unpacks into a succession of compressed image frames with binary headers containing housekeeping. In each image, one direction is spatial and one is spectral. There is one image for the VNIR focal plane and one image for the IR focal plane. The image from each focal plane has a header with 220 housekeeping items that contain full status of the instrument hardware, including data configuration, lamp and shutter status, gimbal position, a time stamp, and the target ID and macro within which the frame of data was taken. A number of the housekeeping items are particular to the image frame to which they are attached; others represent instrument hardware or software status and are identically represented in the header from each focal plane.

CRISM standard data products (Table 2-8) and the supplementary browse products represent rearranged values from the data stream, or corresponding derived products, with the basic unit of organization being that portion of the output from one macro which has a consistent instrument configuration (shutter position, frame rate, pixel binning, compression, exposure time, on/off status and setting of different lamps). The flow of data processing and the relationship of data products is shown in Figure 2-9.

### 2.2.1 EDRs

In an EDR (Figure 3-1) the values are unmodified but are rearranged: the headers are stripped off and placed into a text list file, and the frames are merged into a multiple-band image. The multiple-band image may consist of 8- or 12-bit data, stored as 16-bit values. There is one EDR per focal plane.

The list file is based on the 220 housekeeping items. 5 of the items are composite in that each bit of a 32-bit word encodes particular information on gimbal status or control. These separate items are not broken out, except for the gimbal status at the beginning, middle, and end of each exposure, from which gimbal position is broken out (3 additional items). The housekeeping is pre-pended with 10 additional frame-specific items useful in data validation, processing, and sorting, for a total of 233 items per frame:

- A data quality parameter produced during data validation, as discussed in section 2.5
- $L_s$ , degrees
- Solar distance, km
- Time of day at center of FOV, hhmm.ss with 1 Mars solar day = 2400.00
- Preliminary latitude, longitude at center and edges of FOV, degrees
- Preliminary  $i$  (incidence angle) at center of FOV, degrees
- Preliminary  $e$  (emission angle) at center of FOV, degrees
- Preliminary  $g$  (phase angle) at center of FOV, degrees
- Predicted dust opacity, unitless

For the most part, the output from one macro from one focal plane equals an EDR. However there are only 255 available macro slots, so to best utilize available macro space, Three types of complex inflight calibrations are lumped into one macro from which several EDRs are generated:

- The output from a focal plane lamp macro consists of sequential frames taken at different focal plane lamp settings. These different settings are NOT distinguished by a separate macro ID, but they are stored in separate EDRs.
- The output from a bias calibration macro consists of sequential frames taken at different exposure times with the shutter closed. These different exposures are NOT distinguished by a separate macro ID, but they are stored in separate EDRs.
- Onboard functional test macros cycle the instrument through different frame rate, binning, and compression configurations. These different configurations are NOT distinguished by a separate macro ID, but they are stored in separate EDRs.

In the data archive, EDRs are grouped into the outputs from one observation. For each observation, there is also a text report on data validation for the EDRs generated by each detector.

### **2.2.2 CDRs**

EDRs containing bias measurements or measurements of background, focal plane lamps, or the internal integrating sphere are processed into level-4 CDRs. A level-4 CDR contains derived values needed to convert a scene-viewing EDR into units of radiance. These are in image format, with multiple versions corresponding to different pixel binning states. Other level 4 CDRs are derived from ground measurements. A level-6 CDR contains tabulated information, of two types: (a) a file list of level 4 CDRs generated inflight, or (b) tabulated information, for example, for correcting for detector non-linearity, converting housekeeping to physical units, or converting EDRs from 12 to the original at-sensor 14 bits prior to calibration.

### **2.2.3 ADRs**

An Ancillary Data Record (ADR) is used to correct scene measurements for photometric, thermal emission, or atmospheric effects. An ADR is a hyperdimensional binary table or cube containing reference information used by algorithms that correct at-sensor radiance to the reflected solar component of I/F with thermal and atmospheric effects removed.

### **2.2.4 TRDRs**

A Targeted Reduced Data Record or TRDR (Figure 3-4) is comparable to a scene-viewing EDR except that image data has been converted to units of radiance using level-4 and level-6 CDRs, and the list file is converted into physical units using a level-6 CDR. A TRDR may also contain I/F, Lambert albedo, or a set of derived spectral parameters (summary products) that provide an overview of the data set. These include Lambert albedo at key wavelengths, or key band depths or spectral reflectance ratios. To create these products, estimated corrections for atmospheric, photometric, and thermal effects are applied to the radiance data using corrections given in ADRs. The formulations for all of the summary products have been validated using data from Mars Express/OMEGA.

EPF and targeted observations and multispectral windows are processed into TRDRs. A multispectral survey observation is first processed into a temporary TRDR and then mapped into a distinct data product discussed below.

TRDRs may be resampled in the spectral or spatial direction, to remove optical distortions in the data. If resampling has been performed, that is indicated in the label and file name.

### **2.2.5 DDRs**

The axes of an ADR are physical parameters describing a scene, such as incidence, emission, or phase angle or surface temperature. For each EDR that is processed, these values are kept in a companion Derived Data Record (DDR, Figure 3-3). For a given pixel in an EDR, the physical values are extracted from the DDR, and those are used as coordinates to locate a correction in an ADR. Some of the information concerns pointing and photometric geometries; other information concerns surface properties extracted from Thermal Emission Spectrometer (TES), Mars Orbiter Laser Altimeter (MOLA), or other data sets that are needed to estimate atmospheric and thermal contributions to measured radiance.

### **2.2.6 MRDRs**

A multispectral RDR (MRDR, Figure 3-6) consists of several or more strips of multispectral survey data mosaicked into a map tile. Thus a map tile is constructed from a large number of EDRs. The mosaic is uncontrolled (accepting existing pointing data often resulting in image mismatch at seams within a mosaic). A global pattern of 1964 such tiles (Figure 2-9) has been developed, forming the major data product for multispectral survey observations. The tile contains data in units of I/F extracted from a temporary TRDR, plus Lambert albedo, summary products, and the DDR data used to generate them. So, for every latitude or longitude in an MRDR, there is both an I/F and all the information providing traceability to a companion I/F corrected for atmospheric, photometric, and thermal emission effects. The MRDRs also include text files having information on the wavelength of the layers of the Lambert albedo and I/F multiband images and on the SPICE metakernels used for map projecting the image data.

### **2.2.7 MTRDRs**

A map-projected TRDR (MTRDR, Figure 3-8) is analogous to an MRDR, except that it contains hyperspectral data from a targeted, hyperspectral observation, map-projected and converted to I/F. Summary products are included, as are optional user-defined derived products and descriptions of them.

### **2.2.8 SPICE Files**

Four types of SPICE kernels are needed to calculate CRISM's pointing:

- Frames kernel (FK). This file defines the relationships of the of CRISM's field of view to the spacecraft, with the gimbal at "nadir".
- Instrument kernel (IK). This file describes the relationship of position of each detector element (at a row or wavelength and spatial or column position) to a zero position within the field of view.
- Gimbal C kernel. This file gives a time history of the angle of the gimbal within the gimbal plane, relative to its commanded nadir.
- Metakernel. This file gives, for any time span covered by a gimbal C kernel, the MRO and CRISM SPICE kernels used to create DDRs for observations occurring during that time period.

### **2.2.9 Browse Products**

Browse products are PNG files that show a summary of EDR, TRDR, DDR, or MRDR data characteristics in the spatial plane of the data. For the EDRs, the PNG files show median values from a selected wavelength range. For TRDRs, DDRs, or MRDRs, the PNG files show scaled values of key layers of the data. Accompanying labels describe scaling to the 8-bit PNG files. The PNG files are accompanied by an HTML file that describes the EDR, TRDR, or DDR browse products for one observation, or the MRDR browse products for one map tile.

### **2.2.10 Extra Products**

Extra products in the CRISM archive are all ASCII text files and include a time ordered history of observations and the characteristics of the sites observed, as well as the configuration-managed history of the hardware and software state of the CRISM instrument.

Several engineering-related files, which have a format and nomenclature like that of level 6 CDRs, include a history of alarms settings and software control parameters that are uploaded as binary tables ("data structures"), and events log, heater settings, and the model of data compressibility that is used in observation sequence planning.

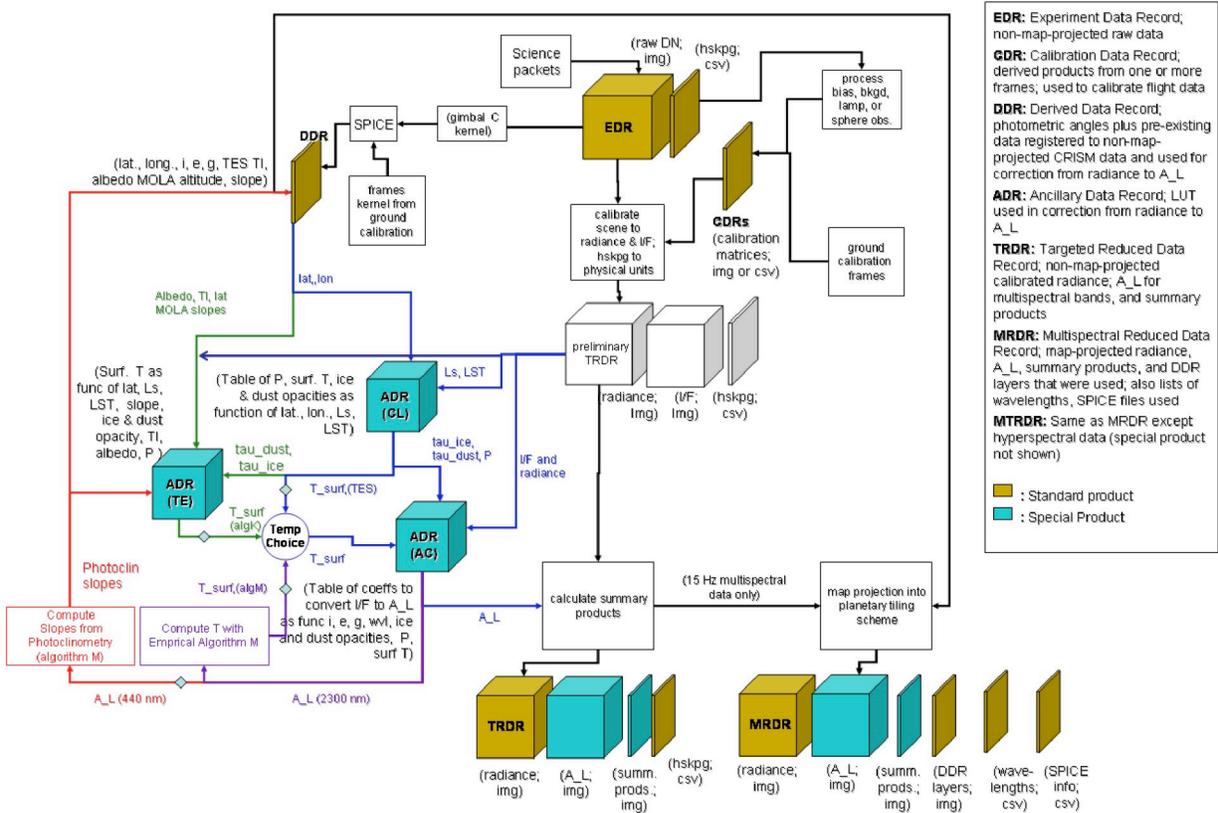
Other files document the characteristics of flight macros that were active during different periods of the MRO mission. There are three files for each macro load: the macro dictionary itself, a summary of each macro's function, and a description of the image data generated by each macro.

Finally, a set of tables connects specific observations with regions of interest on Mars, science objectives, and specific observation conditions. There are five tables:

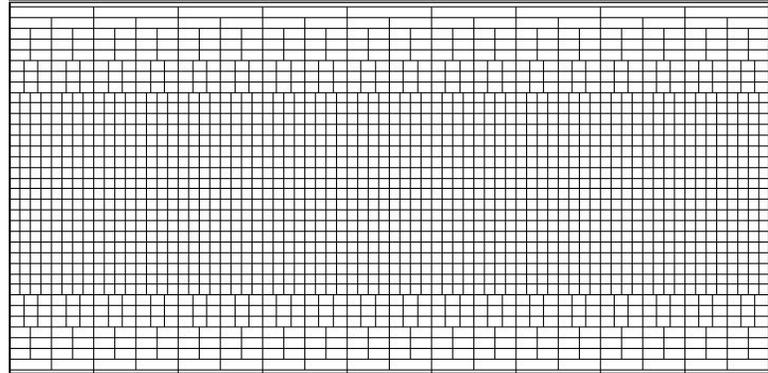
- (a) A site ID table describing the locations and physical features of sites of interest on Mars, compiled by the CRISM science team. This table defines the intended targets of observations by full and half resolution targeted observations or multispectral windows.
- (b) An ancillary information table describing physical properties of a  $0.25^\circ \times 0.25^\circ$  region centered on the center point of each site ID.
- (c) For each site ID, a table of request IDs. There is at least one entry specifying the desired observing conditions such as Ls. For site IDs desired to be observed repeatedly, there are multiple entries.
- (d) An observation ID table summarizing the date and characteristics of each observation actually taken.
- (e) A correspondence table in which one line gives a site ID, request ID, and target ID where there is geographic overlap.

**Table 2-8. Definitions of CRISM data products.**

Data Product	PDS Data Set ID	Data Processing Level	Example PDS Labels
Experiment Data Record (EDR)	MRO-M-CRISM-2-EDR-V1.0	2	Figure 3-1; Appendix A
Calibration Data Record (CDR)	MRO-M-CRISM-4/6-CDR-V1.0	4, 6	Appendices G,H
Derived Data Record (DDR)	MRO-M-CRISM-6-DDR-V1.0	6	Figure 3-3; Appendix B
Ancillary Data Record (ADR)	MRO-M-CRISM-6-ADR-V1.0	6	Appendix H
Targeted RDR (TRDR)	MRO-M-CRISM-3-RDR-TARGETED-V1.0	3	Figure 3-4; Appendix C
Multispectral RDR (MRDR)	MRO-M-CRISM-5-RDR-MULTISPECTRAL-V1.0	5	Figure 3-6; Appendix D
Map-Projected TRDR (MTRDR)	MRO-M-CRISM-5-RDR-MPTARGETED-V1.0	5	Figure 3-8; Appendix E



**Figure 2-9. Sequential processing of EDRs to yield RDRs of Mars data, showing the roles of CDRs and ADRs.**



**Figure 2-10. Tiling scheme for the map-projected multispectral survey, shown in orthographic view and as a global, EQUIRECTANGULAR map form.**

## 2.3 Data Processing

### 2.3.1 Data Processing Level

This SIS uses the Committee On Data Management And Computation (CODMAC) data level numbering system to describe the processing level of the CRISM EDR data product. Table 2-11 shows the description of the CODMAC data processing levels and the correlation with the NASA processing levels. The CODMAC system is used here because it is the standard used by the PDS. CODMAC data processing levels for CRISM data products are listed in Table 2-8.

**Table 2-11. Processing Levels for Science Data Sets**

NASA	CODMAC	Description
Packet data	Raw - Level 1	Telemetry data stream as received at the ground station, with science and engineering data embedded.
Level-0	Edited - Level 2	Instrument science data (e.g., raw voltages, counts) at full resolution, time ordered, with duplicates and transmission errors removed.
Level 1-A	Calibrated - Level 3	Level 0 data that have been located in space and may have been transformed (e.g., calibrated, rearranged) in a reversible manner and packaged with needed ancillary and auxiliary data (e.g., radiances with the calibration equations applied).
Level 1-B	Resampled - Level 4	Irreversibly transformed (e.g., resampled, remapped, calibrated) values of the instrument measurements (e.g., radiances, magnetic field strength).
Level 1-C	Derived - Level 5	Level 1A or 1B data that have been resampled and mapped onto uniform space-time grids. The data are calibrated (i.e., radiometrically corrected) and may have additional corrections applied (e.g., terrain correction).

<b>NASA</b>	<b>CODMAC</b>	<b>Description</b>
Level 2	Derived - Level 5	Geophysical parameters, generally derived from Level 1 data, and located in space and time commensurate with instrument location, pointing, and sampling.
Level 3	Derived - Level 5	Geophysical parameters mapped onto uniform space-time grids.
	Ancillary – Level 6	Data needed to generate calibrated or resampled data sets.

## **2.3.2 Data Product Generation**

### **2.3.2.1 Data acquisition**

The high-level observation plan in Table 2-4 has been translated into a preliminary timeline for a number of types of targets. This has involved internal planning of CRISM observations as described above, as well as coordination with MRO Project objectives and spacecraft resource constraints.

- First, based on the outputs expected from the sequence of macros executed for each type of target, a predicted data volume for each type of observation is calculated. This is summarized in Table 2-12.
- Second, the MRO project has allocated CRISM and other instruments a fraction of spacecraft resources, downlink and spacecraft pointing. CRISM’s downlink is 7.8 Tb for a 26-Tb downlink mission, or 10.8 Tb for a 34-Tb mission, or 15 Tb for a 50-Tb mission. The total number of observations requiring off-nadir spacecraft pointing is set to be less than 6500.
- Third, based on coverage goals summarized in Table 2-4, an approximate total of different numbers of observations types was assembled for the 7.8-Tb CRISM investigation (Table 2-13). During some periods of the mission, approximately half of the orbits are devoted to nadir pointing for survey observations. Off-nadir pointing occurs mostly on remaining orbits. The off-nadir opportunities are of 3 types: (a) Mars Exploration Program (MEP)-selected targets, the highest priority, for which all instruments observe the same target at high spatial resolution; (b) coordinated targets, observed in the same way, of which each instrument will choose a fraction; and (c) single-instrument targets for which other instruments may or may not operate at high spatial resolution. Remaining downlink allocation is filled with targets that are observed at high spatial resolution but without off-nadir pointing. In addition, some non-coordinated observations will be accompanied by a short, reduced-resolution observation (a ridealong). That way, additional sites observed by any of the three instruments will also be covered by simultaneous data from at least one other instrument. CRISM’s ridealong is a short, 15-second multispectral window.

**Table 2-12. Contents of each type of CRISM observation**

Class of observation	Frame rate, Hz	Activity	Pixel binning	#	Wave-lengths	Frames (typical)
Full resolution targeted	3.75	central scan	1	1	545	487
	3.75	EPF scans	10	10	545	15
	3.75	dark sets	1	4	545	12
Half resolution short targeted	3.75	central scan	2	1	545	243
	3.75	EPF scans	10	10	545	15
	3.75	dark sets	2	4	545	12
Half resolution long targeted	3.75	central scan	2	1	545	487
	3.75	EPF scans	10	10	545	15
	3.75	dark sets	2	4	545	12
EPF	3.75	EPF scans	10	11	545	15
	3.75	dark sets	10	4	545	12
TOD	3.75	3-second segments	10	12	545	12
	3.75	dark sets	10	4	545	12
Multispectral survey	15	3-minute segments	10	16	73	2700
	15	dark sets	10	17	73	12
Lossless (polar) multispectral survey	15	3-minute segments	10	16	73	2700
	15	dark sets	10	17	73	12
Multispectral window	30	1 3-minute segment	5	1	73	5400
	30	dark sets	5	2	73	12
Ridealong	30	1 15-second segment	5	1	73	450
	30	dark sets	5	2	73	12

Class of observation	Frame rate, Hz	Activity	Pixel binning	#	Wave-lengths	Frames apiece (typical)
Radiometric calibration	1 (VNIR), 1 (IR)	sphere background	1	2	545	12
	1 (VNIR), 1 (IR)	sphere frames	1	1	545	32
	1 (VNIR), 3.75 (IR)	sphere background	1	2	545	12
	1 (VNIR), 3.75 (IR)	sphere frames	1	1	545	32
	1 (VNIR), 15 (IR)	sphere background	10	2	73	12
	1 (VNIR), 15 (IR)	sphere frames	10	1	73	32
	1 (VNIR), 30 (IR)	sphere background	5	2	73	12
	1 (VNIR), 30 (IR)	sphere frames	5	1	73	32
Bias calibration	1	dark frames, several integration times	1	4	438 (IR only)	10
	3.75	dark frames, several integration times	1	5	438 (IR only)	10
	15	dark frames, several integration times	10	4	55 (IR only)	10
	30	dark frames, several integration times	5	4	55 (IR only)	10
Flat-field calibration	1	dark sets	1	2	545	12
	1	3-minute segments	1	1	545	180
	3.75	dark sets	1	2	545	12
	3.75	3-minute segments	1	1	545	675
	15	dark sets	10	2	73	12
	15	3-minute segments	10	1	73	2700
	30	dark sets	5	2	73	12
Star alignment calibration	1	scans across star	1	4	545	420
	1	dark sets	1	5	545	12
	1	sphere frames	1	1	545	32
	1	sphere background	1	2	545	12
Lamp inter-calibration	1	sphere background	1	2	545	12
	1	sphere frames	1	2	545	32
	1	dark set embedded in lamp macro	1	2	545	12
	1	lamp frames as VNIR+IR frame equivalents	1	2	545	60
	3.75	dark set embedded in lamp macro	2	2	545	12
	3.75	lamp frames as VNIR+IR frame equivalents	2	2	545	60
	30	dark set embedded in lamp macro	5	2	73	12
	30	lamp frames as VNIR+IR frame equivalents	5	2	73	60
	15	dark set embedded in	10	2	73	12

Class of observation	Frame rate, Hz	Activity	Pixel binning	#	Wave-lengths	Frames apiece (typical)
		lamp macro				
	15	lamp frames as VNIR+IR frame equivalents	10	2	73	60

**Table 2-13. Preliminary CRISM data acquisition plan for 7.8-Tb downlink allocation.**

Off-nadir full-res targets	1500
Off-nadir of half-res long targets	900
Off-nadir of half-res short targets	1200
<b>Total off nadir targets</b>	<b>3600</b>
Nadir full-res targets	1200
Nadir of half-res long targets	1500
Nadir of half-res short targets	800
Multispectral windows	1000
<b>Total nadir targets</b>	<b>4500</b>
<b>Total number targets</b>	<b>8100</b>
Number of strips of multispectral survey	2400
Ridealongs	25000
Number of atmospheric grid EPFs	4200
Number of 1 Hz unbinned sphere obs	5400
Number of 1 Hz 2x binned sphere obs	360
Number of 15 Hz 10x binned sphere obs	4800
Number of 30 Hz 5x binned sphere obs	5760
Number of 1 Hz flat fields	24
Number of 3.75 Hz flat fields	24
Number of 15 Hz flat fields	24
Number of 30 Hz flat fields	24
Number of bias calibrations	1440
Number of lamp intercalibrations	26
Total number observations	57582
Number gimbal cycles	11300
Average Mars observations per day	55
Average calibrations per day	25

### 2.3.2.2 Data processing overview

Data processing to standard products for delivery to the PDS (EDRs, CDRs, TRDRs, DDRs, and MRDRs) occurs in the CRISM Science Operations Center (SOC). ADRs are created by the science team and delivered to the SOC for application to the data. Additional processing to special products (MTRDRs) is the responsibility of individual CRISM science team members.

The sequence of processing used to create deliverable data products is discussed in section 2.2 and shown graphically in Figure 2-9. Appendix M provides detailed mathematical formations of CDRs, and of the derivation of radiance in TRDRs using the CDRs.

### **2.3.3 Data Flow and Delivery**

Downlinked CRISM data are forwarded with spacecraft housekeeping and pointing information from JPL to the CRISM Science Operations Center (SOC) at The Johns Hopkins University Applied Physics Laboratory (APL), where they are processed to EDRs in near-real time. DDRs are generated at the SOC using SPacecraft, Instrument, Camera, and Events (SPICE) and other data sources. RDRs are also generated at the SOC from EDR products. After validation CRISM data products are transferred to the PDS Geosciences Node for archiving and distribution.

CRISM data archival is overseen by Co-I Arvidson, manager of the PDS Geosciences Node. The approach outlined above is consistent with the MRO Data Archive Plan (R. Arvidson, author). Ground data including calibration files and the spectral library will be delivered at various times through Mars orbit insertion. For flight data, delivery of EDRs, DDRs, TRDRs, and CDRs will occur at 3-month intervals following 6 months of validation, on hard drives and deep-archive media to be determined by the PDS. Additionally, by 6 months following the end of the primary science orbit, the final versions of TRDRs (if there is an update) and map-projected targeted RDRs will be delivered on the same media.

ADRs and ground-derived CDRs will be delivered by the time of the first regular delivery outlined above.

Delivery of MRDRs will occur at 6-month intervals following 6 months of validation.

Tables 2-14 and 2-15 show, for the cases of low (7.8 Tb) and expected (15 Tb) total instrument downlink, how the downlink expands after conversion to EDRs, DDRs, RDRs, and CDRs.

**Table 2-14. Approximate 7.8 Tb expanded flight data volume for PDS delivery.**

Class of observation	7.8 Tb #	Data vol per EDR, Gb	PDS deliveries	Data vol per RDR+DDR, Gb	Cal. file volume, Tb	PDS deliveries	Delivered volume, Tb
Full-res targets	865	3.581	1	6.363	0.08	2	14.24
Half-res long targets	1154	1.845	1	3.281	0.04	2	9.79
Half-res short targets	2307	1.126	1	1.733	0.08	2	10.96
Strips of multispectral survey	2338	3.864	1				9.03
Multispectral survey tiles	1716			8.703		4	59.74
Multispectral windows	1000	0.815	1	2.443	0.0003	2	5.70
Ridealongs	14124	0.078	1	0.204	0.005	2	7.01
Atmospheric grid EPFs	4472	0.342	1	0.211	0.03	2	3.68
Radiometric calibrations	728	0.680	1		0.05	2	0.57
Lamp intercalibrations	26	2.289	1		0.005	2	0.06
							120.79

**Table 2-15. Approximate 15 Tb expanded flight data volume for PDS delivery.**

Class of observation	15 Tb #	Data vol per EDR, Gb	PDS deliveries	Data vol per RDR+DDR, Gb	Cal. file volume, Tb	PDS deliveries	Delivered volume, Tb
Full-res targets	2624	3.581	1	6.363	0.23	2	44.00
Half-res long targets	1454	1.845	1	3.281	0.05	2	12.37
Half-res short targets	1598	1.126	1	1.733	0.05	2	7.50
Strips of multispectral survey	2366	3.864	1				9.14
Multispectral survey tiles	1716			8.703		4	59.74
Multispectral windows	4000	0.815	1	2.443	0.0014	2	22.82
Ridealongs	25000	0.078	1	0.204	0.008	2	12.55
Atmospheric grid EPFs	5408	0.342	1	0.211	0.03	2	4.46
Radiometric calibrations	4122	0.680	1		0.29	2	5.19
Lamp intercalibrations	26	2.289	1		0.005	2	0.06
							177.82

### 2.3.4 Labeling and Identification

#### 2.3.4.1 EDR, DDR, and TRDR

EDRs, DDRs, and the radiance part of TRDRs represent CRISM standard products. In summary:

- a) EDRs represent raw data and TRDRs represent calibrated data. Both are in units of sensor space. They contain the optical and spatial distortions present at the sensor.
- b) DDRs represent geometric information, indexed to the wavelength bands of EDRs and TRDRs that are closest to 610 nm (VNIR) and 2300 nm (IR).

Optical distortions may be removed from TRDRs by resampling in the spectral or spatial direction. Three types of resampling can occur: (a) resampling in the wavelength direction occurs using nearest-neighbor resampling, as coded in the PS CDR4; (b) resampling in the spatial direction, to remove differences in spatial scale with wavelength or band, is done with bicubic interpolation using the CM CDR4; and (c) VNIR data may be rescaled to match the slightly different magnification of the IR spectrometer, also using bicubic interpolation and the CM CDR4. A resampled TRDR is distinguished by its label and file name. The label uses local data

dictionary keywords to document the type of resampling that has occurred. The file name parallels that of the source TRDR except for file type.

The file naming convention for EDR, DDR, and TRDR products is as follows.

(ClassType)(ObsID)\_(Counter)\_(Activity)(SensorID)\_(Filetype)(version).(Ext)

where:

Class Type =

FRT (Full Resolution Targeted Observation)

HRL (Half Resolution Long Targeted Observation)

HRS (Half Resolution Short Targeted Observation)

EPF (Atmospheric Survey EPF)

TOD (Tracking Optical Depth Observation)

MSS (Multispectral Survey, lossy compressed)

MSP (Multispectral Survey, losslessly compressed)

MSW (Multispectral Window)

CAL (Radiometric Calibration)

FFC (Flat Field Calibration)

ICL (Calibration source intercalibration)

STO (Star Observation)

FUN (Functional test)

UNK (no valid EDRs within observation that indicate class type)

ObsID = nnnnnnnn, Observation ID, unique for the whole CRISM mission, expressed as a hexadecimal number

Counter= nn, a monotonically increasing ordinal counter of EDRs from one Observation ID, expressed as a hexadecimal number

Activity = for an EDR, type of observation, e.g.

BI#### – Bias measurements / Macro#

DF#### – Dark field measurements / Macro#

LP#### – Lamp measurements / Macro #

SP#### – Sphere measurements / Macro #

SC#### – Scene measurements / Macro #

T1#### – Focal plane electronics test pattern 1 / Macro #

T2#### – Focal plane electronics test pattern 2 / Macro #

T3#### – Focal plane electronics test pattern 3 / Macro #

T4#### – Focal plane electronics test pattern 4 / Macro #  
 T5#### – Focal plane electronics test pattern 5 / Macro #  
 T6#### – Focal plane electronics test pattern 6 / Macro #  
 T7#### – Focal plane electronics test pattern 7 / Macro #  
 UN#### – Instrument configuration does not match macro library / Macro #

for a TRDR, type of product, e.g.

RA#### – Radiance / Macro#  
 SU#### – Summary Products / Macro #  
 IF#### – I/F / Macro #  
 AL#### – Lambert albedo / Macro #  
 for a DDR, type of product, e.g.  
 DE#### – Derived product / Macro#

Sensor ID = S or L (or J=joint for an MTRDR)

filetype = EDR, DDR, or "TRR" for TRDR, "RTR" for resampled TRDR

version = 0, 1,...,9, a, ..., z

Ext = IMG or TAB

Each CRISM data product of these types will also have a product ID that is unique within its data set. The product ID scheme for CRISM EDR, DDR, and TRDR products is as follows (see file naming convention for allowable values for each field):

CCCNNNNNNNN\_XX\_AAAAAS\_TTTV

Where:

CCC	=	Class Type
NNNNNNNN	=	Observation ID as a hexadecimal number
XX	=	Counter within this observation
AAAAA	=	Activity Type
S	=	Sensor ID
TTT	=	Product Type (EDR, DDR, "TRR" for TRDR, "RTR" for resampled TRDR)
V	=	Product version number

#### 2.3.4.2 EDR Validation Reports

The file naming convention for EDR validation report is as follows.

(ClassType)(ObsID)\_(SensorID)\_VALIDATION.TXT

where:

Class Type =

- FRT (Full Resolution Targeted Observation)
- HRL (Half Resolution Long Targeted Observation)
- HRS (Half Resolution Short Targeted Observation)
- EPF (Atmospheric Survey EPF)
- TOD (Tracking Optical Depth Observation)
- MSS (Multispectral Survey, lossy compressed)
- MSP (Multispectral Survey, losslessly compressed)
- MSW (Multispectral Window)
- CAL (Radiometric Calibration)
- FFC (Flat Field Calibration)
- ICL (Calibration source intercalibration)
- STO (Star Observation)
- FUN (Functional test)
- UNK (no valid EDRs within observation that indicate class type)

ObsID = nnnnnnnn, Observation ID, unique for the whole CRISM mission, expressed as a hexadecimal number

Sensor ID = S or L (or J=joint for an MTRDR)

Each validation report will also have a product ID that is unique within its data set. The product ID scheme for CRISM EDR validation reports is as follows (see file naming convention for allowable values for each field):

CCCNNNNNNNN\_S\_VALIDATION

Where:

- CCC = Class Type
- NNNNNNNN = Observation ID as a hexadecimal number
- S = Sensor ID

#### **2.3.4.3 EDR Browse Products**

The file naming convention for the HTML browse products for EDRs is as follows.

(ClassType)(ObsID)\_BROWSE\_EDR(version).(Ext)

where:

Class Type =

- FRT (Full Resolution Targeted Observation)
- HRL (Half Resolution Long Targeted Observation)
- HRS (Half Resolution Short Targeted Observation)
- EPF (Atmospheric Survey EPF)
- TOD (Tracking Optical Depth Observation)
- MSS (Multispectral Survey, lossy compressed)
- MSP (Multispectral Survey, losslessly compressed)
- MSW (Multispectral Window)
- CAL (Radiometric Calibration)
- FFC (Flat Field Calibration)
- ICL (Calibration source intercalibration)
- STO (Star Observation)
- FUN (Functional test)
- UNK (no valid EDRs within observation that indicate class type)

ObsID= nnnnnnnn, Observation ID, unique for the whole CRISM mission, expressed as a hexadecimal number

version= 0, 1,...,9, a, ..., z

Ext= HTML

Each EDR HTML browse product will have a product ID that is unique within its data set. The product ID scheme for CRISM EDR HTML browse products is as follows:

CCCNNNNNNNN\_BROWSE\_EDRV.TXT

Where:

- CCC = Class Type
- NNNNNNNN = Observation ID as a hexadecimal number
- TTT = Product Type (EDR, DDR, "TRR" for TRDR)
- V = Product version number

The file naming convention for the PNG browse products for EDRs is as follows.

(ClassType)(ObsID)\_(Counter)\_(Activity)(SensorID)\_RAW(version).(Ext)

where:

Counter= nn, a monotonically increasing ordinal counter of EDRs from one Observation ID

Activity= for an EDR, type of observation, e.g.

Blinn – Bias measurements / Macro#

- DFnnn – Dark field measurements / Macro#
- LPnnn – Lamp measurements / Macro #
- SPnnn – Sphere measurements / Macro #
- SCnnn – Scene measurements / Macro #
- T1nnn – Focal plane electronics test pattern 1 / Macro #
- T2nnn – Focal plane electronics test pattern 2 / Macro #
- T3nnn – Focal plane electronics test pattern 3 / Macro #
- T4nnn – Focal plane electronics test pattern 4 / Macro #
- T5nnn – Focal plane electronics test pattern 5 / Macro #
- T6nnn – Focal plane electronics test pattern 6 / Macro #
- T7nnn – Focal plane electronics test pattern 7 / Macro #
- UNnnn – Instrument configuration does not match macro library / Macro #

Sensor ID= S for VNIR, or L for IR

version= 0, 1,...,9, a, ..., z

Ext= PNG

Each EDR PNG browse product will have a product ID that is unique within its data set. The product ID scheme for CRISM EDR PNG browse products is as follows:

CCCNNNNNNNN\_XX\_AAAAAS\_RAWV

Where:

- CCC = Class Type
- NNNNNNNN = Observation ID as a hexadecimal number
- XX = Counter within this observation
- AAAAA = Activity Type
- S = Sensor ID
- V = Product version number

#### 2.3.4.4 *DDR and TRDR Browse Products*

The file naming convention for the HTML browse products for DDRs and TRDRs is as follows.

(ClassType)(ObsID)\_BROWSE\_DDR(version).(Ext)

or

(ClassType)(ObsID)\_BROWSE\_TRR(version).(Ext)

where:

Class Type =

- FRT (Full Resolution Targeted Observation)
- HRL (Half Resolution Long Targeted Observation)
- HRS (Half Resolution Short Targeted Observation)
- EPF (Atmospheric Survey EPF)
- TOD (Tracking Optical Depth Observation)
- MSS (Multispectral Survey, lossy compressed)
- MSP (Multispectral Survey, losslessly compressed)
- MSW (Multispectral Window)
- FFC (Flat Field Calibration)

ObsID = nnnnnnnn, Observation ID, unique for the whole CRISM mission, expressed as a hexadecimal number

Version = 0, 1, ..., 9, a, ..., z

Ext= HTML

Each DDR or TRDR HTML browse product will have a product ID that is unique within its data set. The product ID scheme for CRISM EDR HTML browse products is as follows:

CCCNNNNNNNN\_BROWSE\_TTTV

Where:

- CCC = Class Type
- NNNNNNNN = Observation ID as a hexadecimal number
- TTT = Product Type (DDR or "TRR" for TRDR)
- V = Product version number

The file naming convention for the PNG browse products is as follows.

(ClassType)(ObsID)\_(Counter)\_(Activity)(SensorID)\_ (BrowseProductType)(version).(Ext)

where:

Class Type =

- FRT (Full Resolution Targeted Observation)
- HRL (Half Resolution Long Targeted Observation)
- HRS (Half Resolution Short Targeted Observation)
- EPF (Atmospheric Survey EPF)
- TOD (Tracking Optical Depth Observation)
- MSS (Multispectral Survey, lossy compressed)
- MSP (Multispectral Survey, losslessly compressed)

MSW (Multispectral Window)

FFC (Flat Field Calibration)

ObsID = nnnnnnnn, Observation ID, unique for the whole CRISM mission, expressed as a hexadecimal number

Counter = nn, the ordinal counter carried through from the source EDR

Activity = for a TRDR,

RA#### – Radiance / Macro#

SU#### – Summary Products / Macro #

IF#### – I/F / Macro #

AL#### – Lambert albedo / Macro #

for a DDR,

DE#### – Derived product / Macro#

Sensor ID = S or L

BrowseProductType = for a DDR,

DER – Derived product showing incidence and emission angles and elevation

for a TRDR,

TRU – a true color representation of the scene

FEM – VNIR spectral indices related to Fe minerals

IRA – IR I/F at 1330 nm, divided by cos i

MAF – IR spectral indices related to mafic mineralogy

HYD – IR spectral indices related to bound water in minerals

ICE – IR spectral indices related to water or carbon dioxide frost or ice

PHY – IR spectral indices related to hydroxylated minerals

Version = 0, 1, ..., 9, a, ..., z

Ext= PNG

Each EDR PNG browse product will have a product ID that is unique within its data set. The product ID scheme for CRISM EDR PNG browse products is as follows:

CCCNNNNNNNN\_XX\_AAAS\_BBBV

Where:

CCC = Class Type

NNNNNNNNN = Observation ID as a hexadecimal number

XX = Counter within this observation

AAAAA = Activity type

S	=	Sensor ID
BBB	=	Browse Product Type, DER, TRU, FEM, IRA, MAF, HYD, ICE or PHY
V	=	Product version number

#### 2.3.4.5 *MRDRs*

The file naming convention for MRDR products is as follows.

(Tile)\_(ProductType)(Subtype)\_(CLat)(Hemisphere)\_(CLon)\_(Resolution)\_version.(Ext)

where:

Tile = Tnnnn, tile number with tile 0000 at the south pole, increasing spiraling northward

Product Type = "MRR" for MRDR

Subtype of product, e.g.

IF – I/F

AL – Lambert albedo

SU – Summary Products

DE – Derived Products for I/F

DL – Derived Products for Lambert albedo

SP – List of observation IDs and SPICE metakernels

WV – List of wavelengths and wavelength ranges of radiance and I/F images

CLat = nn, Planetocentric latitude of tile center

Hemisphere = #, N or S for north or south latitude

CLon = nnn, East longitude of tile center

Resolution = nnnn, in map-projected pixels per degree, e.g. 256 pixels per degree

version = 0, 1,..., 9, a,..., z

Ext = IMG or TAB

The product ID scheme for the CRISM MRDRs is as follows:

TNNNN\_TTTSS\_XXDYYY\_RRRR\_V

Where:

TNNNN	=	Tile number
TTT	=	Product Type ("MRR" for MRDR)
SS	=	Product subtype, i.e., IF, AL, SU, DE, DL, SP, or WV
XX	=	Planetocentric latitude of tile center
D	=	N or S for north or south latitude

YYY = East longitude of tile center  
 RRRR = Map resolution in pixels per degree, e.g. 0256 or 2048  
 V = Product version number

#### 2.3.4.6 *MRDR Browse Products*

Browse products for MRDRs are only PNG files. Their nomenclature follows that of MRDRs except that browse products type (following the browse product types for TRDRs) is substituted for the type of image product:

(Tile)\_(ProductType)(BrowseProductType)\_ (CLat)(Hemisphere) (CLon)\_(Resolution)\_  
version.(Ext)

where:

Tile = Tnnnn, tile number with tile 0000 at the south pole, increasing spiraling northward

Product Type = MRR

BrowseProductType = TRU, FEM, IRA, MAF, HYD, ICE or PHY

CLat = nn, Planetocentric latitude of tile center

Hemisphere = #, N or S for north or south latitude

CLon = nnn, East longitude of tile center

Resolution= nnnn, in map-projected pixels per degree, e.g. 256 pixels per degree

version= 0, 1, ..., 9, a, ..., z

Ext= PNG

The product ID scheme for the CRISM MRDRs is as follows:

TNNNN\_TTTBBB\_XXDYYY\_RRRR\_V

Where:

TNNNN = Tile number  
 TTT = Product Type ("MRR" for MRDR)  
 BBB = Browse Product Type, TRU, FEM, IRA, MAF, HYD, ICE or PHY  
 XX = Planetocentric latitude of tile center  
 D = N or S for north or south latitude  
 YYY = East longitude of tile center  
 RRRR = Map resolution in pixels per degree, e.g. 0256 or 2048  
 V = Product version number

#### 2.3.4.7 MTRDRs

The file naming convention for MTRDRs closely parallels that for MRDRs:

(ProductType)(Subtype)\_ (CLat)(Hemisphere) (CLon)\_(Counter)\_(Resolution)\_(Date of creation).(Ext)

where:

Product Type = "MTR" for MTRDR

Subtype of product, e.g.

IF – I/F

AL – Lambert albedo

SU – Summary Products

DE – Derived Products for I/F

DL – Derived Products for Lambert albedo

AN – Analysis Products

SP - List of observation IDs and SPICE metakernels

WV – List of wavelengths and wavelength ranges of I/F images

IN – Text information on analysis products

CLat = nn, Planetocentric latitude of tile center

Hemisphere = #, N or S for north or south latitude

CLon = nnn, East longitude of tile center

Counter = nn (representing the ordinal number of the TRDR included, if multiple TRDRs are separated; otherwise if they are overlain in a single mosaic, nn = 00)

Resolution = nnnn, in map-projected pixels per degree, typically 2048 pixels per degree

Date of creation = yymmdd, when the file was written (this is to separate MTRDRs which contain different groups of map-projected TRDRs but have the same latitude and longitude)

Ext = IMG or TAB

The product ID scheme for the CRISM MTRDRs is as follows:

TTTSS\_XXDYYY\_CC\_RRRR\_YYMMDD

Where:

TTT	=	Product Type ("MTR" for MTRDR)
SS	=	Product subtype, i.e., IF, AL, SU, DE, DL, AN, SP, WV, or IN
XX	=	Planetocentric latitude of upper left corner
D	=	N or S for north or south latitude
YYY	=	East longitude of upper left corner

- CC = Counter
- RRRR = Map resolution in pixels per degree, e.g. 0256 or 2048
- YYMMDD = Data of file creation

**2.3.4.8 CDRs**

There are three formats for CDRs:

- tabulated ground or flight ancillary data used during processing from an EDR to radiance (level 6-CDRs)
- tables of scene and accompanying calibration EDRs, to process to CDR4s or TRDRs (level 6-CDRs, with distinct nomenclature to distinguish them from data-containing files.)
- derived, image-format ground or flight data used during processing from an EDR to radiance or I/F (level-4 CDRs)

The file naming convention for data-containing level-6 CDRs is as follows.

(ProductType)(Level)\_(Partition)\_(Time)\_(Product)\_(SensorID)\_version.(Ext)

where:

Product Type = CDR

Level = 6

Partition = n, partition of the spacecraft clock.

Time = nnnnnnnnnn, spacecraft start time of applicability of data product; units are spacecraft clock counts, in units of whole seconds.

Product = nn, acronym describing data product from Table 3-5

Sensor ID = S or L (or J=joint)

Version = 0, 1,..., 9, a,..., z

Ext = TAB

The product ID scheme for data-containing CRISM level 6 CDRs is as follows:

CCCC\_P\_TTTTTTTTTT\_AA\_S\_V

Where:		
CCCC	=	Product Type (CDR6)
P	=	Partition number of sclk counts
TTTTTTTTTT	=	Start time of applicability, in units of sclk counts
AA	=	Acronym for contents of product
S	=	Sensor ID
V	=	Version

The file naming convention for EDR processing tables is as follows.

(Product)\_(Sensor)\_(YYYY)\_(DOY)\_version

where:

Product Type = BTF for before-the-fact predicted, or ATF for after-the-fact actual

Sensor = VN or IR

YYYY = year

DOY = day of year

Version = nn

The product ID scheme for the EDR processing tables is as follows:

CCCC\_P\_TTTTTTTTTT\_AA\_S\_V

Where:		
CCC	=	Product (BTF or ATF)
S	=	Sensor ID
P	=	Partition number of sclk counts
YYYY	=	Year covered by table
DOY	=	Day of year covered by table
V	=	Version

The file naming convention for level-4 CDRs is as follows.

(ProductType)(Level)(Partition)(Time)\_  
 (Product)(FrameRate)(Binning)(ExposureParameter)(WavelengthFilter)(Side)(SensorID)\_  
 version.(Ext)

Product Type = CDR

Level = 4

Partition = n, partition of sclk counts

Time = nnnnnnnnnn, spacecraft start time of applicability of ground data product, or spacecraft mean time of acquisition of source EDR of flight data product; units are spacecraft clock counts, in units of whole seconds.

Product = nn, acronym describing data product from Table 3-19

FrameRate = n, rate in Hz at which data are taken (0=1 Hz, 1=3.75 Hz, 3=156 Hz, 4=30 Hz, 5 = N/A)

Binning = n, number of spatial pixels binned (0=unbinned, 1= 2x binned, 2= 5x binned, 3= 10x binned, 4=N/A)

Exposure parameter = nnn, an integer 1-480 indicating commanded exposure time in units of (inverse frame rate)/480; 000 if inapplicable

Wavelength filter = n, and integer 0-3 indicating which onboard menu of rows of the detector are represented

Side = #, 1 or 2 for focal plane or sphere bulbs; or 0 if N/A

Sensor ID = S or L (or J=joint)

version = 0, 1,..., 9, a,..., z

Ext = IMG

The product ID scheme for CRISM level 4 CDRs is as follows:

CCCCPTTTTTTTTTT\_AARBEEEWCS\_V

Where:		
CCCC	=	Product Type (CDR4)
P	=	Partition number of sclk counts
TTTTTTTTTTT	=	Start time of applicability, in units of sclk counts
AA	=	Acronym for contents of product
R	=	Frame rate
B	=	Binning
EEE	=	Exposure parameter
W	=	Wavelength filter
C	=	Side
S	=	Sensor ID
V	=	Version

**2.3.4.9 ADRs**

ADR's are hyperdimensional binary tables of derived values, where the axes of the matrix represent values of a layer of a DDR (e.g., incidence angle, thermal inertia, etc.), and the element in the matrix is a coefficient used either directly or as an input to correct I/F for predicted atmospheric, photometric, or thermal effects.

The file naming convention for ADRs is as follows.

(ProductType)\_(ADR\_Type)\_(Wavelength)\_(Partition)\_(Time)\_version.(Ext)

where:

Product Type = ADR

ADR\_Type = CL, AC, or TE as described in section 3.8

Wavelength = nnnn, in nanometers; 0000 if not applicable

Partition = n, spacecraft clock partition.

Time = nnnnnnnnnn, spacecraft start time of applicability of data product; units are spacecraft clock counts, in units of whole seconds.

version = 0, 1,..., 9, a,..., z

Ext = DAT

The product ID scheme for CRISM ADRs is as follows:

CCC\_AA\_NNNN\_P\_TTTTTTTTTT\_V

Where:		
CCC	=	Product Type (ADR)
AA	=	Acronym for contents of product
NNNN	=	Wavelength in nearest whole nanometers
P	=	Partition number of sclk counts
TTTTTTTTTT	=	Start time of applicability, in units of sclk counts
V	=	Version

#### 2.3.4.10 SPICE Files

The file naming convention CRISM-generated SPICE kernels is as follows.

MRO\_CRISM\_(KernelType)\_(YYYY\_DOY)\_(Filetype)\_(version).(Ext)

where:

Kernel Type =

- FK (frames kernel)
- IK (instrument kernel)
- CK (gimbal C-kernel)
- MK (metakernel)

YYYY\_DOY is the year and day of year of the start of a 2-week period covered in a single gimbal C kernel or metakernel; or else these fields are filled with zeroes

filetype =

- P for predicted
- R for reconstructed
- N for not applicable

version = 0, 1, ..., 9, a, ..., z

Ext =

- TI (text-format, instrument kernel)
- TF (text-format, frames kernel)
- BC (binary-format, gimbal C kernel)
- BO (binary-format, gimbal offset C kernel)
- TM (text-format, metakernel)

#### **2.3.4.11 Extra Products**

Files that document the history of instrument software settings have a format and nomenclature like that of level 6 CDRs, as described in section 2.3.4.8.

The file naming convention for the macro dictionary is as follows.

MacroDict(YYYYMMDD).PY

where:

YYYYMMDD = year, month, and day of the last onground revision of the macro dictionary

The file naming convention for the description of the image data generated by each macro is as follows.

MacroDict(YYYYMMDD)\_BURSTS.CSV

The file naming convention for the summary of each macro's function is as follows.

MacroDict(YYYYMMDD)\_SUM.CSV

The nomenclature of tables that connect specific observations with regions of interest on Mars, science objectives, and specific observation conditions is described in Table 2-16. For the SITE\_ID, ANCILLARY, REQ\_ID, and CORRESP tables there is one table for the mission, and the string YYYY\_MM\_DD is the date of the last update. For the OBS\_ID table, there is one table per day, as indicated by YYYY\_MM\_DD.

**Table 2-16. Nomenclature of Observation Tracking Tables**

File Name	File Contents
SITE_ID_YYYY_MM_DD.TAB	Description of the locations and physical features of sites of interest on Mars, compiled by the CRISM science team. Date is last update.
SITE_ID_YYYY_MM_DD.HDR	Header record to site ID table.
SITE_ID_YYYY_MM_DD.LBL	Label to site ID table.
ANCILLARY_YYYY_MM_DD.TAB	Tabulated statistics on physical properties of sites of interest on Mars, compiled by the CRISM science team . Date is last update.
ANCILLARY_YYYYMMDD.HDR	Header record to ancillary information table.
ANCILLARY_YYYYMMDD.LBL	Label to ancillary information table.
REQ_ID_MC##- ####_YYYY_MM_DD.TAB	A table of request IDs, with one or more entries, specifying the desired observing conditions such as Ls. One table per site ID (MC##-####).
REQ_ID_MC##- ####_YYYY_MM_DD.HDR	Generic header record to request ID tables.
REQ_ID_MC##- ####_YYYY_MM_DD.LBL	Label to request ID tables.
OBS_ID_YYYY_MM_DD.TAB	Table summarizing the date and characteristics of each observation actually taken.
OBS_ID_YYYY_MM_DD.HDR	Header record to observation ID table.
OBS_ID_YYYY_MM_DD.LBL	Label to observation ID table.
CORRESP_YYYY_MM_DD.TAB	Correspondence table in which one line gives a site ID, request ID, and target ID where there is geographic overlap.
CORRESP_YYYY_MM_DD.HDR	Header record to correspondence table.
CORRESP_YYYY_MM_DD.LBL	Label to correspondence table.

## 2.4 Standards Used in Generating Data Products

### 2.4.1 PDS Standards

The CRISM data product complies with the PDS standards for file formats and labels, specifically the PDS image and table data objects [Applicable Documents 5 and 6].

### 2.4.2 Time Standards

Two time standards are used in CRISM data products:

- spacecraft time in seconds (PDS label keywords SPACECRAFT\_CLOCK\_START\_COUNT and SPACECRAFT\_CLOCK\_STOP\_COUNT)
- UTC (PDS label keywords START\_TIME, STOP\_TIME, and PRODUCT\_CREATION\_TIME)

One additional time-related field is used in CRISM data products:

- target ID, which is a unique identifier associated with each MRO observation (PDS label keyword OBSERVATION\_ID)

### **2.4.3 Coordinate Systems**

The cartographic coordinate system used for the CRISM data products conforms to the IAU planetocentric system with East longitudes being positive. The IAU2000 reference system [7] for Mars cartographic coordinates and rotational elements was used for computing latitude and longitude coordinates.

## **2.5 Data Validation**

Data validation is an iterative process throughout the history of processing the data set. Key steps in the process are given below.

### **2.5.1 EDR level**

For each observation, every EDR is compared against frame-by-frame predictions of commanded instrument state. The results of the comparison are written as a data validation report that accompanies the EDRs for that observation.

In the case of a hardware or configuration discrepancy (shutter position, lamp status or level, pixel binning, frame rate, channel selection, power status of detectors), processing of the image data to RDR level does not occur in order to avoid introducing invalid results. Missing frames or portions of frames are replaced with a value of 65535 (this cannot be a valid data value) and only that portion of the EDR is not further processed.

If an expected calibration data set (background, focal plane lamp, or sphere) is not successfully acquired and downloaded, the next closest in time calibration can be used. In this case there is a discrepancy between the predicted EDR processing table and the actual one, and this is recorded in the data quality index upon processing of the scene EDR to the TRDR level.

### **2.5.2 EDR to RDR level**

A data quality keyword is used to encode Figures-of-Merit into one parameter that is included in each line of the list file with the EDR and TRDR. This begins with the EDR and is modified in the RDR. At the EDR level, missing data, saturation, and basic hardware status are assessed. At the RDR level coverage of a target's latitude and longitude within the boundaries of an observation is assessed, for the central swath of a targeted observation or EPF, or for a multispectral window. Also at the RDR level underexposure is flagged if it occurred. Usage of temporally non-adjacent calibration files (due to loss of data from a background, lamp, or sphere macro) is indicated. High spectrometer housing temperature is flagged. Once the summary

product backplanes are derived, an excessive violet I/F is flagged as a possible indication of water ice clouds.

The 16-byte data quality field is interpreted as follows:

Byte 0: populated in EDR; 1 = focal planes not properly powered; 0 = focal planes properly powered;

Byte 1: populated in EDR; updated in RDR; 1 = saturated data (8-bit 255; 12-bit 4095; or within 10% of 14-bit saturation - bias-removed DN of >9000) present outside of bad pixel mask; 0 = saturated data not present;

Byte 2: populated in EDR; 1 = missing data (some pixels populated with 65535); 0 = no missing data;

Byte 3: populated in EDR: 1 = shutter out of commanded position; 0 = shutter in position;

Byte 4: populated in EDR; 1 = focal plane lamp setting out of commanded range; 0 = focal plane lamp setting in commanded range;

Byte 5: populated in EDR; 1 = sphere goal out of commanded range; 0 = sphere goal in commanded range;

Byte 6: populated in EDR; 1 = more lines or bands than expected; 0 = not more than expected;

Byte 7: populated in RDR; 1 = VNIR detector out of calibrated temperature range; 0 = VNIR detector within calibrated temperature range

Byte 8: populated in RDR; 1 = IR detector out of calibrated temperature range; 0 = IR detector within calibrated temperature range

Byte 9: populated in RDR; 1 = sphere temperature out of calibrated range; 0 = temperature sphere within calibrated range

Byte 10: populated in RDR; 1 = spectrometer housing temperature >-75C; 0 = spectrometer housing temperature ≤-75C; Byte 10: populated in RDR; 1 = target not covered; 0 = target covered (for targeted observation or EPF or multispectral window);

Byte 11: populated in RDR; 1 = target not covered; 0 = target covered (for targeted observation or EPF or multispectral window);

Byte 12: populated in RDR; 1 = non-adjacent calibration files used; 0 = temporally adjacent calibration files used;

Byte 13: populated in RDR; 1 = violet I/F (from summary product backplane) suggests clouds or ice (>0.1); 0 = low violet I/F;

Byte 14 through Byte 15 spare

Missing frames or portions of frames or saturated data are indicated in an RDR with a value of 65535 (this cannot be a valid data value).

### **2.5.3 RDR level**

Once data are calibrated to units of radiance, some of the pixels that are present in an EDR cannot have meaningful values. These include the regions at the edge of each detector which contain background measurements that are used during application of the calibration algorithm (see Appendix M). Those pixels are set to a value of exactly 65535, which cannot have a meaningful significant in the units used for radiance or I/F.

## 3. DETAILED DATA PRODUCT SPECIFICATIONS

### 3.1 EDR

#### 3.1.1 Data Product Structure and Organization

At the SOC, EDRs are constructed from each Target-ID file received. An EDR consists of a part or all of the output from one of the constituent command macros that make up one observation tagged by a unique observation ID. The data in one EDR represent a consistent instrument configuration (shutter position, frame rate, pixel binning, compression, exposure time, on/off status and setting of different lamps). This is shown schematically in Figure 3-1. There is a single multiple-band image (suffix \*.IMG) stored in one file, plus a detached list file in which each record has information specific to one frame of the multiple-band image (suffix \*.TAB). One label points to both files.

The multiple-band image has dimensions of sample, line, and wavelength. The size of the multiple-band image varies according to the observation mode but is deterministic given the macro ID. A typical multiple-band image might have XX pixels in the sample (cross-track) dimension, YY pixels in the line (along-track) dimension, and ZZ pixels in the wavelength dimension, where

- XX=640/binning, where 640 is the number of columns read off the detector, and binning is 1, 2, 5, or 10,
- YY=the number of frames of data with a consistent instrument configuration , and
- ZZ=the number of rows (wavelengths) that are retained by the instrument.

Pixels are 16-bit unsigned integer values, most significant bit first.

Appended to the multiple-band image is a binary table of the detector rows that were used, as selected by the wavelength filter. This is a one-column table, with each row containing one detector row number expressed as a 16-bit unsigned integer values, most significant bit first.

Data are not precisely registered in the spectral direction. For one column, the projection onto Mars' surface may vary by as much as  $\pm 0.4$  detector elements in the XX dimension depending on position in the FOV (distortions are worst at the edges of the VNIR and IR FOVs). For a single wavelength, its location in the ZZ direction may vary by as much as  $\pm 1$  detector element depending on wavelength (distortions are worst at the short- and long-wavelength ends of the IR detector).

The detached comma-separated ASCII file is YY lines in length, containing raw instrument housekeeping plus other frame dependent information. Locations of the temperature sensors and heaters whose states are reported in the housekeeping are shown in Appendix N.

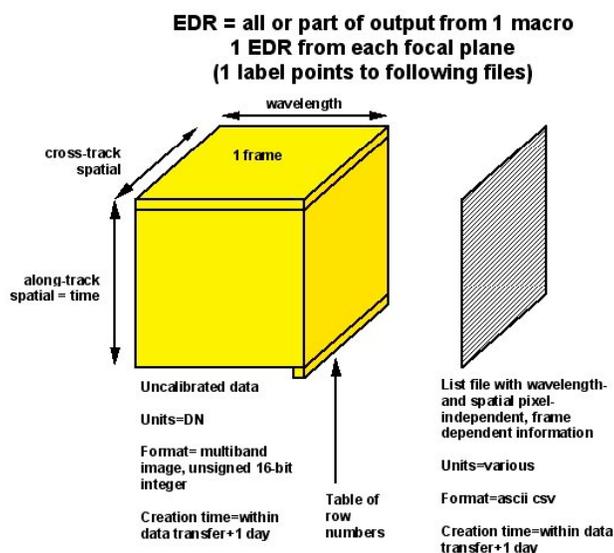
Most of the contents of an EDR represent unmodified but rearranged values from the data stream. The data stream downlinked by the spacecraft unpacks into a succession of image-like frames with binary headers containing housekeeping (Table 3-2). For each focal plane, there are 220 identical housekeeping items that contain full status of the instrument hardware, including

data configuration, lamp and shutter status, gimbal position, a time stamp, and the target ID and macro within which the frame of data was taken.

To convert to an EDR format, the headers are stripped off and placed into the list file in text form, and the frames are merged into a multiple-band image. The list file is based on the 220 housekeeping items. 5 of the items are composite in that each bit of a 32-bit word encodes particular information on gimbal status or control. These separate items are not broken out, except for the gimbal status at the beginning, middle, and end of each exposure, from which gimbal position is broken out (3 additional items). The housekeeping is pre-pended with 10 additional frame-specific items useful in data validation, processing, and sorting, for a total of 233 items per frame:

- A data quality parameter produced during data validation, as discussed in section 2.5
- $L_s$ , degrees
- Solar distance, km
- Time of day at center of FOV, hhmm.ss with 1 Mars solar day = 2400.00
- Preliminary latitude, longitude at center of FOV, degrees
- Preliminary  $i$  (incidence angle) at center of FOV, degrees
- Preliminary  $e$  (emission angle) at center of FOV, degrees
- Preliminary  $g$  (phase angle) at center of FOV, degrees
- Predicted dust opacity, unitless

The pointing and geometric information is derived from spacecraft positions and quaternions plus the gimbal position. Predicted dust opacity is interpolated from an ADR .



**Figure 3-1. Contents of a CRISM Experiment Data Record (EDR).**

**Table 3-2. Items in housekeeping list file**

Column	Mnemonic	Description	Source of information	Length (bytes)	Format (and range if applicable)	Notes
1	DATA_QUALITY_CODE	Data quality	Added parameter	16	Integer	1,2
2	SOLAR_LONGITUDE	Ls	Added parameter	7	Float	1,2
3	SOLAR_DISTANCE	Solar distance	Added parameter	12	Float	1,2
4	LOCAL_TIME	Local time (hh:mm:ss)	Added parameter	7	Character	1,2
5	CENTER_LATITUDE	Estimated latitude	Added parameter	7	Float	1,2
6	CENTER_LONGITUDE	Estimated longitude	Added parameter	7	Float	1,2
7	CENTER_INCIDENCE_ANGLE	Estimated incidence angle	Added parameter	7	Float	1,2
8	CENTER_EMISSION_ANGLE	Estimated emission angle	Added parameter	7	Float	1,2
9	CENTER_PHASE_ANGLE	Estimated phase angle	Added parameter	7	Float	1,2
10	PREDICTED_DUST_OPACITY	Predicted dust opacity	Added parameter	5	Float	1,2
11	SYNCHRONIZATION_PATTERN	Synchronization pattern	Spectrometer Image Header	10	Integer; valid value 4277809352	1,3
12	DATATYPE	Type of data (0 for image data; 1 for encoder diagnostics)	Spectrometer Image Header	5	Integer	1,3
13	NUMLINES	Amount of image data sent (lines, 0 - 480)	Spectrometer Image Header	3	Integer	1,3
14	EXPOSURE_MET	Spacecraft time of exposure, in spacecraft clock units	Spectrometer Image Header	10	Integer	1,3
15	EXPOSURE_SS	Time of exposure fractional second (1/2 <sup>16</sup> seconds)	Spectrometer Image Header	5	Integer	1,3
16	SCAN_MOTOR_STATUS1	Scan motor status word 1	Spectrometer Image Header	16	Character; see Table 3-3 for significance of each character	1,3
17	SCAN_MOTOR_STATUS2	Scan motor status word 2	Spectrometer Image Header	16	Character; see Table 3-3 for significance of each character	1,3
18	SCAN_MOTOR_STATUS3	Scan motor status word 3	Spectrometer Image Header	16	Character; see Table 3-3 for significance of each character	1,3
19	SCAN_MOTOR_ENCPOS1	Angular position of gimbal, beginning of frame	Derived from scan motor status word 1	8	Integer	1,3
20	SCAN_MOTOR_ENCPOS2	Angular position of gimbal, middle of frame	Derived from scan motor status word 2	8	Integer	1,3
21	SCAN_MOTOR_ENCPOS3	Angular position of gimbal, end of frame	Derived from scan motor status word 3	8	Integer	1,3
22	SPECT_ID	Spectrometer identifier	Spectrometer Image Header	1	Integer; 0 = IR, 1 = VNIR	1,3
23	TEMP_MON	Temperature monitoring enabled or disabled	Spectrometer Image Header	1	Integer; 0 = Off, 1 = On	1,3
24	EXPOSURE	Exposure time parameter; number of 1/480ths of inverse frame rate; specified separately for each detector	Spectrometer Image Header	3	0 - 480	1,3

Column	Mnemonic	Description	Source of information	Length (bytes)	Format (and range if applicable)	Notes
25	RATE	Rate of frame acquisition; 0 = 1 Hz; 1 = 3.75 Hz; 2 = 5 Hz; 3 = 15 Hz; 4 = 30 Hz	Spectrometer Image Header	1	Integer; 0-4	1,3
26	SOURCE	Data source, either actual detector or a test pattern	Spectrometer Image Header	1	Integer; 0 = Detector, 1 - 7 = Test pattern	1,3
27	FILTER	Wavelength filter; which onboard table is used to define which detector rows are recorded	Spectrometer Image Header	1	Integer; 0 - 3	1,3
28	BINNING	Pixel binning mode; 0 = 1:1, 1 = 2:1, 2 = 5:1, 3 = 10:1	Spectrometer Image Header	1	Integer; 0 - 3	1,3
29	LOSSY	Enable/disable lossy compression	Spectrometer Image Header	1	Integer; 0 = Disable, 1 = Enable	1,3
30	FAST	Enable/disable Fast compression	Spectrometer Image Header	1	Integer; 0 = Disable, 1 = Enable	1,3
31	DPU_BOARD_TEMP	DPU_PWR_0 (DPU power board temperature)	Analog Status	5	Integer	1,4
32	DPU_P5_VOLTAGE	DPU_PWR_1 (DPU +5 voltage)	Analog Status	5	Integer	1,4
33	DPU_P5_CURRENT	DPU_PWR_3 (DPU +5 current)	Analog Status	5	Integer	1,4
34	SCAN_MOT_CURR	DPU_PWR_4 (Scan motor current)	Analog Status	5	Integer	1,4
35	IR_BOARD_TEMP	IR_PWR_0 (IR power board temperature)	Analog Status	5	Integer	1,4
36	IR_FPU_P12_VOLTAGE	IR_PWR_1 (IR focal plane unit [FPU] +12 voltage)	Analog Status	5	Integer	1,4
37	IR_FPU_P7_VOLTAGE	IR_PWR_2 (IR FPU +7 voltage)	Analog Status	5	Integer	1,4
38	IR_FPU_CURRENT	IR_PWR_3 (IR FPU current)	Analog Status	5	Integer	1,4
39	HEATER_34_CURRENT	IR_PWR_4 (Heater 3 & 4 current)	Analog Status	5	Integer	1,4
40	VNIR_BOARD_TEMP	VNIR_PWR_0 (VNIR power board temperature)	Analog Status	5	Integer	1,4
41	VNIR_FPU_P12_VOLTAGE	VNIR_PWR_1 (VNIR FPU +12 voltage)	Analog Status	5	Integer	1,4
42	VNIR_FPU_P7_VOLTAGE	VNIR_PWR_2 (VNIR FPU +7 voltage)	Analog Status	5	Integer	1,4
43	VNIR_FPU_CURRENT	VNIR_PWR_3 (VNIR FPU current)	Analog Status	5	Integer	1,4
44	HEATER_12_CURRENT	VNIR_PWR_4 (Header 1 & 2 current)	Analog Status	5	Integer	1,4
45	COOL_BOARD_TEMP	COOL_PWR_0 (Cooler power board temperature)	Analog Status	5	Integer	1,4
46	COOL_P15_VOLTAGE	COOL_PWR_1 (Cooler +15 voltage)	Analog Status	5	Integer	1,4
47	COOL_CURRENT	COOL_PWR_3 (Cooler current)	Analog Status	5	Integer	1,4
48	HOP_HEATER_12_CURR	COOL_PWR_4 (High-output paraffin actuator [HOP] heater 1 & 2 current)	Analog Status	5	Integer	1,4

Column	Mnemonic	Description	Source of information	Length (bytes)	Format (and range if applicable)	Notes
49	SHUT_MOTOR_CURR_IR	IR_FP_0 (Shutter motor current (IR))	Analog Status	5	Integer	1,4
50	IR_DETECTOR_TEMP1	IR_FP_1 (IR detector temperature 1)	Analog Status	5	Integer	1,4
51	IR_DETECTOR_TEMP2	IR_FP_2 (IR detector temperature 2)	Analog Status	5	Integer	1,4
52	COOLER_TEMP1	IR_FP_3 (Cooler temperature 1)	Analog Status	5	Integer	1,4
53	COOLER_TEMP2	IR_FP_4 (Cooler temperature 2)	Analog Status	5	Integer	1,4
54	COOLER_TEMP3	IR_FP_5 (Cooler temperature 3)	Analog Status	5	Integer	1,4
55	SHUT_MOTOR_TEMP_IR	IR_FP_6 (Shutter motor temperature (IR))	Analog Status	5	Integer	1,4
56	SPHERE_TEMP_IR	IR_FP_7 (Integrating sphere temperature (IR))	Analog Status	5	Integer	1,4
57	SPIDER_TEMP_IR	IR_FP_8 (Telescope spider temperature (IR))	Analog Status	5	Integer	1,4
58	SPECT_CAVITY_TEMP_IR	IR_FP_9 (Spectral cavity temperature (IR))	Analog Status	5	Integer	1,4
59	OSU_CAVITY_TEMP_IR	IR_FP_10 (OSU cavity temperature (IR))	Analog Status	5	Integer	1,4
60	IR_FPU_BOARD_TEMP	IR_FP_11 (IR FPU board temperature)	Analog Status	5	Integer	1,4
61	IR_SPHERE_CURR	IR_FP_12 (IR sphere lamp current)	Analog Status	5	Integer	1,4
62	HOP_TEMP_IR	IR_FP_13 (HOP temperature (IR))	Analog Status	5	Integer	1,4
63	SHUT_MOTOR_CURR_VNIR	VNIR_FP_0 (Shutter motor current (VNIR))	Analog Status	5	Integer	1,4
64	VNIR_DETECTOR_TEMP1	VNIR_FP_1 (VNIR detector temperature 1)	Analog Status	5	Integer	1,4
65	VNIR_DETECTOR_TEMP2	VNIR_FP_2 (VNIR detector temperature 2)	Analog Status	5	Integer	1,4
66	TELESCOPE_TEMP	VNIR_FP_3 (Telescope temperature (VNIR))	Analog Status	5	Integer	1,4
67	OPTICAL_BENCH_TEMP	VNIR_FP_4 (Optical bench temperature (VNIR))	Analog Status	5	Integer	1,4
68	SPIDER_TEMP_VNIR	VNIR_FP_5 (Telescope spider temp. (VNIR))	Analog Status	5	Integer	1,4
69	SPECT_CAVITY_TEMP_VNIR	VNIR_FP_6 (Spectral cavity temperature (VNIR))	Analog Status	5	Integer	1,4
70	OSU_CAVITY_TEMP_VNIR	VNIR_FP_7 (OSU cavity temperature (VNIR))	Analog Status	5	Integer	1,4
71	VNIR_FPU_BOARD_TEMP	VNIR_FP_8 (VNIR FPU board temperature)	Analog Status	5	Integer	1,4
72	BAFFLETEMP	VNIR_FP_9 (Baffle temperature (VNIR))	Analog Status	5	Integer	1,4
73	SCAN_PWR	Scan motor power	Digital Status	1	Integer; 0 = Off, 3 = On	1,5
74	IR_PRI_PWR	IR FPU primary power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5

Column	Mnemonic	Description	Source of information	Length (bytes)	Format (and range if applicable)	Notes
75	HTR3_PWR	Heater 3 (on cooler radiator) power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
76	HTR4_PWR	Heater 4 (on spectrometer housing) power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
77	VNIR_PRI_PWR	VNIR FPU primary power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
78	HTR1_PWR	Heater 1 (on gimbal electronics housing) power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
79	HTR2_PWR	Heater 2 (on gimbal electronics housing) power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
80	COOL_PRI_PWR	Cooler primary power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
81	HOP_HTR1_PWR	HOP heater 1 power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
82	HOP_HTR2_PWR	HOP heater 2 power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
83	COVER_TELLTALE_PWR	Imager cover telltale power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
84	COVER_TELLTALE	Cover Telltale	Digital Status	1	Integer; 0 = Not closed, 1 = Closed	1,5
85	IR_COOL1_LEVEL	IR Cooler 1 level	Digital Status	4	Integer; 0 - 4095	1,5
86	IR_COOL2_LEVEL	IR Cooler 2 level	Digital Status	4	Integer; 0 - 4095	1,5
87	IR_COOL3_LEVEL	IR Cooler 3 level	Digital Status	4	Integer; 0 - 4095	1,5
88	IR_FLOOD1_LEVEL	IR flood lamp 1 level	Digital Status	4	Integer; 0 - 4095	1,5
89	IR_FLOOD2_LEVEL	IR flood lamp 2 level	Digital Status	4	Integer; 0 - 4095	1,5
90	IR_SPHERE_GOAL	Sphere lamp 1 closed-loop goal (IR)	Digital Status	4	Integer; 0 - 4095	1,5
91	IR_SPHERE_LEVEL	Sphere lamp 1 level (IR); relevant to open-loop operation only	Digital Status	4	Integer; 0 - 4095	1,5
92	IR_SOURCE	IR data source, either actual detector or a test pattern	Digital Status	1	Integer; 0 = Detector, 1 - 7 = Test pattern	1,5
93	IR_SHUT_LED	Shutter fiducial light-emitting diode (LED) power (IR)	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
94	IR_SPHERE_PWR	Sphere lamp 1 power (IR)	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
95	IR_FLOOD1_PWR	IR flood lamp 1 power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
96	IR_FLOOD2_PWR	IR flood lamp 2 power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
97	IR_COOL1_PWR	IR cooler 1 power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
98	IR_COOL2_PWR	IR cooler 2 power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
99	IR_COOL3_PWR	IR cooler 3 power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
100	IR_LVDS_1	IR low-voltage differential signal (LVDS) driver #1 enable	Digital Status	1	Integer; 0 = Disable, 1 = Enable	1,5
101	IR_LVDS_2	IR LVDS driver #2 enable	Digital Status	1	Integer; 0 = Disable, 1 = Enable	1,5

Column	Mnemonic	Description	Source of information	Length (bytes)	Format (and range if applicable)	Notes
102	IR_DAC_POWER	IR digital-to-analog converter (DAC) power (for coolers and lamps)	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
103	IR_DAC_PD	IR DAC power down	Digital Status	1	Integer; 0 = Run, 1 = Power down	1,5
104	IR_ANA_5V_PWR	IR analog 5V power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
105	IR_ADC_Q1_PWR	IR detector quadrant #1 analog-to-digital converter (ADC, or A/D) power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
106	IR_ADC_Q2_PWR	IR detector quadrant #2 A/D power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
107	IR_ADC_Q3_PWR	IR detector quadrant #3 A/D power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
108	IR_ADC_Q4_PWR	IR detector quadrant #4 A/D power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
109	IR_BIAS_PWR	IR detector bias power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
110	IR_AMP_HI_PWR	IR detector amp high power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
111	IR_CLOCK_DRIVE	IR detector clock driver	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
112	IR_COOLER_TEMP3_CONV	IR cooler temperature 3 conversion enable; disabling turns off power to temperature sensor in case of introduced noise in detector	Digital Status	1	Integer; 0 = Disable, 1 = Enable	1,5
113	IR_COOLER_TEMP2_CONV	IR cooler temperature 2 conversion enable; disabling turns off power to temperature sensor in case of introduced noise in detector	Digital Status	1	Integer; 0 = Disable, 1 = Enable	1,5
114	IR_COOLER_TEMP1_CONV	IR cooler temperature 1 conversion enable; disabling turns off power to temperature sensor in case of introduced noise in detector	Digital Status	1	Integer; 0 = Disable, 1 = Enable	1,5
115	IR_TEMP2_CONV	IR detector temperature 2 conversion enable; disabling turns off power to temperature sensor in case of introduced noise in detector	Digital Status	1	Integer; 0 = Disable, 1 = Enable	1,5
116	IR_TEMP1_CONV	IR detector temperature 1 conversion enable; disabling turns off power to temperature sensor in case of introduced noise in detector	Digital Status	1	Integer; 0 = Disable, 1 = Enable	1,5

Column	Mnemonic	Description	Source of information	Length (bytes)	Format (and range if applicable)	Notes
117	IR_SHUTTER_MOTOR_CURRENT_CONV	Shutter motor current conversion enable (IR); disabling turns off power to current sensor in case of introduced noise in detector	Digital Status	1	Integer; 0 = Disable, 1 = Enable	1,5
118	IR_MUX_TEMP_CONV	IR multiplexed (MUX) temperature conversion enable; disabling turns off power to temperature sensor in case of introduced noise in detector	Digital Status	1	Integer; 0 = Disable, 1 = Enable	1,5
119	IR_SHUT_ENB	Shutter motor phase enabled (IR)	Digital Status	1	Integer; 0 - 3	1,5
120	IR_SHUT_PHASE	Shutter motor phase (IR)	Digital Status	1	Integer; 0 - 3	1,5
121	IR_DAC_STATE	IR DAC power state	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
122	IR_SHUT_FID	Shutter fiducial LED (IR)	Digital Status	1	Integer; 0 = Off, 1 = On (fiduciated)	1,5
123	IR_ADC_Q1_STATE	IR detector quadrant #1 A/D latch-up	Digital Status	1	Integer; 0 = Ok, 1 = Latched	1,5
124	IR_ADC_Q2_STATE	IR detector quadrant #2 A/D latch-up	Digital Status	1	Integer; 0 = Ok, 1 = Latched	1,5
125	IR_ADC_Q3_STATE	IR detector quadrant #3 A/D latch-up	Digital Status	1	Integer; 0 = Ok, 1 = Latched	1,5
126	IR_ADC_Q4_STATE	IR detector quadrant #4 A/D latch-up	Digital Status	1	Integer; 0 = Ok, 1 = Latched	1,5
127	VNIR_FLOOD1_LEVEL	VNIR flood lamp 1 level	Digital Status	4	Integer; 0 - 4095	1,5
128	VNIR_FLOOD2_LEVEL	VNIR flood lamp 2 level	Digital Status	4	Integer; 0 - 4095	1,5
129	VNIR_SPHERE_GOAL	Sphere lamp 1 closed-loop goal (VNIR)	Digital Status	4	Integer; 0 - 4095	1,5
130	VNIR_SPHERE_LEVEL	Sphere lamp 1 level (VNIR); relevant to open-loop operation only	Digital Status	4	Integer; 0 - 4095	1,5
131	VNIR_HEATER	VNIR heater	Digital Status	1	0 = Off 1 = On	1,5
132	VNIR_SOURCE	VNIR data source, either actual detector or a test pattern	Digital Status	1	0 = Detector 1 - 7 = Test pattern	1,5
133	VNIR_SHUT_LED	Shutter fiducial LED power (VNIR)	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
134	VNIR_SPHERE_PWR	Sphere lamp 2 power (VNIR)	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
135	VNIR_FLOOD1_PWR	VNIR flood lamp 1 power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
136	VNIR_FLOOD2_PWR	VNIR flood lamp 2 power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
137	VNIR_LVDS_1	VNIR LVDS driver #1 enable	Digital Status	1	Integer; 0 = Disable, 1 = Enable	1,5
138	VNIR_LVDS_2	VNIR LVDS driver #2 enable	Digital Status	1	Integer; 0 = Disable, 1 = Enable	1,5
139	VNIR_DAC_POWER	VNIR DAC power (for lamps)	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
140	VNIR_DAC_PD	VNIR DAC power down	Digital Status	1	0 = Run 1 = Power down	1,5

Column	Mnemonic	Description	Source of information	Length (bytes)	Format (and range if applicable)	Notes
141	VNIR_ANA_5V_PWR	VNIR analog 5V power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
142	VNIR_ADC_Q1_PWR	VNIR detector quadrant #1 A/D power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
143	VNIR_ADC_Q2_PWR	VNIR detector quadrant #2 A/D power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
144	VNIR_ADC_Q3_PWR	VNIR detector quadrant #3 A/D power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
145	VNIR_ADC_Q4_PWR	VNIR detector quadrant #4 A/D power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
146	VNIR_CHARGE_PUMP	VNIR detector charge pump power	Digital Status	1	Integer; 0 = off; 1 = 500 kHz; 2 = 250 kHz; 3 = 125 kHz (default)	1,5
147	VNIR_BIAS_PWR	VNIR detector bias power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
148	VNIR_AMP_HI_PWR	VNIR detector amp high power	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
149	VNIR_CLOCK_DRIVE	VNIR detector clock driver	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
150	VNIR_TEMP2_CONV	VNIR detector temperature 2 conversion enable; disabling turns off power to temperature sensor in case of introduced noise in detector	Digital Status	1	Integer; 0 = Disable, 1 = Enable	1,5
151	VNIR_TEMP1_CONV	VNIR detector temperature 1 conversion enable; disabling turns off power to temperature sensor in case of introduced noise in detector	Digital Status	1	Integer; 0 = Disable, 1 = Enable	1,5
152	VNIR_SHUTTER_MOTOR_CURRENT_CONV	Shutter motor current conversion enable (VNIR); disabling turns off power to current sensor in case of introduced noise in detector	Digital Status	1	Integer; 0 = Disable, 1 = Enable	1,5
153	VNIR_MUX_TEMP_CONV	VNIR multiplexed temperature conversion enable; disabling turns off power to temperature sensor in case of introduced noise in detector	Digital Status	1	Integer; 0 = Disable, 1 = Enable	1,5
154	VNIR_SHUT_ENB	Shutter motor phase enabled (VNIR)	Digital Status	1	Integer; 0 - 3	1,5
155	VNIR_SHUT_PHASE	Shutter motor phase (VNIR)	Digital Status	1	Integer; 0 - 3	1,5
156	VNIR_DAC_STATE	VNIR DAC power state	Digital Status	1	Integer; 0 = Off, 1 = On	1,5
157	VNIR_SHUTTER_FID	Shutter fiducial LED (VNIR)	Digital Status	1	Integer; 0 = Off, 1 = On (fiduciated)	1,5
158	VNIR_ADC_Q1_STATE	VNIR detector quadrant #1 A/D latch-up	Digital Status	1	Integer; 0 = Ok, 1 = Latched	1,5

Column	Mnemonic	Description	Source of information	Length (bytes)	Format (and range if applicable)	Notes
159	VNIR_ADC_Q2_STATE	VNIR detector quadrant #2 A/D latch-up	Digital Status	1	Integer; 0 = Ok, 1 = Latched	1,5
160	VNIR_ADC_Q3_STATE	VNIR detector quadrant #3 A/D latch-up	Digital Status	1	Integer; 0 = Ok, 1 = Latched	1,5
161	VNIR_ADC_Q4_STATE	VNIR detector quadrant #4 A/D latch-up	Digital Status	1	Integer; 0 = Ok, 1 = Latched	1,5
162	STATUS_INT	Status interval (seconds); interval at which analog digital and software status are reported in status packets to low-speed telemetry	Software Status	5	Integer; 1 – 65535 (0 = Off)	1,6
163	MACRO_BLOCKS	Number of macro blocks free	Software Status	5	Integer	1,6
164	TLM_VOLUME	Telemetry volume produced (KB) on the low speed engineering channel since the last CRM_STAT_CLR command	Software Status	5	Integer	1,6
165	WATCH_ADDR	Memory watch address	Software Status	5	Integer	1,6
166	WATCH_MEM_ID	Memory watch id (page no.)	Software Status	3	Integer	1,6
167	WATCH_DATA	Watched memory	Software Status	5	Integer	1,6
168	SW_VERSION	Software version number	Software Status	3	Integer	1,6
169	ALARM_ID	Latest alarm Id	Software Status	3	Integer; see Table 3-5	1,6
170	ALARM_TYPE	Latest alarm type	Software Status	1	Integer; 0 = Persistent, 1 = Transient	1,6
171	ALARM_COUNT	Count of alarms since the last CRM_STAT_CLR command	Software Status	3	Integer	1,6
172	CMD_EXEC	Commands executed since the last CRM_STAT_CLR command	Software Status	3	Integer	1,6
173	CMD_REJECT	Commands rejected since the last CRM_STAT_CLR command	Software Status	3	Integer	1,6
174	MAC_CMD_EXEC	Macro commands executed since the last CRM_STAT_CLR command	Software Status	3	Integer	1,6
175	MAC_CMD_REJECT	Macro commands rejected since the last CRM_STAT_CLR command	Software Status	3	Integer	1,6
176	MAC_ID	ID of most recent macro executed	Software Status	3	Integer	1,6

Column	Mnemonic	Description	Source of information	Length (bytes)	Format (and range if applicable)	Notes
177	MACRO_LEARN	Macro learn mode; in learn mode commands are appended to a macro being loaded to memory; when not in learn mode commands are executed	Software Status	1	Integer; 0 = Not learning, 1 = Learning	1,6
178	MONITOR_RESPONSE	Monitor response enabling; if enabled a persistent out-of-limits condition will cause an onboard safing macro to be executed; 0 = disabled; 1 = enabled	Software Status	1	Integer; 0 = Disable, 1 = Enable	1,6
179	MEM_WRITE	Memory write enable; required to upload data structures with commandable monitor limits or pixel processing value	Software Status	1	Integer; 0 = Disable, 1 = Enable	1,6
180	IR_SPECTRA	Last value for number of IR spectra to collect	Software Status	5	Integer; 0 – 65534 Remaining; 65535: Forever	1,6
181	VNIR_SPECTRA	Last value for number of VNIR spectra to collect	Software Status	5	Integer; 0 – 65534 Remaining; 65535: Forever	1,6
182	COOL_1_SETPOINT	Cooler 1 temperature goal; value corresponds to temperature goal for COOLER_TEMP1	Software Status	5	Integer	1,6
183	COOL_2_SETPOINT	Cooler 2 temperature goal; value corresponds to temperature goal for COOLER_TEMP2	Software Status	5	Integer	1,6
184	COOL_3_SETPOINT	Cooler 3 temperature goal; value corresponds to temperature goal for COOLER_TEMP3	Software Status	5	Integer	1,6
185	VNIR_HEATER_GOAL	VNIR heater temperature goal; value corresponds to temperature goal for VNIR_DETECTOR_TEMP1	Software Status	5	Integer	1,6
186	HEATER_1_GOAL	Heater 1 (on gimbal electronics housing) goal; value corresponds to temperature goal for OSU_CAVITY_TEMP_VNIR	Software Status	5	Integer	1,6
187	HEATER_2_GOAL	Heater 2 (on gimbal electronics housing) goal; value corresponds to temperature goal for OSU_CAVITY_TEMP_VNIR	Software Status	5	Integer	1,6

Column	Mnemonic	Description	Source of information	Length (bytes)	Format (and range if applicable)	Notes
188	HEATER_3_GOAL	Heater 3 (on cooler radiator) goal; value corresponds to temperature goal for OSU_CAVITY_TEMP_IR	Software Status	5	Integer	1,6
189	HEATER_4_GOAL	Heater 4 (on spectrometer housing) goal; value corresponds to temperature goal for SPECT_CAVITY_TEMP_IR	Software Status	5	Integer	1,6
190	HEATER_1_HYSTERESIS	Heater 1 (on gimbal electronics housing) hysteresis	Software Status	3	Integer	1,6
191	HEATER_2_HYSTERESIS	Heater 2 (on gimbal electronics housing) hysteresis	Software Status	3	Integer	1,6
192	HEATER_3_HYSTERESIS	Heater 3 (on cooler radiator) hysteresis	Software Status	3	Integer	1,6
193	HEATER_4_HYSTERESIS	Heater 4 (on spectrometer housing) hysteresis	Software Status	3	Integer	1,6
194	VNIR_HEATER_HYSTERESIS	VNIR heater hysteresis	Software Status	3	Integer	1,6
195	TARGET_ID	Target Id	Software Status	10	Integer	1,6
196	TARGET_TIME	Time of target closest approach (whole second component); same scale as EXPOSURE_MET	Software Status	10	Integer	1,6
197	TARGET_SUBSECONDS	Time of target fractional second ( $1/2^{16}$ seconds)	Software Status	5	Integer	1,6
198	PROFILE_ID	Profile Id	Software Status	5	Integer; 0 - 1819	1,6
199	SCAN_STATUS_WORD	Scan motor status word	Software Status	16	Character; see Table 3-3	1,6
200	SCAN_CONTROL_WORD	Scan motor control word	Software Status	16	Character; see Table 3-4	1,6
201	SLEW_ANGLE	Gimbal angle ( $\mu$ radians)	Software Status	11	Integer	1,6
202	OFFSET_ANGLE	Target for offset angle from gimbal profile defined in PROFILE_ID ( $\mu$ radians)	Software Status	11	Integer	1,6
203	OFFSET_RATE	Target for offset rate from gimbal profile defined in PROFILE_ID ( $\mu$ radians/s)	Software Status	11	Integer	1,6
204	GOAL_ANGLE	Gimbal goal angle from gimbal profile defined in PROFILE_ID ( $\mu$ radians)	Software Status	11	Integer	1,6
205	VNIR_HTR_MODE	VNIR heater control mode	Software Status	1	Integer; 0 = Off, 1 = On, 2 = Software control	1,6
206	OBSERVE	Observation state	Software Status	1	Integer; 0 = Idle, 1 = Observing	1,6

Column	Mnemonic	Description	Source of information	Length (bytes)	Format (and range if applicable)	Notes
207	OFFSET_ADJUST	Scan offset adjustment	Software Status	1	Integer; 0 = Disable, 1 = Enable	1,6
208	HTR_1_MODE	Heater 1 (on gimbal electronics housing) control mode	Software Status	1	Integer; 0 = Off; 1 = On; 2 = Software control	1,6
209	HTR_2_MODE	Heater 2 (on gimbal electronics housing) control mode	Software Status	1	Integer; 0 = Off; 1 = On; 2 = Software control	1,6
210	HTR_3_MODE	Heater 3 (on cooler radiator) control mode	Software Status	1	Integer; 0 = Off; 1 = On; 2 = Software control	1,6
211	HTR_4_MODE	Heater 4 (on spectrometer housing) control mode	Software Status	1	Integer; 0 = Off; 1 = On; 2 = Software control	1,6
212	COVER_MODE	Cover deployment mode	Software Status	1	Integer; 0 = Disable deployment; 1 = Enable deployment	1,6
213	SCAN_MODE	Scan platform control mode	Software Status	1	Integer; 0 = off; 1 = holding; the gimbal is held at the current position; 2 = slewing; the gimbal is moved to a commanded angle; 3 = following a profile; the gimbal follows a computed and uploaded profile; 4 = home; the gimbal searches for its index fiducial	1,6
214	OBS_MAC_ID	Id of most recent observation macro executed	Software Status	3	Integer	1,6
215	SHUTTER_POS	Shutter position from 0 to 32	Software Status	2	Integer; 0 - 32; nominal open is 3; viewing sphere is 17; closed is 32	1,6
216	SHUTTER_DRIVE	Shutter drive selection; VNIR channel for nominal use; IR is backup; both together is contingency for stuck shutter;	Software Status	1	Integer; 0 = IR side; 1 = VNIR side; 2 = both sides	1,6
217	SCAN_LOG_ENB	Scan platform logging enabling; with this enabled requests for spectra return high-rate scan diagnostic data	Software Status	1	Integer; 0 = Disable, 1 = Enable	1,6
218	IR_TEMP_MONITOR	IR temperature monitor enable/disable	Software Status	1	Integer; 0 = Off, 1 = On	1,6
219	IR_EXPOSE	IR exposure time parameter; number of 1/480ths of inverse frame rate	Software Status	3	Integer; 0 - 480	1,6

Column	Mnemonic	Description	Source of information	Length (bytes)	Format (and range if applicable)	Notes
220	IR_RATE	IR frame acquisition rate	Software Status	1	Integer; 0 = 1 Hz; 1 = 3.75 Hz; 2 = 5 Hz; 3 = 15 Hz; 4 = 30 Hz	1,6
221	VNIR_TEMP_MONITOR	VNIR temperature monitor enable/disable	Software Status	1	Integer; 0 = Off, 1 = On	1,6
222	VNIR_EXPOSE	VNIR exposure time parameter; number of 1/480ths of inverse frame rate	Software Status	3	Integer; 0 - 480	1,6
223	VNIR_RATE	VNIR frame acquisition rate	Software Status	1	Integer; 0 = 1 Hz; 1 = 3.75 Hz; 2 = 5 Hz; 3 = 15 Hz; 4 = 30 Hz	1,6
224	IR_FILTER	IR wavelength filter table; which onboard table is used to define which detector rows are recorded	Software Status	1	Integer; 0 - 3	1,6
225	IR_BINNING	IR pixel binning mode	Software Status	1	Integer; 0 = 1:1, 1 = 2:1, 2 = 5:1, 3 = 10:1	1,6
226	IR_LOSSY	IR lossy compression enabled or disabled; 12 to 8 bit look-up table commanded line by line in uploaded data structure	Software Status	1	Integer; 0 = Disable, 1 = Enable	1,6
227	IR_FAST	Enable/disable IR Fast compression	Software Status	1	Integer; 0 = Disable, 1 = Enable	1,6
228	VNIR_FILTER	VNIR wavelength filter table; which onboard table is used to define which detector rows are recorded	Software Status	1	Integer; 0 - 3	1,6
229	VNIR_BINNING	VNIR pixel binning mode	Software Status	1	Integer; 0 = 1:1, 1 = 2:1, 2 = 5:1, 3 = 10:1	1,6
230	VNIR_LOSSY	VNIR lossy compression enabled or disabled; 12 to 8 bit look-up table commanded line by line in uploaded data structure	Software Status	1	Integer; 0 = Disable, 1 = Enable	1,6
231	VNIR_FAST	Enable/disable Fast compression	Software Status	1	Integer; 0 = Disable, 1 = Enable	1,6
232	IR_PIXEL_PROC_CHECKSUM	IR pixel processing table CRC-CCITT checksum; the data structure containing gains offsets and which LUT to use is 480 rows and 3 columns; this is the least significant end of the sum and serves as a fingerprint	Software Status	5	Integer	1,6

Column	Mnemonic	Description	Source of information	Length (bytes)	Format (and range if applicable)	Notes
233	VNIR_PIXEL_PROC_CHECKSUM	VNIR pixel processing table CRC-CCITT checksum; the data structure containing gains offsets and which LUT to use is 480 rows and 3 columns; this is the least significant end of the sum and serves as a fingerprint	Software Status	5	Integer	1,6

Notes:

(1) Source of information describes whether information is a value-added field or part of original instrument housekeeping, and if so, the type of housekeeping represented.

(2) The added parameters represent values calculated in post-processing that are useful to describe frame-dependent data quality, or approximate geometric, lighting, and atmospheric conditions at the time of the observation that are relevant to post-processing corrections.

(3) The spectrometer image header describes the instrument configuration relevant to an individual frame of data such as exposure time, frame rate, data editing and compression, etc.

(4) Analog status represents reading of voltage, current and temperature of different components of the CRISM instrument. Monitors are run by different electronics boards in the instrument. The nomenclature is as follows. DPU\_PWR\_0 represents the 0th status item monitored by the DPU power board, DPU\_PWR\_1 the 1st, etc. IR\_PWR is the IR power board in the DPU. VNIR\_PWR is the VNIR power board in the DPU. COOL\_PWR is the cooler power board in the DPU. IR\_FP is the IR focal plane electronics board in the base of the OSU. VNIR\_FP is the VNIR focal plane electronics board in the base of the OSU.

(5) Digital status represents on/off settings of the instrument, levels of coolers or calibration lamps, or the source of data reported from each focal plane. The source may be measured data from the detector, or one of several tests patterns stored in the focal plane electronics (for diagnostic purposes).

(6) Software status represents the status of RAM memory, the frequency of housekeeping reporting, the history of commanding, the history of reporting of alarms, commanded setting of coolers and heaters, and the commanded configuration of the instrument (as opposed to the actual configuration reported in the spectrometer image header).

**Table 3-3. Bit mapping of scan motor status word**

Name	Length (bits)	Value	Description
Direction	1	0 = Down 1 = Up	Platform direction
Index Latch	1	0 = No index 1 = Index seen	Latched (i.e. sticky) index pulse
Limit 2	1	0 = No limit 1 = Limit seen	Latched (i.e. sticky) limit switch #2
Limit 1	1	0 = No limit 1 = Limit seen	Latched (i.e. sticky) limit switch #1
Inphase	1	0 – 1	Raw inphase signal
Quadrature	1	0 – 1	Raw quadrature signal
Index	1	0 = No index 1 = Index	Raw index signal
Hall Sensor	3	0 – 7	Hall sensors
Encoder	22	Signed integer	Encoded scan platform position

**Table 3-4. Bit mapping of scan motor control word**

Name	Length (bits)	Value	Description
Enable Counter	1	0 = Disable 1 = Enable	Enable/disable encoder position counter
Reset Counter	1	0 = No operation 1 = Reset	Reset (i.e. zero) encoder position counter
Reset Index	1	0 = No operation 1 = Reset	Reset index latch
Motor Drive	1	0 = Disable 1 = Enable	Enable/disable motor drive
Test Clock	1	0 = Disable 1 = Enable	Enable/disable sending external clock (for ground testing)
Index Arm	1	0 = No operation 1 = Index	Arm index latch
Hall Latch	1	0 = No operation 1 = Latch	Latch Hall inputs
Hall Control	1	0 = Automatic 1 = Computer	Enable/disable computer control of Hall outputs
Fine Mode	1	0 = Coarse 1 = Fine	Coarse or fine control of motor drive DAC
Reset Limits	1	0 = No operation 1 = Reset	Reset limit latches
Hall Outputs	3	0 – 7	Hall outputs
Drive	12	Signed integer	Motor drive DAC

**Table 3-5. Alarms coded in housekeeping**

ID	Description	Information
0	<i>Unused</i>	
1	Bad packet	0
2	Out of macro contexts	Macro Id
3 ... 15	<i>Reserved</i>	
16	Invalid target id	
17	Scan platform loss of control	
18 ... 127	<i>Reserved</i>	
128 ... 169	Monitored value is too low; see Table 3-6	Value and limit
170 ... 191	<i>Reserved</i>	
192 ... 233	Monitored value is too high; see Table 3-6	Value and limit
234 ... 255	<i>Reserved</i>	

**Table 3-6. Alarms for monitored housekeeping and responses to out-of-limits conditions**

Source	Alarm Ids Low / High		Autonomy Macro Executed	
			Value too Low	Value too High
DPU power board temperature	128	192		
DPU +5 voltage	129	193		
DPU +5 current	130	194		
Scan motor current 1 & 2	131	195		10
IR power board temperature	132	196		5
IR FPU +12 voltage	133	197		
IR FPU +7 voltage	134	198		
IR FPU current	135	199		5
Heater 3 & 4 current	136	200		12
VNIR power board temperature	137	201		4
VNIR FPU +12 voltage	138	202		
VNIR FPU +7 voltage	139	203		
VNIR FPU current	140	204		4
Heater 1 & 2 current	141	205		11
Cooler power board temperature	142	206		8
Cooler +15 voltage	143	207		
Cooler current	144	208		8
HOP heater 1 & 2 current	145	209		13
Shutter motor current (IR)	146	210		7
IR detector temperature 1	147	211	8	
IR detector temperature 2	148	212	8	
Cooler temperature 1	149	213		8
Cooler temperature 2	150	214		8
Cooler temperature 3	151	215		8
Shutter motor temperature (IR)	152	216		
Integrating sphere temperature (IR)	153	217		
Telescope spider temperature (IR)	154	218		
Spectral cavity temperature (IR)	155	219		
OSU cavity temperature (IR)	156	220		
Sphere lamp current (IR)	157	221		14
IR FPU board temperature	158	222		5
HOP temperature (IR)	159	223		13
Shutter motor current (VNIR)	160	224		6
VNIR detector temperature 1	161	225		15
VNIR detector temperature 2	162	226		15
Telescope temperature	163	227		
Optical bench temperature	164	228		
Telescope spider temp. (VNIR)	165	229		
Spectral cavity temperature (VNIR)	166	230		
OSU cavity temperature (VNIR)	167	231		
VNIR FPU board temperature	168	232		4
Baffle temperature	169	233		

### 3.1.2 Label Description

Each CRISM EDR is described by a PDS label stored in a separate text file with an extension ".LBL". A PDS label is object-oriented and describes objects in the data file. The PDS label contains keywords for product identification, along with descriptive information needed to interpret or process the data objects in the file.

PDS labels are written in Object Description Language (ODL) [5]. PDS label statements have the form of "keyword = value". Each label statement is terminated with a carriage return character (ASCII 13) and a line feed character (ASCII 10) sequence to allow the label to be read by many operating systems. Pointer statements with the following format are used to indicate the location of data objects:

^object = location

where the carat character (^, also called a pointer) is followed by the name of the specific data object. The location is the name of the file that contains the data object.

The CRISM EDR label is a combined-detached label (see reference 5) that describes both the image and table files that make up a CRISM EDR. An example EDR label is in Appendix A.

EDR label keywords with CRISM-specific values are listed in Table 3-7.

**Table 3-7. CRISM-specific values for EDR label keywords**

Keyword	Valid Values
PRODUCT_TYPE	EDR TARGETED_RDR DDR MAP_PROJECTED_MULTISPECTRAL_RDR MAP_PROJECTED_TARGETED_RDR CDR ADR
OBSERVATION_TYPE	FRT (Full Resolution Targeted Observation) HRL (Half Resolution Long Targeted Observation) HRS (Half Resolution Short Targeted Observation) EPF (Atmospheric Survey EPF) TOD (Tracking Optical Depth Observation) MSS (Multispectral Survey, lossy compressed) MSP (Multispectral Survey, losslessly compressed) MSW (Multispectral Window) FFC (Flat-field calibration) CAL (Radiometric Calibration) ICL (Calibration source intercalibration) STO (Star Observation) FUN (Functional test) OTB (Practice observation taken on orbiter test bed with engineering model DPU) UNK (no valid EDRs within observation that indicate class type)
OBSERVATION_ID	8-byte hexadecimal integer
MRO:OBSERVATION_NUMBER	Counter from product ID, hexadecimal

Keyword	Valid Values
MRO:ACTIVITY_ID	Type of measurement and macro ID ### used to execute it, i.e.: BI### – Bias measurement DF### – Dark field measurement LP### – Lamp measurement SP### – Sphere measurement SC### – Scene measurement T1### – Focal plane electronics test pattern 1 T2### – Focal plane electronics test pattern 1 T3### – Focal plane electronics test pattern 1 T4### – Focal plane electronics test pattern 1 T5### – Focal plane electronics test pattern 1 T6### – Focal plane electronics test pattern 1 T7### – Focal plane electronics test pattern 1 UN### – Instrument configuration does not match macro library
MRO:FRAME_RATE	"1", "3.75", "5", "15", or "30"
MRO:SENSOR_ID	"S" for VNIR, "L" for IR, or "J" for joint
SHUTTER_MODE_ID	"OPEN", "SPHERE", OR "CLOSED"
LIGHT_SOURCE_NAME	"NONE", "VNIR LAMP 1", "VNIR LAMP 2", "IR LAMP 1", "IR LAMP 1", "SPHERE LAMP 1", "SPHERE LAMP 2"
MRO:CALIBRATION_LAMP_STATUS	"OFF", "OPEN LOOP" or "CLOSED LOOP" (for integrating sphere only)
MRO:CALIBRATION_LAMP_LEVEL	Value between 0 and 4095
PIXEL_AVERAGING_WIDTH	1, 2, 5, or 10
COMPRESSION_TYPE	NONE, or 8_BIT
MRO:INSTRUMENT_POINTING_MODE	"DYNAMIC POINTING" if SCAN_MODE (housekeeping file column 213) equals 3 ; else "FIXED POINTING"
SCAN_MODE_ID	(If DYNAMIC POINTING): "SHORT" (for full-resolution or half-resolution short central swath), "LONG" (for half-resolution long central swath), or "EPF" (for EPF even if part of a different class of observation)
SAMPLING_MODE_ID	"HYPERSPETRICAL" if wavelength filter used returns contiguous rows or "MULTISPECTRAL" if not
MRO:EXPOSURE_PARAMETER	The value supplied to the CRISM instrument to command the exposure time. At a given frame rate identified in MRO:FRAME_RATE, there are 480 possible exposure times ranging form 1 to 480.
MRO:WAVELENGTH_FILTER	Which of four onboard menus of rows was selected for downlink. The four choices are 0, 1, 2, or 3.

Keyword	Valid Values
MRO:WAVELENGTH_FILE_NAME	For an EDR, the wavelength file is a 5-column, 480-row text file. The five elements in each row are the row number and a 0 or 1 for each of MRO:WAVELENGTH_FILTER 0, 1, 2 and 3, indicating whether data from that row of the detector is included in the EDR when that option is selected in MRO:WAVELENGTH_FILTER. For a TRDR, the wavelength file is an image whose value at the location of a detector element is the center wavelength of that element, in nanometers.
MRO:PIXEL_PROC_FILE_NAME	For an EDR, the name of the ASCII file giving gain and offset to convert from 14 to 12 bits, and LUT used if lossy 12 to 8 bit compression is enabled (3 columns specified on a line-by-line basis)
MRO:LOOKUP_TABLE_FILE_NAME	For an EDR, the name of the ASCII file giving the 8-bit outputs from 12-bit inputs for each of the 8 onboard LUTs (8 columns specified for each 12-bit value 0-4095)

## 3.2 DDR

### 3.2.1 Data Product Structure and Organization

The DDR (Figure 3-8) consists of supporting data needed for the full processing described above, projected into the format of a TRDR. There is a one-for-one spatial correspondence of each spatial pixel in a TRDR to each pixel in the DDR. The DDR for an observation is stored separately from the EDR and TRDR to minimize and streamline data product processing and updating. The EDR does not require highly accurate pointing information to construct, which the DDR does. Thus the EDR can be assembled promptly by having it decoupled from the DDR. A change in instrument calibration - not knowledge of its pointing - would require an update of the contents of the radiance portion of a TRDR but not the contents of the DDR. Thus having the DDR decoupled from the TRDR minimizes the amount of reprocessing necessary when knowledge of instrument radiometric characteristics changes.

The DDR contains one multiple-band image. The size of the multiple-band image varies according to the observation mode but is deterministic given the macro ID. A typical multiple-band image might have XX pixels in the sample (cross-track) dimension, YY pixels in the line (along-track) dimension, and ZZ pixels in the wavelength dimension, where:

- XX=640/binning, where 640 is the number of columns read off the detector, and binning is 1, 2, 5, or 10
- YY=the number of frames of data taken by the macro, and
- ZZ=the number layers in the DDR.

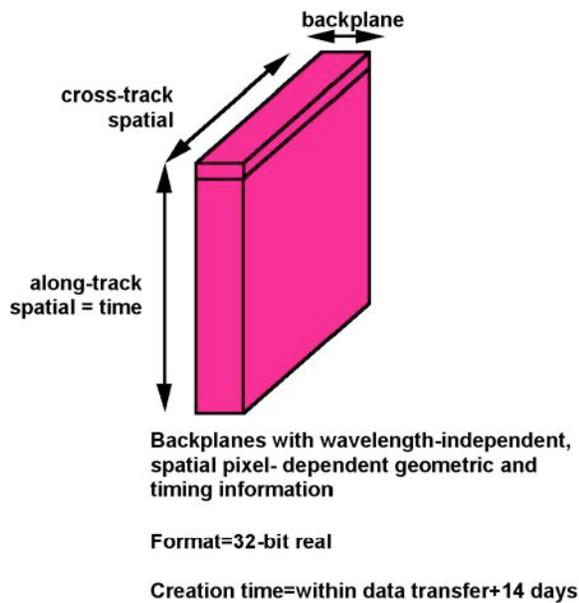
Due to optical distortions present in the EDRs and non-resampled TRDRs, not all wavelengths represent exactly the same spatial location. Therefore the spatial location for a DDR represent those of the VNIR band closest to 610 nm and the IR band closest to 2300 nm. There are separate DDRs for VNIR and IR data.

There are 14 layers in the DDR, all represented as 32-bit real numbers. The files are created at approximately 14 days after transfer of target ID files, when sufficiently accurate pointing information is available.

- Solar incidence angle relative to areoid, at same planetary radius as surface projection of pixel, units degrees
- Emission angle relative to areoid, at same planetary radius as surface projection of pixel, units degrees
- Solar phase angle, units degrees
- Areocentric latitude, units degrees N
- Areocentric longitude, units degrees E
- Solar incidence angle relative to planetary surface as estimated using MOLA shape model, units degrees
- Emission angle relative to planetary surface as estimated using MOLA shape model, units degrees
- Slope magnitude, using MOLA shape model and reference ellipsoid, units degrees
- Slope azimuth, using MOLA shape model and reference ellipsoid, units degrees clockwise from N
- Elevation relative to MOLA datum, units meters
- TES thermal inertia, units  $J m^{-2} K^{-1} s^{-0.5}$
- TES bolometric albedo
- Local solar time, hours
- Spare

Once image data are assembled into EDRs and calibrated into TRDRs, DDRs are created for the data. A version 0 DDR represents values based on predicted pointing, and is generated to provide quick-look information. Version 1 and subsequent versions of a DDR are based on actual, reconstructed pointing.

**DDR = accompanies 1 shutter-open macro**  
**1 DDR from each focal plane**  
(label points to following files)



**Figure 3-8. Contents of a CRISM  
Derived Data Record (DDR).**

### **3.2.2 Label Description**

See section 2.3.4 for general information on CRISM product labels. A DDR label is detached and points to the single multiband image in the DDR. An example DDR label is in Appendix B.

DDR label keywords with CRISM-specific values are listed in Table 3-9.

**Table 3-9. CRISM-specific values for DDR label keywords**

Keyword	Valid Values
PRODUCT_TYPE	EDR TARGETED_RDR DDR MAP_PROJECTED_MULTISPECTRAL_RDR MAP_PROJECTED_TARGETED_RDR CDR ADR
OBSERVATION_TYPE	FRT (Full Resolution Targeted Observation) HRL (Half Resolution Long Targeted Observation) HRS (Half Resolution Short Targeted Observation) EPF (Atmospheric Survey EPF) TOD (Tracking Optical Depth Observation) MSS (Multispectral Survey, lossy compressed) MSP (Multispectral Survey, losslessly compressed) MSW (Multispectral Window) FFC (Flat-field calibration) (DDR is created only for an EDR of a Mars scene)
OBSERVATION_ID	8-byte hexadecimal integer
MRO:OBSERVATION_NUMBER	Counter from product ID, hexadecimal
MRO:ACTIVITY_ID	Only valid value is: SC### – Scene measurement
MRO:FRAME_RATE	"1", "3.75", "5", "15", or "30"
MRO:SENSOR_ID	"S" for VNIR, "L" for IR, or "J" for joint
SHUTTER_MODE_ID	"OPEN", "SPHERE", OR "CLOSED"
PIXEL_AVERAGING_WIDTH	1, 2, 5, or 10
MRO:INSTRUMENT_POINTING_MODE	"DYNAMIC POINTING" if SCAN_MODE (housekeeping file column 213) equals 3 ; else "FIXED POINTING"
SCAN_MODE_ID	(If DYNAMIC POINTING): "SHORT" (for full-resolution or half-resolution short central swath), "LONG" (for half-resolution long central swath), or "EPF" (for EPF even if part of a different class of observation)
BAND_NAME	Brief descriptive name of each layer of data in DDR

### 3.3 Targeted RDR

#### 3.3.1 Data Product Structure and Organization

The TRDR consists of the output of one of the constituent macros associated with a target ID that contains scene data (Mars or other), as shown in Figure 3-10. Not all EDRs are processed to TRDR level; macros containing bias, background, sphere, or calibration lamp data are processed instead to CDRs. Only scene EDRs are processed to the TRDR level.

The TRDR contains one or more multiple-band images (suffix \*.IMG). One matches the dimensions of the multiple-band image of raw DN in an EDR, except that the data are in units of

radiance. The size of the multiple-band image varies according to the observation mode but is deterministic given the ID of the command macro used to acquire the data. Appended to the multiple-band image is a binary table of the detector rows that were used, as selected by the wavelength filter. This is a one-column table, with each row containing one detector row number expressed as a 16-bit unsigned integer values, most significant bit first.

Other multiple-band images may contain I/F, Lambert albedo, or derived summary products (Table 3-11). The Lambert albedo image, if present, parallels the structure of the I/F image. The summary products image has the same spatial dimensions, but a different dimension in the spectral direction and it lacks that table of row numbers.

The size of the multiple-band image varies according to the observation mode but is deterministic given the macro ID. A typical multiple-band image might have XX pixels in the sample (cross-track) dimension, YY pixels in the line (along-track) dimension, and ZZ pixels in the wavelength dimension, where:

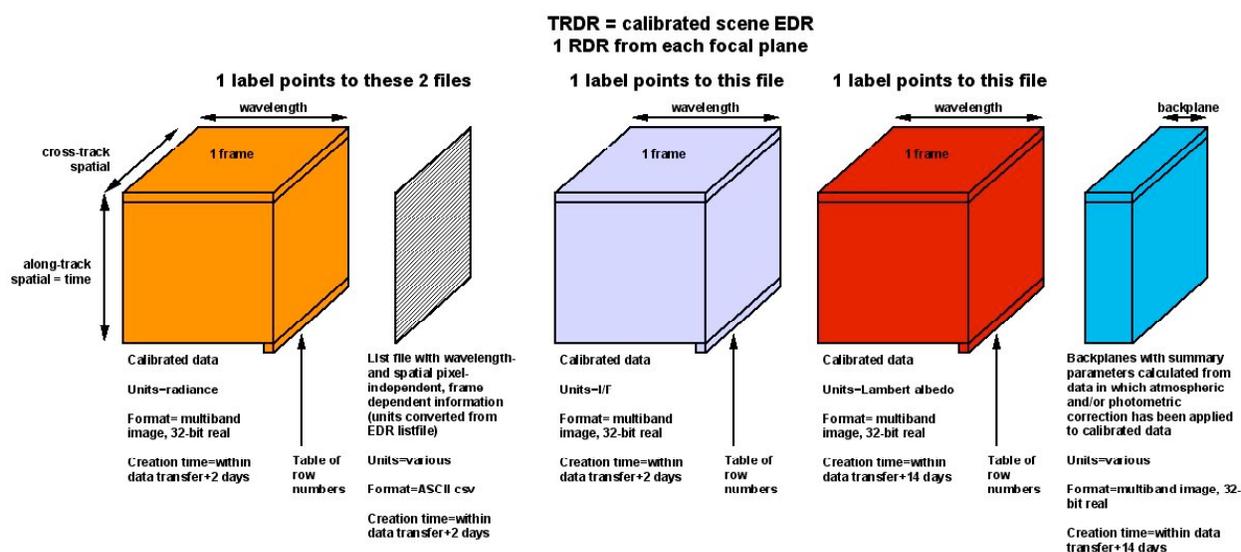
- $XX=640/\text{binning}$ , where binning is 1, 2, 5, or 10, and dark is the number of masked and scattered light pixels
- $YY$ =the number of frames of data taken by the macro, and
- $ZZ$ =the number of rows (wavelengths) that are retained by the instrument.

The procedure for deriving this multiple-band image from an EDR is discussed in detail in Appendix M.

The data in a TRDR do not have optical distortions removed. In one column, the projection onto Mars' surface may vary by as much as  $\pm 0.4$  not-binned detector elements in the XX dimension depending on position in the FOV (distortions are worst at the edges of the VNIR and IR FOVs). For a single wavelength, its location in the ZZ direction may vary by as much as  $\pm 1$  not-binned detector elements depending on wavelength and position in the XX direction (distortions are worst at the short- and long-wavelength ends of the IR detector).

To correct for optical distortions, multiband images may be resampled in the spectral or spatial direction. Three types of resampling may have occurred: (a) resampling in the wavelength direction occurs using nearest-neighbor resampling, as coded in the PS CDR; (b) resampling in the spatial direction, to remove differences in spatial scale with wavelength or band, is done with bicubic interpolation using the CM CDR; and (c) VNIR data may be rescaled to match the slightly different magnification of the IR spectrometer, also using bicubic interpolation and the CM CDR. A resampled TRDR is distinguished by its label and file name. The label uses local data dictionary keywords to document the type of resampling that has occurred. In the file name, "RTR" for resampled TRDR replaces "TRR."

Components of the TRDR are generated at a different time. The list file can be created nearly as soon as data are received at the SOC; once the approximate spacecraft pointing information, gimbal position, and tables to convert telemetry from digital to physical units are available. The radiance or I/F multiple-band image requires bracketing sphere observations to process and so it might be delayed one day. Construction of the summary product or Lambert albedo multiband images requires coregistered TES and MOLA derived data products and thus accurate, reconstructed spacecraft pointing for the data sets. That information will not be available for up to two weeks.



**Figure 3-10. Contents of a CRISM Reduced Data Record for a single observation (TRDR).**

**Table 3-11. Formulation of parameters for summary products**

	NAME	PARAMETER	FORMULATION	RATIONALE	INPUT DATA
SURFACE COMPOSITION PARAMETERS					
1	R770	0.77 micron reflectance	R770	Rock/dust	Lambert albedo
2	RBR	Red/blue ratio	R770/R440	Rock/dust	Lambert albedo
3	BD530	0.53 micron band depth	$1 - (R530 / (a * R709 + b * R440))$	Crystalline ferric minerals	Lambert albedo
4	SH600	0.6 micron shoulder height	$R600 / (a * R530 + b * R709)$	Select ferric minerals	Lambert albedo
5	BD640	0.64 micron band depth	$1 - (R648 / (a * R600 + b * R709))$	Select ferric minerals (esp. maghemite)	Lambert albedo
6	BD860	0.86 micron band depth	$1 - (R860 / (a * R800 + b * R984))$	Select ferric minerals (esp. hematite)	Lambert albedo
7	BD920	0.92 $\mu$ m band depth	$1 - (R920 / (a * R800 + b * R984))$	Fe mineralogy	Lambert albedo
8	RPEAK1 *	Reflectance peak 1	wavelength where 1st derivative=0 of 5th order polynomial fit to R600, R648, R680, R710, R740, R770, R800, R830	Fe mineralogy	Lambert albedo
9	BDI1000VIS	1 micron integrated band depth; VNIR wavelengths	divide R830, R860, R890, R915 by RPEAK1 then integrate over (1 - normalized radiances) to get integrated band depth	Fe mineralogy	Lambert albedo
10	BDI1000IR	1 micron integrated band depth; IR wavelengths	divide R1030, R1050, R1080, R1150 by linear fit from peak R (of the 15) between 1.3-1.87 $\mu$ m to R2530 extrapolated backwards, then integrate over (1 - normalized radiances) to get integrated band depth	Fe mineralogy; corrected for overlying aerosol induced slope	Lambert albedo
11	IRA	IR albedo	R1330	IR albedo	Lambert albedo

	NAME	PARAMETER	FORMULATION	RATIONALE	INPUT DATA
12	OLINDEX	Olivine index	$(R1695 / (0.1 * R1050 + 0.1 * R1210 + 0.4 * R1330 + 0.4 * R1470)) - 1$	Olivines will be strongly > 0	Lambert albedo
13	LCPINDEX	LCP index	$((R1330 - R1050) / (R1330 + R1050)) * ((R1330 - R1815) / (R1330 + R1815))$	Pyroxene is strongly +; Favors LCP	Lambert albedo
14	HCPINDEX	Pyroxene index	$((R1470 - R1050) / (R1470 + R1050)) * ((R1470 - R2067) / (R1470 + R2067))$	Pyroxene is strongly +; Favors HCP	Lambert albedo
15	VAR	1.0-2.3 micron spectral variance	Fit a line from 1-2.3 microns and find variance of observed values from fit values by summing in quadrature over the # intervening wavelengths	OI & Px will have high values; (to be used w/ OLPXINDEX)	Lambert albedo
16	ISLOPE1	Spectral slope 1	$(R1815 - R2530) / (2530 - R1815)$	ferric coating on dark rock	Lambert albedo
17	BD1435	1.435 micron CO2 ice band depth	$1 - (R1430 / (a * R1370 + b * R1470))$	H2O ice	Lambert albedo
18	BD1500	1.5 micron H2O ice band depth	$1 - ((R1510 + R1558) * 0.5) / (a * R1808 + b * R1367)$	H2O ice	Lambert albedo
19	ICER1	CO2 and H2O ice band depth ratio	$R1510 / R1430$	CO2 H2O ice mixtures; > 1 for more CO2, < 1 for more water	Lambert albedo
20	BD1750	1.7 micron H2O band depth	$1 - (R1750) / (a * R1557 + b * R1815)$	Gypsum	Lambert albedo
21	BD1900	1.9 micron H2O band depth	$1 - ((R1930 + R1985) * 0.5) / (a * R1875 + b * R2067)$	H2O	Lambert albedo
22	BDI2000	2 micron integrated band depth	divide R1660, R1811, R2009, R2141, R2206, R2253, R2292, R2318, R2352, R2391, R2431, R2457 by linear fit from peak R (of 15) between 1.3-1.87µm to R2530, then integrate over (1 - normalized radiances) to get integrated band depth	Fe mineralogy	Lambert albedo
23	BD2100	2.1 micron shifted H2O band depth	$1 - ((R2120 + R2140) * 0.5) / (a * R1930 + b * R2250)$	H2O	Lambert albedo
24	BD2210	2.21 micron Al-OH band depth	$1 - (R2210) / (a * R2140 + b * R2250)$	Al-OH minerals	Lambert albedo
25	BD2290	2.3 micron Mg, Fe-OH band depth / 2.292 micron CO2 ice band depth	$1 - (R2290) / (a * R2250 + b * R2350)$	Mg, Fe-OH minerals; ALSO CO2 ice	Lambert albedo
26	D2300	2.3 micron dropoff	$1 - (R2290 + R2330 + R2330) / (R2140 + R2170 + R2210)$	Hydrated min will be > 1	Lambert albedo
27	SINDEX	Detects convexity at 2.29 µm due to absorptions at 1.9/2.1 µm & 2.4 µm	$1 - (R2100 + R2400) / (2 * R2290)$	Hydrated min (e.g. mono and polyhydrated sulfates) will be > 1	Lambert albedo
28	ICER2	2.7 micron CO2 ice band	$R2530 / R2600$	CO2 vs water ice /soil; CO2 will be >>1, water and soil will be ~1	Lambert albedo
29	BDCARB	Carbonate overtone band depth, or metal-OH band	$1 - (\text{sqrt}(((R2330) / (a * R2230 + b * R2390)) * (R2530 / (c * R2390 + d * R2600))))$	Carbonates or hydroxylated silicate; both overtones need to be present to increase parameter value	Lambert albedo
30	BD3000	3 micron H2O band depth	$1 - (R3000 / (R2530 * (R2530 / R2210)))$	bound H2O (accounts for spectral slope)	Lambert albedo

	NAME	PARAMETER	FORMULATION	RATIONALE	INPUT DATA
31	BD3100	3.1 micron H2O ice band depth	$1 - (R3120 / (a \cdot R3000 + b \cdot R3250))$	H2O ice	Lambert albedo
32	BD3200	3.2 micron CO2 ice band depth	$1 - (R3320 / (a \cdot R3250 + b \cdot R3390))$	CO2 ice	Lambert albedo
33	BD3400	3.4 micron carbonate band depth	$1 - ((a \cdot R3390 + b \cdot R3500) / (c \cdot R3250 + d \cdot R3630))$	carbonates	Lambert albedo
34	CINDEX	3.9 micron carbonate index	$(R3750 + (R3750 - R3630) / (3750 - 3630) \cdot (3950 - 3750)) / R3950 - 1$	carbonates will be > 'bkgrnd' values > 0	Lambert albedo
<b>ATMOSPHERIC PROPERTIES PARAMETERS</b>					
35	R440	0.44 micron reflectance	R440	Clouds/hazes	I/F
36	IRR1	IR ratio 1	R800 / R1020	Aphelion ice clouds (>1) vs. seasonal or dust(< 1)	I/F
37	BD1270O2	1265 nm O2 emission band	$1 - ((a \cdot R1261 + b \cdot R1268) / (c \cdot R1250 + d \cdot R1280))$	O2 emission; inversely correlated with high altitude water; signature of ozone	I/F
38	BD1400H2O	1.4 micron H2O band depth	$1 - ((a \cdot R1370 + b \cdot R1400) / (c \cdot R1330 + d \cdot R1510))$	H2O vapor	I/F
39	BD2000CO2	2 micron CO2 band	$1 - (R2010 / (a \cdot R1815 + b \cdot R2170))$	atmospheric CO2	I/F
40	BD2350	2.35 micron CO band depth	$1 - ((a \cdot R2320 + b \cdot R2330 + c \cdot R2350) / (d \cdot R2290 + e \cdot R2430))$	CO	I/F
41	BD2600	2.6 micron H2O band depth	$1 - (R2600 / (a \cdot R2530 + b \cdot R2630))$	H2O vapor (accounts for spectral slope)	I/F
42	IRR2	IR ratio 2	R2530 / R2210	aphelion ice clouds vs. seasonal or dust	I/F
43	R2700	2.70 micron reflectance	R2694	high aerosols	I/F
44	BD2700	2.70 micron CO2 band depth	$1 - (R2694 / (R2530 \cdot (R2530 / R2350)))$	atmospheric structure (accounts for spectral slope)	I/F
45	IRR3	IR ratio 3	R3500 / R3390	aphelion ice clouds (higher values) vs. seasonal or dust	I/F

### 3.3.2 Label Description

See section 2.3.4 for general information on CRISM product labels. A TRDR contains two labels, both detached. One points to both the multiband radiance image and the housekeeping listfile. A second label points to the multiband summary product image. An example TRDR label is in Appendix C.

TRDR label keywords with CRISM-specific values are listed in Table 3-12.

**Table 3-12. CRISM-specific values for TRDR label keywords**

Keyword	Valid Values
PRODUCT_TYPE	EDR TARGETED_RDR DDR MAP_PROJECTED_MULTISPECTRAL_RDR MAP_PROJECTED_TARGETED_RDR CDR ADR
OBSERVATION_TYPE	FRT (Full Resolution Targeted Observation) HRL (Half Resolution Long Targeted Observation) HRS (Half Resolution Short Targeted Observation) EPF (Atmospheric Survey EPF) TOD (Tracking Optical Depth Observation) MSS (Multispectral Survey, lossy compressed) MSP (Multispectral Survey, losslessly compressed) MSW (Multispectral Window) (TRDRs are only generated for EDRs including a Mars scene)
OBSERVATION_ID	8-byte hexadecimal integer
MRO:OBSERVATION_NUMBER	Counter from product ID, hexadecimal
MRO:ACTIVITY_ID	The only valid value is: SC### – Scene measurement
MRO:FRAME_RATE	"1", "3.75", "5", "15", or "30"
MRO:SENSOR_ID	"S" for VNIR, or "L" for IR
SHUTTER_MODE_ID	The only valid value is "OPEN"
LIGHT_SOURCE_NAME	The only valid value is "NONE"
MRO:CALIBRATION_LAMP_STATUS	The only valid value is "OFF"
MRO:CALIBRATION_LAMP_LEVEL	The only valid value is 0
PIXEL_AVERAGING_WIDTH	1, 2, 5, or 10
MRO:INSTRUMENT_POINTING_MODE	"DYNAMIC POINTING" if SCAN_MODE (housekeeping file column 213) equals 3 ; else "FIXED POINTING"
SCAN_MODE_ID	(If DYNAMIC POINTING): "SHORT" (for full-resolution or half-resolution short central swath), "LONG" (for half-resolution long central swath), or "EPF" (for EPF even if part of a different class of observation)
SAMPLING_MODE_ID	"HYPERSPSPECTRAL" if wavelength filter used returns contiguous rows or "MULTISPECTRAL" if not
MRO:EXPOSURE_PARAMETER	The value supplied to the CRISM instrument to command the exposure time. At a given frame rate identified in MRO:FRAME_RATE, there are 480 possible exposure times ranging from 1 to 480.
MRO:WAVELENGTH_FILTER	Which of four onboard menus of rows was selected for downlink. The four choices are 0, 1, 2, or 3.

Keyword	Valid Values
MRO:WAVELENGTH_FILE_NAME	For an EDR, the wavelength file is a 5-column, 480-row text file. The five elements in each row are the row number and a 0 or 1 for each of MRO:WAVELENGTH_FILTER 0, 1, 2 and 3, indicating whether data from that row of the detector is included in the EDR when that option is selected in MRO:WAVELENGTH_FILTER. For a TRDR, the wavelength file is an image whose value at the location of a detector element is the center wavelength of that element, in nanometers.
MRO:PIXEL_PROC_FILE_NAME	For an EDR, the name of the ASCII file giving gain and offset to convert from 14 to 12 bits, and LUT used if lossy 12 to 8 bit compression is enabled (3 columns specified on a line-by-line basis)
BAND_NAME	Brief descriptive name of each layer of data in the summary product multi-band image
MRO:INVALID_PIXEL_LOCATION	X,Y,Z locations within a TRDR at which data values are invalid because they represent cosmic ray hits
MRO:REPLACED_PIXEL_LOCATION	X,Y,Z locations within a TRDR at which data values were replaced by interpolating from surrounding pixels, because original data values were affected by cosmic ray hits
MRO:ATMO_CORRECTION_FLAG	Whether or not a correction has been performed for photometric and atmospheric effects; "OFF" or "ON"
MRO:PHOTOCLIN_CORRECTION_FLAG	Validity only in the case where the value of keyword MRO:THERMAL_CORRECTION_MODE is PHYSICAL_MODEL;ADR_TE. If MRO:PHOTOCLIN_CORRECTION_FLAG is OFF, then slopes used to calculate temperature come from the companion DDR. If it is ON, then the slopes are calculated using photoclinometry of CRISM data
MRO:THERMAL_CORRECTION_MODE	Whether and what type of thermal correction has been performed to calibrated data. Valid values are "OFF", "CLIMATOLOGY;ADR_CL", "EMPIRICAL_MODEL_FROM_SPECTRUM;ALG_M", "PHYSICAL_MODEL;ADR_TE"
MRO:SPATIAL_SUBSAMPLING_FLAG	If = 1, keystone corrected to 610 or 2300 nm by cubic resampling
MRO:SPATIAL_SUBSAMPLING_FILE	If MRO:SPATIAL_SUBSAMPLING_FLAG=1, name of instrument kernel or "CM" CDR used
MRO:SPATIAL_RESCALING_FLAG	If =1, VNIR rescaled to IR- 2300 nm - by cubic resampling
MRO:SPATIAL_RESCALING_FILE	If MRO:SPATIAL_RESCALING_FLAG=1, names of instrument kernel or "CM" CDR and frames kernel used
MRO:SPECTRAL_RESAMPLING_FLAG	If =1, nearest-neighbor spectral resampling has been performed

Keyword	Valid Values
MRO:SPECTRAL_RESAMPLING_FILE	If MRO:SPECTRAL_RESAMPLING_FLAG=1, names of "PS" CDR used

### 3.4 Map-Projected Multispectral RDR

#### 3.4.1 Data Product Structure and Organization

This RDR (Figure 3-13) consists of mosaicked, map-projected multispectral TRDRs. All data are represented as 32-bit real numbers. The files are updated at approximately 14 days after transfer of target ID files, when sufficiently accurate pointing information is available. The multispectral map RDR contains up to five multiple-band images at 256 pixels/degree, and up to two list files.

The first multiple-band image is map-projected I/F without any further corrections applied, taken directly from the temporary TRDR associated with a strip of multispectral data. Although in the TRDRs there are separate multiple-band images for the VNIR and IR detectors, in this case the data are merged. The size of the multiple-band image varies between map tiles. A typical multiple-band image might have 1280 pixels in the latitude direction, a variable number of pixels in the longitude direction, and approximately 72 pixels in the wavelength dimension, representing each of the selected channels in multispectral mode.

The second multiple-band image is geometrically identical to the map-projected I/F multiple-band image, except that the data have been processed using the ADR binary tables to Lambert albedo (the thermally-corrected estimated surface contribution to reflected I/F, divided by  $\cos I$ ).

The third and fourth multiple-band image contains map-projected data from the temporary DDR associated with a strip of multispectral data, used to derive I/F from radiance. One file corresponds to the I/F image, and one file corresponds to the Lambert albedo images. In each of these, 11 additional layers are specific to individual multispectral strips used to assemble the tile, and are thus not contained in the source DDRs.

- Solar longitude, units degrees
- Solar distance at time of measurement, units AU
- VNIR OBSERVATION\_ID of constituent measurement
- IR OBSERVATION\_ID of constituent measurement
- The VNIR OBSERVATION\_NUMBER carried through from the source scene EDRs;
- The IR OBSERVATION\_NUMBER carried through from the source scene EDRs;
- The VNIR LINE\_SAMPLE carried through from the temporary TRDR used to populate the MRDR; this identifies the VNIR wavelength calibration at the spatial pixel of the MRDR
- The IR LINE\_SAMPLE carried through from the temporary TRDR used to populate the MRDR; this identifies the IR wavelength calibration at the spatial pixel of the MRDR

- The LINE\_SAMPLE from the source VNIR TRDR; this together with column number, observation ID, and ordinal counter provides traceability back to a spatial pixel in a source EDR
- The LINE from the source IR TRDR
- The LINE from the source VNIR TRDR

The fifth multiple-band image contains map-projected summary products from the temporary RDR associated with a strip of multispectral data.

The first listfile, in ASCII format, contains one pair of values for every observation ID used to create the tile, the observation ID and the SPICE metakernel that described the kernels required for its map projection.

The second listfile, also in ASCII format, contains wavelengths of each layer in the Lambert albedo and I/F images..

Because of the mosaicked nature of an MRDR, the following protocol is used to select between overlapping TRDRs for inclusion in the MRDR:

- 1) If I/F is available but not Lambert albedo, the TRDR with the lower incidence angle at the areoid is used
- 2) If Lambert albedo is available, then an alternate strategy is available but not implemented:
  - 2a) If both TRDRs have incidence angles  $>70^\circ$ , the one with the lower incidence angle is used.
  - 2b) If one incidence angle is  $>70^\circ$  and one is  $<70^\circ$ , the TRDR with  $i < 70^\circ$  is used.
  - 2c) If both incidence angles are  $<70^\circ$ , then the TRDR with the lower 440-nm Lambert albedo is used.

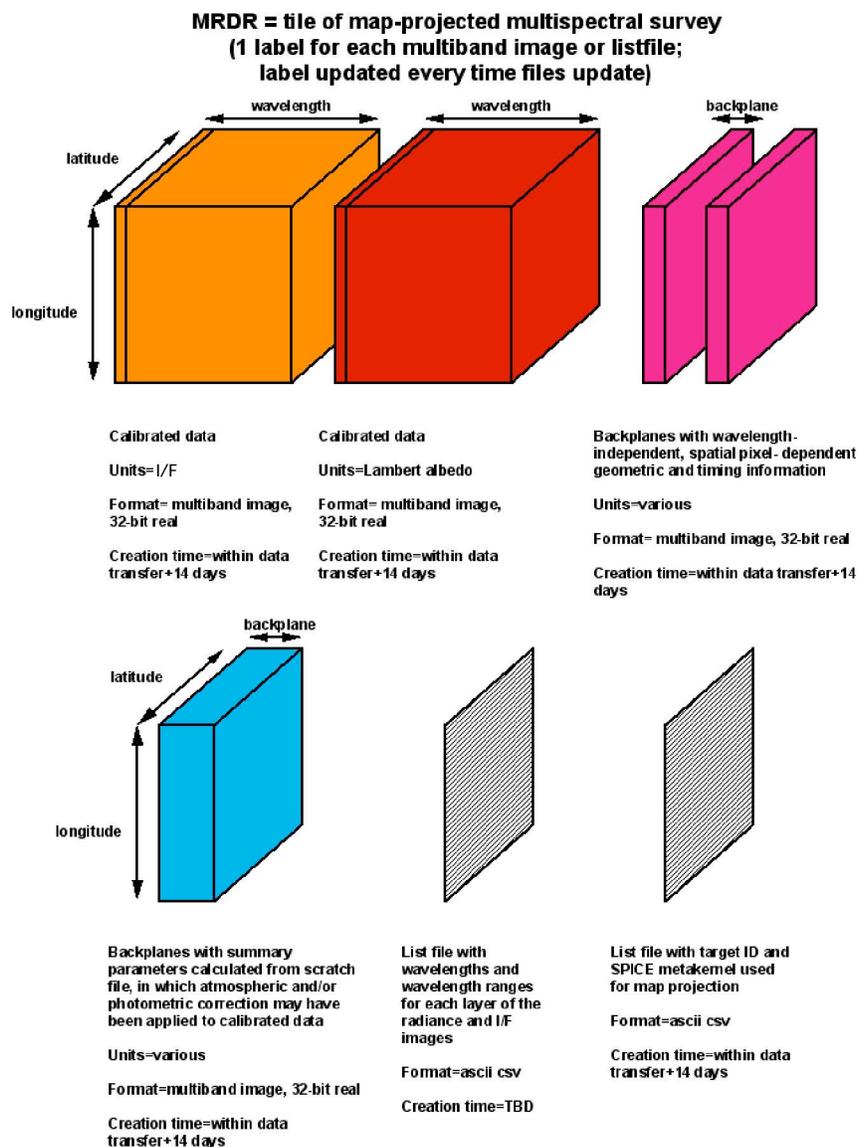
Each component of this RDR is updated no sooner than approximately 14 days after data receipt when adequate pointing information is available.

### **3.4.2 Map projection standards**

Areocentric latitude and longitude, incidence, emission, and phase angles will be derived from spacecraft attitude, gimbal position, pixel location, and MOLA shape model of Mars. The adopted projection convention is planetocentric, positive east, using the 2000 IAU prime meridian and pole of rotation. The projection varies in  $5^\circ$  latitude bands, using EQUIRECTANGULAR equatorward of  $65^\circ$  latitude and POLAR STEREOGRAPHIC poleward of that latitude. For the latitude band projected equirectangularly, the center latitude of projection is the equatorward boundary of each band to minimize "distortion." For the latitude band projected polar stereographically, in the north  $0^\circ$  longitude is down, and in the south  $0^\circ$  longitude is up. Map projection occurs approximately 14 days after receipt of target ID files when sufficiently accurate SPICE files become available.

For multispectral RDRs, the planet is divided into 1964 non-overlapping, 256 pixel/degree tiles as shown in Figure 2-10. Their longitude width increases poleward to keep tiles approximately the same in area.

Map projected targeted RDRs (MTRDRs, section 3.6) will use the same projection as the MRDR containing its upper left latitude and longitude.



**Figure 3-13. Contents of a CRISM Reduced Data Record for a multispectral map tile (MRDR).**

### 3.4.3 Label Description

See section 2.3.4 for general information on CRISM product labels. Each component file of the MRDR has a single label pointing to it. An example MRDR label is in Appendix D.

MRDR label keywords with CRISM-specific values are listed in Table 3-14.

**Table 3-14. CRISM-specific values for MRDR label keywords**

Keyword	Valid Values
PRODUCT_TYPE	EDR TARGETED_RDR DDR MAP_PROJECTED_MULTISPECTRAL_RDR MAP_PROJECTED_TARGETED_RDR CDR ADR
BAND_NAME	Brief descriptive name of each layer of data in the summary product multi-band image or the geometric/timing multi-band image
MRO:ATMO_CORRECTION_FLAG	Whether or not a correction has been performed for photometric and atmospheric effects; "OFF" or "ON"
MRO:PHOTOCLIN_CORRECTION_FLAG	Validity only in the case where the value of keyword MRO:THERMAL_CORRECTION_MODE is PHYSICAL_MODEL;ADR_TE. If MRO:PHOTOCLIN_CORRECTION_FLAG is OFF, then slopes used to calculate temperature come from the companion DDR. If it is ON, then the slopes are calculated using photoclinometry of CRISM data
MRO:THERMAL_CORRECTION_MODE	Whether and what type of thermal correction has been performed to calibrated data. Valid values are "OFF", "CLIMATOLOGY;ADR_CL", "EMPIRICAL_MODEL_FROM_SPECTRUM;ALG_M", "PHYSICAL_MODEL;ADR_TE"

### 3.5 Map-Projected Targeted RDR

#### 3.5.1 Data Product Structure and Organization

The map-projected targeted RDR, or MTRDR (Figure 3-15), contains up to six multiple-band images at 2048 or 4096 pixels/degree. All data in these multiple-band images are represented as 32-bit real numbers. Up to three text files contain supplementary information on the contents of the multiple-band images.

MTRDRs are created external to the SOC by the CRISM science team using the CRISM Analysis Tool, and are delivered to the SOC for archival purposes.

The first multiple-band image is map-projected I/F. A typical multiple-band image might have XX pixels in the longitude dimension, YY pixels in the latitude dimension, and ZZ pixels in the wavelength dimension, where XX and YY depend on the site(s) and ZZ is the number of channels (nominally 545).

The second multiple-band image is map-projected Lambert albedo, i.e., I/F corrected for atmospheric and thermal effects and divided by  $\cos i$ . A typical multiple-band image might have XX pixels in the longitude dimension, YY pixels in the latitude dimension, and up ZZ pixels in the wavelength dimension, where XX and YY depend on the site(s) and ZZ is the number of channels (nominally 545).

The third and fourth multiple-band images are geometrically identical to the map-projected I/F and Lambert albedo multiple-band images respectively, except that they contain map-projected data from the DDR, used to derive I/F from radiance. They are augmented with 11 additional layers that are specific to individual TRDRs used to assemble the tile, and are thus not contained in the DDR:

- Solar longitude, units degrees
- Solar distance at time of measurement, units AU
- VNIR observation ID of constituent measurement
- IR observation ID of constituent measurement
- The VNIR ordinal counter carried through from the source scene EDRs;
- The IR ordinal counter carried through from the source scene EDRs;
- The VNIR column number carried through from the temporary TRDR used to populate the MRDR; this identifies the VNIR wavelength calibration at the spatial pixel of the MRDR
- The IR column number carried through from the temporary TRDR used to populate the MRDR; this identifies the IR wavelength calibration at the spatial pixel of the MRDR
- The ordinal number of the frame from the source VNIR TRDR; this together with column number, observation ID, and ordinal counter provides traceability back to a spatial pixel in a source EDR
- The ordinal number of the frame from the source IR TRDR;
- Time of day, hhmm.ss

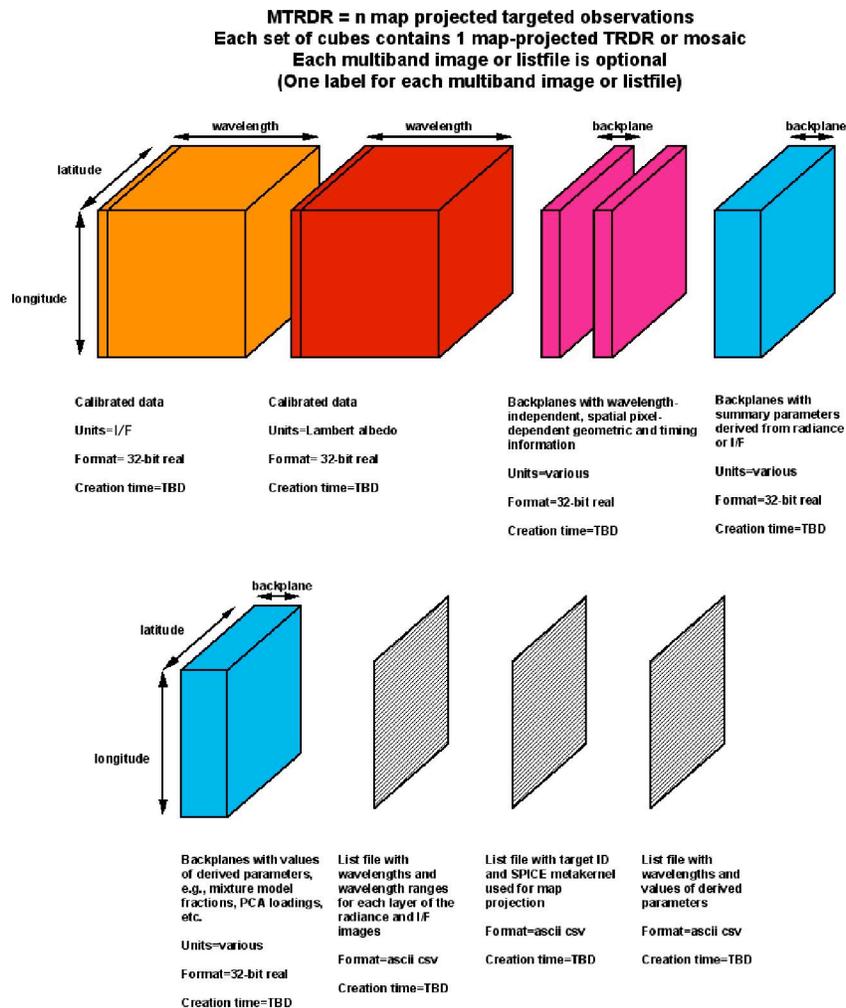
The fifth multiple-band image contains map-projected summary products.

The sixth multiple-band image contains map-projected outputs of the CRISM analysis tool. These are user-defined.

The seventh file, in ASCII format, is a list containing one pair of values for every observation ID used to create the tile, the observation ID and the SPICE metakernel that described the kernels required for its map projection.

The eighth file, also in ASCII format, contains wavelengths and wavelength ranges of each layer in the Lambert albedo and I/F images..

The ninth file, also in ASCII format, provides explanatory information on any additional layers in the fifth multiple-band image. This might include, for example, description of principal components or end members whose fractional abundances are represented in the fourth multiple-band image.



**Figure 3-15. Contents of a CRISM Reduced Data Record for a MTRDR**

### 3.5.2 Label Description

See section 2.3.4 for general information on CRISM product labels. An example MTRDR label is in Appendix E.

MTRDR label keywords with CRISM-specific values are listed in Table 3-16.

**Table 3-16. CRISM-specific values for MTRDR label keywords**

Keyword	Valid Values
PRODUCT_TYPE	EDR TARGETED_RDR DDR MAP_PROJECTED_MULTISPECTRAL_RDR MAP_PROJECTED_TARGETED_RDR CDR ADR

Keyword	Valid Values
OBSERVATION_TYPE	FRT (Full Resolution Targeted Observation) HRL (Half Resolution Long Targeted Observation) HRS (Half Resolution Short Targeted Observation) EPF (Atmospheric Survey EPF) TOD (Tracking Optical Depth Observation) MSS (Multispectral Survey, lossy compressed) MSP (Multispectral Survey, losslessly compressed) MSW (Multispectral Window) (MTRDRs are only generated for EDRs including a Mars scene)
OBSERVATION_ID	8-byte hexadecimal integer
MRO:OBSERVATION_NUMBER	Counter from product ID
MRO:ACTIVITY_ID	The only valid value is: SC#### – Scene measurement
MRO:SENSOR_ID	"S" for VNIR, or "L" for IR
SHUTTER_MODE_ID	The only valid value is "OPEN"
LIGHT_SOURCE_NAME	The only valid value is "NONE"
MRO:CALIBRATION_LAMP_STATUS	The only valid value is "OFF"
MRO:CALIBRATION_LAMP_LEVEL	The only valid value is 0
PIXEL_AVERAGING_WIDTH	1, 2, 5, or 10
MRO:INSTRUMENT_POINTING_MODE	"DYNAMIC POINTING" if SCAN_MODE (housekeeping file column 213) equals 3 ; else "FIXED POINTING"
SCAN_MODE_ID	(If DYNAMIC POINTING): "SHORT" (for full-resolution or half-resolution short central swath), "LONG" (for half-resolution long central swath), or "EPF" (for EPF even if part of a different class of observation)
SCAN_RATE	1, 3.75, 15, or 30 (Hz frame rate)
SAMPLING_MODE_ID	"HYPERSPETRAL" if wavelength filter used returns contiguous rows or "MULTISPECTRAL" if not
MRO:EXPOSURE_PARAMETER	The value supplied to the CRISM instrument to command the exposure time. At a given frame rate identified in MRO:FRAME_RATE, there are 480 possible exposure times ranging from 1 to 480.
MRO:WAVELENGTH_FILTER	Which of four onboard menus of rows was selected for downlink. The four choices are 0, 1, 2, or 3.
MRO:WAVELENGTH_FILE_NAME	For an EDR, the wavelength file is a 5-column, 480-row text file. The five elements in each row are the row number and a 0 or 1 for each of MRO:WAVELENGTH_FILTER 0, 1, 2 and 3, indicating whether data from that row of the detector is included in the EDR when that option is selected in MRO:WAVELENGTH_FILTER. For a TRDR, the wavelength file is an image whose value at the location of a detector element is the center wavelength of that element, in nanometers.

Keyword	Valid Values
MRO:PIXEL_PROC_FILE_NAME	For an EDR, the name of the ASCII file giving gain and offset to convert from 14 to 12 bits, and LUT used if lossy 12 to 8 bit compression is enabled (3 columns specified on a line-by-line basis)
BAND_NAME	Brief descriptive name of each layer of data in the summary product multi-band image

### 3.6 Level-6 CDR

#### 3.6.1 Data Product Structure and Organization

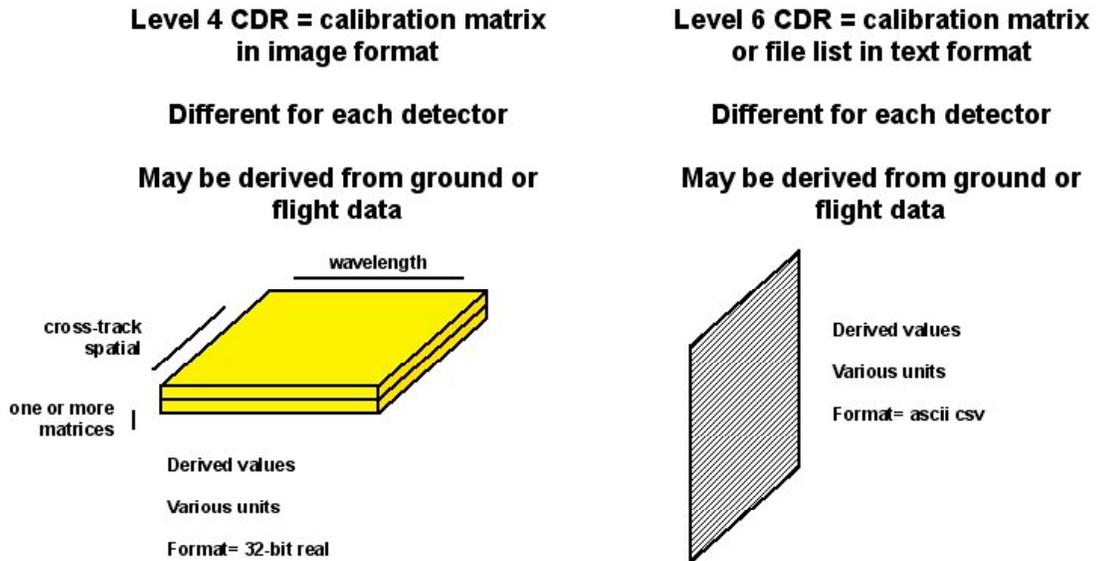
A level-6 CDR (Figure 3-17) consists of tabulated derived data. Typically it is used for calibration of EDRs to CDRs, radiance or I/F. Derivation of the level-6 CDRs from flight data is described in Appendix M. The different types of calibration-related level-6 CDRs are given in Table 3-18.

The CDR6 format is also used to store operationally significant engineering information that the user may find helpful, but that are beyond the scope of the required elements of the archive. This includes a time ordered history of observations and the characteristics of the sites observed, as well as the configuration-managed history of the hardware and software state of the CRISM instrument. These "operational CDRs" are described in Table 3-19.

File format is comparable to that of EDR and RDR list files. The tables are ASCII comma-separated value (CSV) format.

#### 3.6.2 Label Description

See section 2.3.4 for general information on CRISM product labels. An example level-6 CDR label is in Appendix F. An example level-4 CDR label is in Appendix G.



**Figure 3-17. Contents of a CRISM Calibration Data Record (CDR). Level 4 is image data; level 6 is text.**

**Table 3-18. Descriptions of calibration-related level-6 CDRs**

PRODUCTS	FORM FOR EACH FOCAL PLANE	PRODUCT ACRONYM
<b>INFREQUENTLY UPDATED PRODUCTS</b>		
Coefficients for correcting raw housekeeping for effects of lamps, coolers, frame rate	ASCII table , 11 columns (only one file applicable to both VNIR and IR)	HD
Coefficients for calibrating housekeeping from digital to physical units	ASCII table , 5 columns (only one file applicable to both VNIR and IR)	HK
Coefficients to convert housekeeping voltages for perturbations due to current	ASCII table , 7 columns (only one file applicable to both VNIR and IR)	HV
Gain and offset to use for each row for 12 to 14 bit conversion; 12 to 8 bit lookup tables used for each row	ASCII table, 4 columns, 1 per detector	PP
Wavelength tables	ASCII table, 5 columns, 1 per detector	WV
Bandwidth for each row (band) in central columns of each detector at which spectral smile and keystone are minimum.	ASCII table, 2 cols VNIR and 11 cols IR, 1 per detector	BW
Center wavelength for each row (band) in central columns of each detector at which spectral smile and keystone are minimum.	ASCII table, 2 columns, 1 per detector	SW
12 to 8 bit lookup tables	ASCII table, 1 col. of 12-bit input, 8 cols. of 8-bit output	LK
8 to 12 bit lookup tables (inverse of 12 to 8)	ASCII table, 8 cols. of 8-bit input, 1 col. of 12-bit output	LI

<b>PRODUCTS</b>	<b>FORM FOR EACH FOCAL PLANE</b>	<b>PRODUCT ACRONYM</b>
Linearity correction	ASCII table, 7 columns, 1 per detector	LC
Bias step function as a function of frame rate and quadrant	ASCII table, 3 columns, 1 per detector	BS
Additive correction of bias to nominal detector operating temperature	ASCII table, 3 columns, 1 per detector	DB
Additive correction of bias to nominal focal plane electronics operating temperature	ASCII table, 3 columns, 1 per detector	EB
Interquadrant ghost removal scaling factors	ASCII table, 6 columns, 1 per detector	GH
Average Mars spectrum for limiting cases in different operating modes	ASCII table, 6 columns, 1 per detector	AS
Saturation limit for each detector quadrant and frame rate	ASCII table, 3 columns, 1 per detector	SL
Valid limits for each detector quadrant and frame rate for 14-bit DN level and noise	ASCII table, 5 columns, 1 per detector	VL
Atmospheric transmission for each wavelength bin averaged over IR columns 270-369 or VNIR columns 260-359, the part of each detector at which spectral smile and keystone are minimum	ASCII table, 2 columns, 1 per detector	CT
<b>FREQUENTLY UPDATED PRODUCTS</b>		
Standard telemetry file: CRISM low-rate telemetry in raw counts, from the beginning of a UTC calendar day to its end. This is used in preference to the telemetry attached to each image for correction of thermal effects.	ASCII table, 224 columns	ST
Predicted EDR processing table: Predicted table of EDRs containing scene data and the corresponding EDRs containing time-dependent calibration measurements. It is constructed from uplinked commands	ASCII table, 21 columns	BTF
EDR processing table: Table of EDRs containing scene data and the corresponding EDRs containing time-dependent calibration measurements. Used to process scene EDRs to TRDRs, and calibration EDRs to CDRs. If there is a discrepancy between the actual and predicted EDRs used for calibration, the TRDRs resulting from scene EDRs are quality-flagged.	ASCII table, 6 columns	ATF

**Table 3-19. Descriptions of operational level-6 CDRs**

<b>PRODUCTS</b>	<b>FORM FOR EACH FOCAL PLANE</b>	<b>PRODUCT ACRONYM</b>
Digital values of alarm limits and instrument parameters. Used for validation of uplinked sequences.	ASCII table with columns of start time of applicability, raw digital value, and comments (only one file applicable to both VNIR and IR)	DR
Calibrated physical values of alarm limits. Used for validation of uplinked sequences.	ASCII table with columns of start time of applicability, value as Celsius, volts, or amps, and comments (only one file applicable to both VNIR and IR)	DC
Digital values of heater and cooler settings. Used for validation of uplinked sequences.	ASCII table with columns of start time of applicability, raw digital value, and comments (only one file applicable to both VNIR and IR)	SR
Calibrated physical values of heater and cooler settings. Used for validation of uplinked sequences.	ASCII table with columns of start time of applicability, value as Celsius, and comments (only one file applicable to both VNIR and IR)	SC
Expected compression ratio of data in different instrument configurations. Used for management of solid state recorder usage.	ASCII table with columns activity, wavelength filter, binning, lossy compression setup, lossless compression setup, and expected compression ratio of data with that configuration.	CP
Mission event log. Includes times of updates to instrument software or settings, command loads, flight tests, or other notable events.	ASCII table with columns of start time and comments (only one file applicable to both VNIR and IR)	EL

### 3.7 Level-4 CDR

#### 3.7.1 Data Product Structure and Organization

A level-4 CDR (Figure 3-17) consists of a derived image product needed for calibration to radiance or I/F. Derivation of the level-4 CDRs from flight data is described in Appendix M. The different types of level-4 CDRs are given in Table 3-20. The data may be bitmap or 32-bit real numbers, depending on the product.

A level-4 CDR contains one or more images. The size varies according to pixel binning. The dimensions are XX' pixels in the sample (cross-track) dimension, YY pixels in the wavelength dimension, where:

- $XX' = (640) / \text{binning}$ , where 640 is the number of columns read off the detector, and binning is 1, 2, 5, or 10
- YY = the number of rows (wavelength) that are retained by the instrument.

### 3.7.2 Label Description

See section 2.3.4 for general information on CRISM product labels. An example level-4 CDR label is in Appendix G.

**Table 3-20. Descriptions of level-4 CDRs**

PRODUCTS	FORM FOR EACH FOCAL PLANE	VERSIONS FOR DIFFERENT PIXEL BINNING / CHANNEL SELECTION?	VERSIONS FOR DIFFERENT FRAME RATE?	ACRONYM
<b>GROUND CALIBRATION PRODUCTS</b>				
Masks of detector dark columns, scattered light columns, scene columns	2D matrix per detector, 8 bit	Y	N	DM
Nonuniformity file: time-tagged, row-normalized measurement of detector nonuniformity	Two 2D matrices, 32 bit	Y	Y	NU
Matrices to remove estimated leaked higher order light	Four 2D matrices per detector, 16 bit integer, row numbers Four 2D matrices per detector, 32 bit, weighting coefficients	Y	N	LL
Sphere spectral radiance at set point (pixel by pixel coefficients to a 2nd order polynomial function of optical bench temperature)	Three 2D matrices per detector, 32 bit, for each sphere bulb	Y	N	SS
Shutter position reproducibility correction to sphere radiance (pixel by pixel coefficients to a linear function of the ratio of corrected sphere image to sphere spectral radiance model)	2 2D matrices per detector, 32 bit, for each sphere bulb	Y	N	SH
Temperature dependence of detector responsivity (pixel by pixel coefficients to a 2nd order polynomial function of detector temperature)	Three 2D matrices per detector, 32 bit	Y	N	TD
Along-slit angle measured from slit center	2D matrix per detector, 32 bit	Y	N	CM
Number of lines by which to shift each column (sample) of an image to minimize the effects of spectral smile	2D matrix per detector, 32 bit	Y	N	PS
Wavelength image (each pixel) determined onground	2D matrix per detector, 32 bit	Y	N	WA

<b>PRODUCTS</b>	<b>FORM FOR EACH FOCAL PLANE</b>	<b>VERSIONS FOR DIFFERENT PIXEL BINNING / CHANNEL SELECTION?</b>	<b>VERSIONS FOR DIFFERENT FRAME RATE?</b>	<b>ACRONYM</b>
Nearest-neighbor resampled wavelength image (each pixel determined onground)	2D matrix per detector, 32 bit	Y	N	RW
Spectral bandpass, or full width half maximum (each pixel determined onground)	One (VNIR) or ten(IR) 2D matrices per detector, 32 bit	Y	N	SB
Solar flux at 1 AU (for each pixel to take into account spectral smile effects)	2D matrix per detector, 32 bit	Y	N	SF
Nearest-neighbor resampled solar flux at 1 AU (for each pixel to take into account spectral smile effects)	2D matrix per detector, 32 bit	Y	N	RF
Atmospheric transmission as measured from a nadir-pointed hyperspectral scan across Olympus Mons	2D matrix per detector, 32 bit	Y	N	AT
Atmospheric transmission as measured from a nadir-pointed hyperspectral scan across Olympus Mons, nearest-neighbor resampled in the wavelength direction	2D matrix per detector, 32 bit	Y	N	RT
<b>FREQUENTLY UPDATED PRODUCTS</b>				
Bad pixel mask: time-tagged bitmap of bad pixels	2D matrix, 8 bits, per detector	Y	Y	BP
Bias file: time-tagged, fitted VNIR and IR images extrapolated to zero exposure time	2D matrix, 32 bit, per detector	Y	Y	BI
Background file: time-tagged, bias- and ghost-subtracted, linearized, averaged VNIR and IR background frames	2D matrix, 32 bit, per detector	Y	Y	BK
Noise file: time-tagged, image of pixel-by-pixel uncertainties in background images	2D matrix, 32 bit, per detector	Y	Y	UB
Processed sphere image in units of DN/ms	2D matrix, 32 bit, per detector (1 for each sphere bulb)	Y	N	SP

CDR label keywords with CRISM-specific values are listed in Table 3-21.

**Table 3-21. CRISM-specific values for CDR label keywords**

Keyword	Valid Values
PRODUCT_TYPE	EDR TARGETED_RDR DDR MAP_PROJECTED_MULTISPECTRAL_RDR MAP_PROJECTED_TARGETED_RDR CDR ADR
OBSERVATION_TYPE	If produced from flight data: FRT (Full Resolution Targeted Observation) HRL (Half Resolution Long Targeted Observation) HRS (Half Resolution Short Targeted Observation) EPF (Atmospheric Survey EPF) TOD (Tracking Optical Depth Observation) MSS (Multispectral Survey, lossy compressed) MSP (Multispectral Survey, losslessly compressed) MSW (Multispectral Window) CAL (Radiometric Calibration) FFC (Flat-field calibration) ICL (Calibration source intercalibration) STO (Star Observation) FUN (Functional test) UNK (no valid EDRs within observation that indicate class type, or ground-derived)
OBSERVATION_ID	10-digit hexadecimal integer (if produced from flight data)
MRO:OBSERVATION_NUMBER	Counter from product ID (if produced from flight data)
MRO:ACTIVITY_ID	Valid values (if produced from flight data) are: BI#### – Bias measurement DF#### – Dark field measurement LP#### – Lamp measurement SP#### – Sphere measurement SC#### – Scene measurement (for flat-field calibration)
SOURCE_PRODUCT_ID	The product ID of the EDR from which a CDR was constructed (if produced from flight data)
MRO:EXPOSURE_PARAMETER	The value supplied to the CRISM instrument to command the exposure time. At a given frame rate identified in MRO:FRAME_RATE, there are 480 possible exposure times ranging from 1 to 480.
MRO:WAVELENGTH_FILTER	Which of four onboard menus of rows was selected for downlink. The four choices are 0, 1, 2, or 3.
MRO:SENSOR_ID	"S" for VNIR, or "L" for IR
SHUTTER_MODE_ID	"OPEN", "SPHERE", OR "CLOSED" (if produced from flight data)
LIGHT_SOURCE_NAME	"NONE", "VNIR LAMP 1", "VNIR LAMP 2", "IR LAMP 1", "IR LAMP 1", "SPHERE LAMP 1", "SPHERE LAMP 2"

Keyword	Valid Values
MRO:CALIBRATION_LAMP_STATUS	"OFF", "OPEN LOOP" or "CLOSED LOOP" (for integrating sphere only)
MRO:CALIBRATION_LAMP_LEVEL	Value between 0 and 4095
PIXEL_AVERAGING_WIDTH	1, 2, 5, or 10
MRO:DETECTOR_TEMPERATURE	Physical units; used to correct bias or responsivity for detector temperature. On each detector there are two temperature sensors. The primary source of IR detector temperature is IR temperature sensor 1 (column 50 in the EDR list file). The backup source of IR detector temperature is IR temperature sensor 2 (column 51 in the EDR list file). The primary source of VNIR detector temperature is VNIR temperature sensor 2 (column 65 in the EDR list file). The backup source of VNIR detector temperature is VNIR temperature sensor 1 (column 64 in the EDR list file)."
MRO:FPE_TEMPERATURE	Physical units; used to correct bias for electronics temperature. The temperature of the IR focal plane electronics (if MRO:SENSOR_ID = "L"), or the VNIR focal plane electronics (if MRO:SENSOR_ID = "S").
MRO:OPTICAL_BENCH_TEMPERATURE	Physical units; backup to correct sphere radiance for sphere temperature
MRO:SPHERE_TEMPERATURE	Physical units; used to correct sphere radiance for sphere temperature
MRO:SPECTROMETER_HOUSING_TEMPERATURE	Physical units; used in backup correction of background for spectrometer housing temperature. The primary source of this temperature is a measurement digitized by the VNIR focal plane electronics, column 58 in the EDR list file. The backup source of this temperature is a measurement digitized by the IR focal plane electronics, column 69 in the EDR list file
BAND_NAME	Brief descriptive name of each layer of data in the CDR

### 3.8 ADR

An Ancillary Data Record or ADR contains a hyperdimensional binary table of derived values, where the axes of the matrix represent values of a layer of a DDR (e.g., incidence angle, thermal inertia, etc.), the output of another ADR, or a value extracted from a TRDR.

The overall objective of ADRs is to correct I/F in a TRDR for predictive atmospheric, photometric, or thermal effects to isolate the surface-reflected component of I/F or radiance as Lambert albedo. There are three types of ADRs:

1. The "CL" ADR is a table of climatologically predicted surface temperatures and atmospheric dust and ice opacities, given for a latitude and longitude from the DDR and Ls and local solar time from the TRDR label.
2. The "AC" ADR is a table of correction from I/F to Lambert albedo, for an incidence, emission, and phase angle and surface elevation from the DDR, dust and ice optical depths and surface temperature from the CL ADR, and observed I/F from a TRDR. There is a separate AC ADR for each wavelength that is corrected; nominal wavelengths are those used in multispectral mapping, in wavelength filter 1.
3. The "TE" ADR is a table of calculated surface temperature for latitude, thermal inertia, elevation, and slope magnitude and azimuth from the DDR, dust and ice opacity from the CL ADR, Ls and local solar time from the TRDR label, and bolometric albedo estimated from Lambert albedo at wavelengths <2300 nm. This supplants surface temperature that is returned from the CL ADR.

ADR contents are described in Tables 3-22 through 3-24. An example ADR label is in Appendix H.

**Table 3-22. LUT for atmospheric opacity (ADR type = CL)**

VARIABLE	RANGE	UNIT
Latitude	-90-90°	degrees
Longitude	-90-90°	degrees
Ls	0-360°	degrees
Local time	15	(assumed local time)r
Surface temperature	180-310	°K
Dust opacity	0-1.0	dimensionless opacity
Ice opacity	0-1.0	dimensionless opacity

**Table 3-23. LUT for predicted atmospheric / photometric / thermal correction (ADR type = AC)**

VARIABLE	RANGE	WAVELENGTH
Wavelength	410-3920 nm	(separate table for each wavelength)
Incidence angle at areoid	25-75°	degrees
Emission angle at areoid	0-45°	degrees
Phase angle at areoid	45-135°	degrees
Elevation	-8000-26000	meters
Dust optical depth	0-1	dimensionless opacity
Ice optical depth	0-0.6	dimensionless opacity
Surface temperature	140-300 K	°K
Observed I/F	0.03-0.50	dimensionless

**Table 3-24. LUT for local surface temperature (ADR type = TE)**

VARIABLE	RANGE	UNITS
Latitude	-90-90°	degrees
Slope magnitude	0-10	degrees
Slope azimuth	0-270	degrees clockwise from north
Elevation	-8000-26000	meters
Thermal inertia	5-5000	J m <sup>-2</sup> K <sup>-1</sup> s <sup>-0.5</sup>
Dust+ice opacity	0-1.0	dimensionless opacity
Ls	0-360°	degrees
Local time	13-17	(assumed local time)r
Bolometric albedo	0.15-0.35	dimensionless

### 3.9 CRISM-Generated SPICE Files

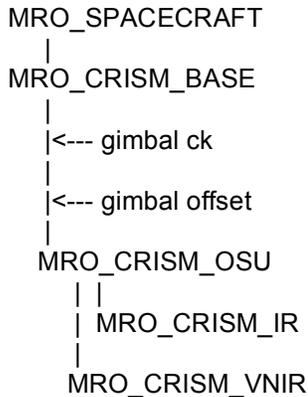
Four types of SPICE kernels are needed to calculate CRISM's pointing:

1) Frames kernel (FK). This file defines the relationships of the of CRISM's field of view to the spacecraft, with the gimbal at "nadir". These transformations in frames of reference include:

- gimbal base (MRO\_CRISM\_BASE) -> spacecraft (MRO\_SPACECRAFT)
- optical axis at gimbal "nadir" (MRO\_CRISM\_OSU) -> gimbal base (MRO\_CRISM\_BASE)
- (the gimbal C kernel defines the relationship of optic axis at a gimbal position to the gimbal nadir)
- (the gimbal offset defines the software offset between commanded nadir and physical nadir)
- IR zero position for IK (MRO\_CRISM\_IR) -> optical axis (MRO\_CRISM\_OSU); nominal there two are coaligned and offsets of the IR FOV from the optical axis are entirely accounted for in the IK

- VNIR zero position for IK (MRO\_CRISM\_VNIR) -> optical axis (MRO\_CRISM\_OSU); nominal there two are coaligned and offsets of the VNIR FOV from the optical axis are entirely accounted for in the IK

Graphically, this is:



The CRISM frames kernel is delivered to NAIF and is incorporated into the MRO frames kernel.

2) Instrument kernel (IK). This file describes the relationship of position of each detector element (at a row or wavelength and spatial or column position) to a zero position within the field of view. Nominally, that is in the VNIR row closest to 610 nm or the IR row closest to 2300 nm, at the column position closest to the optical axis. Due to keystone distortion, there is a different relationship for every row number of either detector.

The CRISM instrument kernel is delivered to NAIF.

3) Gimbal C kernel. This file gives a time history of the angle of the gimbal within the gimbal plane, relative to its commanded nadir. It is constructed from gimbal attitude measurements in image headers, i.e., from the TAB file part of an EDR. One file covers a 2-week time span of CRISM data.

CRISM gimbal C kernels are delivered to NAIF.

4) Metakernel. This file gives, for any time span covered by a gimbal C kernel, the MRO and CRISM SPICE kernels used to create DDRs for observations occurring during that time period. Note that kernels are loaded in the order listed., so the highest priority kernel is listed last.

### 3.10 Browse Products

Browse products are synoptic versions of data products to help identify products of interest. There are browse products for EDRs, TRDRs, DDRs, and MRDRs.

#### 3.10.1 EDR Browse Products

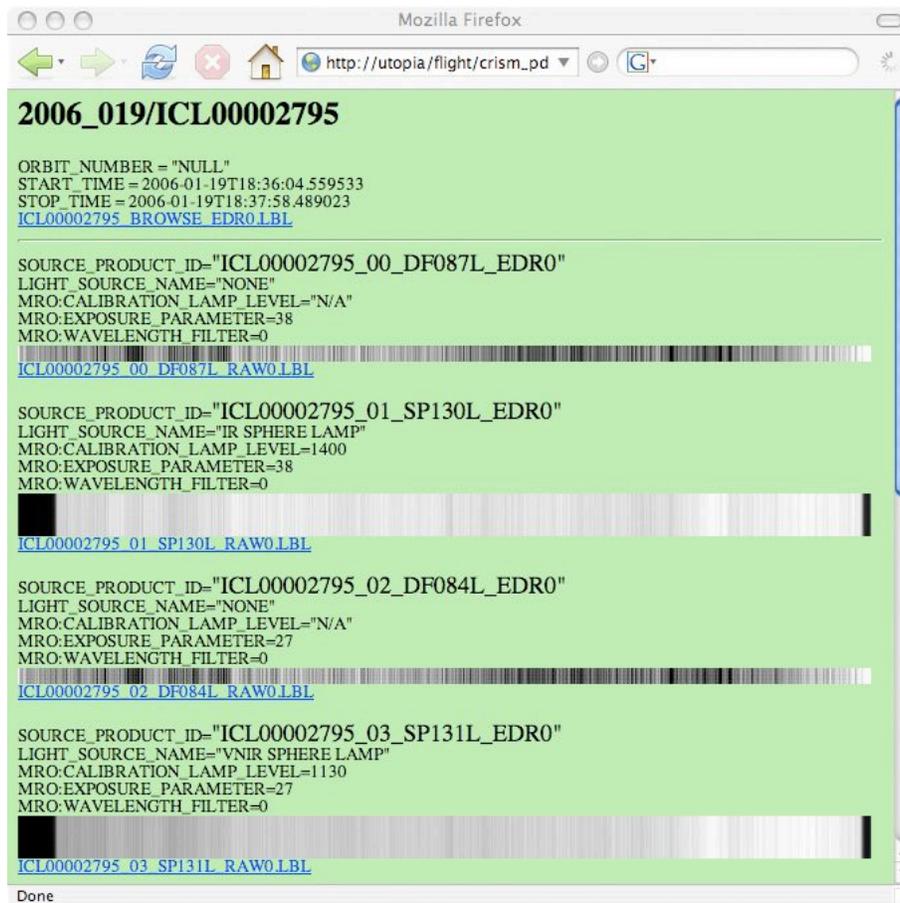
There are two types of products. One is an HTML file that gives the key parameters of the component EDRs for each observation, and links to PNG files for each EDR in the observation. A detached label to the HTML file describes the observation at a high level.

The browse product for each EDR is a scaled (0-255), median DN value from selected wavelengths for each spatial element in an EDR multiband image, stored in PNG format. The dimensions of the PNG file, XX pixels in the sample (cross-track) dimension and YY pixels in the line (along-track) dimension, match the spatial dimensions of the source EDR. A detached label to the PNG file describes the source EDR and the scaling between its raw data values and the PNG file.

Figure 3-25 shows an example EDR HTML browse product, linking to the PNG files for the component EDRs and to all of the associated labels.

An example set of EDR browse product labels is in Appendix I.

**Figure 3-25. Example EDR browse product**



### 3.10.2 DDR Browse Products

There are two types of DDR browse products. One is an HTML file that contains the key parameters for the component DDRs for a single observation, and links to PNG files for each DDR. A detached label to the HTML file describes the observation at a high level.

The browse product for each DDR is a 3-color product (browse product type DER), with each color plane scaled (0-255) and stored in PNG format:

red= solar incidence angle at areoid, degrees, scaled 90-0 to 0-250

green = Elevation, meters relative to MOLA datum, scaled -9000 - 27,000 to 0-250

blue = emission angle at areoid, degrees, scaled 0-90 to 0-250

The dimensions of the PNG file, XX pixels in the sample (cross-track) dimension and YY pixels in the line (along-track) dimension, match the spatial dimensions of the source DDR. A detached label to the PNG file describes the source EDR and the scaling between its raw data values and the PNG file.

An example set of DDR browse product labels is in Appendix J.

### **3.10.3 TRDR Browse Products**

There are two types of TRDR browse products. One is an HTML file that contains the key parameters of the component TRDRs in an observation, and links to PNG files for each TRDR in that observation. A detached label to the HTML file describes the observation at a high level.

There are up to two browse products for each VNIR TRDR, and up to five browse products for each IR TRDR. All are stored in PNG format. The dimensions of each PNG file, XX pixels in the sample (cross-track) dimension and YY pixels in the line (along-track) dimension, match the spatial dimensions of the source TRDR. A detached label to each PNG file describes the source TRDR and the scaling between its raw data values and the PNG file.

The first VNIR browse product (browse product type TRU) is a true color representation of the scene, derived from I/F after correction for atmospheric or photometric effects:

red= 600-nm I/F, scaled 0.0-1.0 to 0-250

green = 530-nm I/F, scaled 0.0-1.0 to 0-250

blue = 440-nm I/F, scaled 0.0-1.0 to 0-250

The second VNIR browse product (type FEM) shows information related to Fe minerals. It is derived from the spectral parameters stored in summary products that have been corrected for atmospheric and photometric effects:

red= 530-nm band depth (derived from summary product BD530)

green = 600-nm shoulder (derived from summary product SH600)

blue = 1-micron band depth (derived from summary product BDI1000VIS)

The first IR browse product (type IRA) shows I/F at 1330 nm, with correction for atmospheric effects.

The second IR browse product (type MAF) shows information related to mafic mineralogy. It is derived from the spectral parameters stored in summary products that have been corrected for atmospheric and photometric effects:

red= scaled olivine index (derived from summary product OLINDEX)

green = scaled LCP index (derived from summary product LCPINDEX)

blue = scaled HCP index (derived from summary product LCPINDEX)

The third IR browse product (type HYD) shows information related to bound water in minerals. It is also derived from the spectral parameters stored in summary products that have been corrected for atmospheric and photometric effects:

red = strength of bands due to bound water (derived from summary product SINDEXT); this is indicative of hydrated minerals, particularly sulfates

green = 2.1 micron H<sub>2</sub>O band depth, in monohydrated sulfate (derived from summary product BD2100)

blue = 1.9 micron H<sub>2</sub>O band depth (derived from summary products BD1900)

The fourth IR browse product (type ICE) shows information related to water or carbon dioxide frost or ice. It is also derived from the spectral parameters stored in summary products that have been corrected for atmospheric and photometric effects:

red = 1.9 micron H<sub>2</sub>O band depth (derived from summary product BD1900)

green = 1.5 micron H<sub>2</sub>O band depth (derived from summary product BD1500)

blue = 1.435 micron CO<sub>2</sub> ice band depth (derived from summary product BD1435)

The fifth IR browse product (type PHY) shows information related to hydroxylated minerals including phyllosilicate. It is also derived from the spectral parameters stored in summary products that have been corrected for atmospheric and photometric effects:

red = 2.29 micron band depth (derived from summary product D2300 )

green = 2.21 micron band depth (derived from summary product BD2210)

blue = 1.9 micron H<sub>2</sub>O band depth (derived from summary products BD1900)

An example set of TRDR browse product labels is in Appendix K.

### **3.10.4 MRDR Browse Products**

There are five browse products for MRDRs, that parallel the image products created for TRDR browse products. Formulations are identical to those for TRDR browse products. The dimensions of the products, XX pixels in the longitude dimension and YY pixels in the latitude dimension, match those of the source RDR.

A detached label to each PNG file describes the source MRDR and the scaling between its raw data values and the PNG file.

An example set of TRDR browse product labels is in Appendix L.

## **3.11 Extra Products**

The detailed contents of operational CDR6's are described in Table 3-19.

Among the observation tracking tables, the format of only the OBS\_ID table is well defined at this time. This table is used to provide a synopsis of the disposition and quality of CRISM observations that have actually been commanded to the instrument. Its contents are described in Table 3-26. There is one row per commanded EDR.

**Table 3-26. Contents of OBS\_ID Table.**

Information	Description
REQUEST_ID	May be null if it is not site-related, such calibration or functional test (class = FUN or CAL).
PARTICIPATING_INSTRUMENTS	Any combination of the characters CHX to indicate instruments planning to participate.
COORDINATED_TARGET	1 if true
MEP_TARGET	1 if true
RIDEALONG	1 if true
OBSERVATION_ID	8-byte hexadecimal integer, if in integrated target list.
OBSERVATION_TYPE	FRT, HRL, HRS, EPF, TOD, MSW, MSS, MSP, CAL, FFC, ICL, STO, or FUN
ACTIVITY_ID	AC### where AC is a 2-letter designation of the type of measurement made, and ### as a 3-numeral designation of the instrument command macro that was executed to acquire the data. Macro numbers are in the range 0-255. BI is measurement of detector bias, DF is a measurement of background including dark current and thermal background, LP is measurement of a focal plane lamp, SP is measurement of the internal integrating sphere, and SC is measurement of an external scene. TP indicates that the EDR contains any test pattern produced by instrument electronics. T1 through T7 specify the test pattern, test pattern 1 through test pattern 7. UN indicates data in which housekeeping does not match the commanded instrument configuration.
PLAN_OBSERVATION_NUMBER	Monotonically increasing ordinal counter of the EDRs generated from one spectrometer for a single OBSERVATION_ID.
PLAN_SENSOR_ID	Spectrometer identifier. 0 = IR; 1 = VNIR.
PLAN_LINES	Number of frames
PLAN_BANDS	Number of wavelengths
PLAN_BINNING	Spatial pixel binning mode; specified separately for each detector; 0 = 1:1; 1 = 2:1; 2 = 5:1; 3 = 10:1
PLAN_RATE	Rate of frame acquisition; 0 = 1 Hz; 1 = 3.75 Hz; 2 = 5 Hz; 3 = 15 Hz; 4 = 30 Hz; specified separately for each detector
PLAN_EXPOSURE_PARAMETER	At a given frame rate there are 480 possible exposure times ranging from 1 to 480. An exposure parameter of 480 yields an exposure time equal to the inverse of the frame rate. An exposure time parameter of 1 yields an exposure time 1/480 as large.
PLAN_SHUTTER_POS	Shutter position from 0 to 32; nominal open is 3; viewing sphere is 17; closed is 32.
PLAN_FILTER	Wavelength filter table; which of uploadable tables 0-3; specified separately for each detector
PLAN_FAST	Lossless Fast compression enabled or disabled; specified separately for each detector; 0 = disabled; 1 = enabled
PLAN_LOSSY	Lossy compression enabled or disabled; 12 to 8 bit look-up table commanded line by line in uploaded data structure; specified separately for each detector; 0 = disabled; 1 = enabled
PLAN_IR_FLOOD1_PWR	IR flood lamp 1 power (IR); 0 = off; 1 = on.
PLAN_IR_FLOOD1_LEVEL	IR flood lamp 1 level 0-4095.
PLAN_IR_FLOOD2_PWR	IR flood lamp 2 power (IR); 0 = off; 1 = on.
PLAN_IR_FLOOD2_LEVEL	IR flood lamp 2 level 0-4095.
PLAN_IR_SPHERE_PWR	IR sphere lamp power; 0 = off; 1 = on.
PLAN_IR_SPHERE_GOAL	Closed-loop goal, 0-4095.

Information	Description
PLAN_VNIR_FLOOD1_PWR	VNIR flood lamp 1 power (VNIR); 0 = off; 1 = on.
PLAN_VNIR_FLOOD1_LEVEL	VNIR flood lamp 1 level 0-4095.
PLAN_VNIR_FLOOD2_PWR	VNIR flood lamp 2 power (VNIR); 0 = off; 1 = on.
PLAN_VNIR_FLOOD2_LEVEL	VNIR flood lamp 2 level 0-4095.
PLAN_VNIR_SPHERE_PWR	VNIR sphere lamp power; 0 = off; 1 = on.
PLAN_VNIR_SPHERE_GOAL	Closed-loop goal, 0-4095.
PLAN_COMPRESSION_RATIO	Compression ratio used to model data volume.
PLAN_CLOSEST_APPROACH_TIME	yyyy-mm-ddThh:mm:ss.sss, ISO UTC time format
PLAN_START_TIME	yyyy-mm-ddThh:mm:ss.sss, ISO UTC time format
PLAN_STOP_TIME	yyyy-mm-ddThh:mm:ss.sss, ISO UTC time format
PLAN_LOWER_RIGHT_LATITUDE	Planned latitude of the surface point at the edge of the FOV on the antisunward (right-hand) side of the groundtrack at the observation start.
PLAN_LOWER_RIGHT_LONGITUDE	Planned longitude of the surface point at the edge of the FOV on the antisunward (right-hand) side of the groundtrack at the observation start.
PLAN_LOWER_LEFT_LATITUDE	Planned latitude of the surface point at the edge of the FOV on the sunward (left-hand) side of the groundtrack at the observation start.
PLAN_LOWER_LEFT_LONGITUDE	Planned longitude of the surface point at the edge of the FOV on the sunward (left-hand) side of the groundtrack at the observation start.
PLAN_UPPER_RIGHT_LATITUDE	Planned latitude of the surface point at the edge of the FOV on the antisunward (right-hand) side of the groundtrack at the observation end.
PLAN_UPPER_RIGHT_LONGITUDE	Planned longitude of the surface point at the edge of the FOV on the antisunward (right-hand) side of the groundtrack at the observation end.
PLAN_UPPER_LEFT_LATITUDE	Planned latitude of the surface point at the edge of the FOV on the sunward (left-hand) side of the groundtrack at the observation end.
PLAN_UPPER_LEFT_LONGITUDE	Planned longitude of the surface point at the edge of the FOV on the sunward (left-hand) side of the groundtrack at the observation end.
RECEIPT	Received on ground; 0 = no, 1 = partially received with no gap filled, 2 = partially received with gap filled, 3 = received.
PRODUCT_ID	CCNNNNNNNNN_XX_AAAAAS_EDRV where CCC = OBSERVATION_TYPE, NNNNNNNN = OBSERVATION_ID as a hexadecimal number, XX = OBSERVATION_NUMBER, AAAAA = ACTIVITY_ID, S = SENSOR_ID S or L, V = Product version number
ENCODING_COMPRESSION_RATIO	Actual compression ratio of data.
CLOSEST_APPROACH_TIME	yyyy-mm-ddThh:mm:ss.sss, ISO UTC time format
START_TIME	yyyy-mm-ddThh:mm:ss.sss, ISO UTC time format
STOP_TIME	yyyy-mm-ddThh:mm:ss.sss, ISO UTC time format
LOWER_RIGHT_LATITUDE	Actual latitude of the surface point at the edge of the FOV on the antisunward (right-hand) side of the groundtrack at the observation start.
LOWER_RIGHT_LONGITUDE	Actual longitude of the surface point at the edge of the FOV on the antisunward (right-hand) side of the groundtrack at the observation start.

Information	Description
LOWER_LEFT_LATITUDE	Actual latitude of the surface point at the edge of the FOV on the sunward (left-hand) side of the groundtrack at the observation start.
LOWER_LEFT_LONGITUDE	Actual longitude of the surface point at the edge of the FOV on the sunward (left-hand) side of the groundtrack at the observation start.
UPPER_RIGHT_LATITUDE	Actual latitude of the surface point at the edge of the FOV on the antisunward (right-hand) side of the groundtrack at the observation end.
UPPER_RIGHT_LONGITUDE	Actual longitude of the surface point at the edge of the FOV on the antisunward (right-hand) side of the groundtrack at the observation end.
UPPER_LEFT_LATITUDE	Actual latitude of the surface point at the edge of the FOV on the sunward (left-hand) side of the groundtrack at the observation end.
UPPER_LEFT_LONGITUDE	Actual longitude of the surface point at the edge of the FOV on the sunward (left-hand) side of the groundtrack at the observation end.
DATA_QUALITY_INDEX	See description in section 2.5.2
FILE_SPECIFICATION_NAME	Pathname of image EDR in data directory, e.g., EDR/2006_350/FRT00001270/FRT00001270_01_SC001S_EDR 0.IMG
LINES	Number of frames
COMMENT	Text string describing nature of observation

## 4. APPLICABLE SOFTWARE

### 4.1 Utility Programs

To facilitate timely and consistent analysis of CRISM data, common software for preliminary analysis will be developed under the direction of Co-I Mustard. To support data interpretation, the Science Team will also develop a spectral library of well-characterized Mars analog materials, measured under dry N<sub>2</sub>-purged conditions over CRISM's wavelength range and convolved with the CRISM's slit function. This special measurement environment is necessary because many lithologies of interest adsorb water strongly and under ambient conditions are spectrally dissimilar to their state on Mars.

The spectral library is documented separately; the reference is listed in section 1.2.

Key data-reduction and management capabilities of the CRISM analysis tool (CAT) include:

- The CAT will have the ability to read EDRs, TRDRs, DDRs, MRDRs, MTRDRs, CDRs, and ADRs.
- The CAT will have the ability to map-project data following the conventions given in section 3.4.2.
- The CAT will have ability to access the SOC and to download and apply the current calibration algorithm and CDRs, to create the multiple-band image component of a targeted RDR from a scene-viewing EDR.

- The CAT will have the ability to access the SOC and to download and apply current ADRs for correction of atmospheric, photometric, and thermal emission effects.
- The CAT will have the ability to derive a site-specific atmospheric and photometric correction using the EPF measurements that accompany a target ID.
- The CAT will have the ability to populate and write map-projected targeted RDRs.

The CAT will also support algorithms including classification (e.g. spectral angle mapping), mixture modeling, principal components analysis, and refinements and techniques that use the spectral library as input. As an interpretational tool, the CAT will be able to overlay the analysis results onto layers of the targeting basemap, or onto the multispectral survey.

The CAT is based on the commercially available ENVI software package which requires IDL to run. When available, the CAT can be downloaded from the CRISM web site at:

<http://crism.jhuapl.edu/>

## **4.2 Applicable PDS Software Tools**

PDS-labeled images and tables can be viewed with the program NASAView, developed by the PDS and available for a variety of computer platforms from the PDS web site <http://pdsproto.jpl.nasa.gov/Distribution/license.html>.

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## APPENDIX A. EDR LABEL

```
PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE    = "2003-11-19, S. Slavney (GEO);
                        2005-02-01, C. Hash (ACT);
                        2006-01-04, C. Hash (ACT);"

/* EDR Identification */

DATA_SET_ID             = "MRO-M-CRISM-2-EDR-V1.0"
PRODUCT_ID             = "MSP00002798_01_SC211S_EDR0"
/* cccnnnnnnnnn_xx_ooaaaas_EDRv          */
/* ccc = Class Type                      */
/* nnnnnnnnn = Observation ID (hex)      */
/* xx = counter within observation (hex) */
/* ooaaa = obs type, macro number        */
/* s = sensor ID (S or L)                */
/* v = version number                    */

INSTRUMENT_HOST_NAME   = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID         = MRO
INSTRUMENT_NAME        = "COMPACT RECONNAISSANCE IMAGING
                        SPECTROMETER FOR MARS"
INSTRUMENT_ID         = CRISM
TARGET_NAME           = MARS
PRODUCT_TYPE          = EDR
PRODUCT_CREATION_TIME = 2006-01-31T00:57:50
START_TIME            = 2006-01-19T18:42:43.592479
STOP_TIME             = 2006-01-19T18:42:58.529979
SPACECRAFT_CLOCK_START_COUNT = "2/822163382:17971"
SPACECRAFT_CLOCK_STOP_COUNT = "2/822163397:13875"
ORBIT_NUMBER          = "NULL"
OBSERVATION_TYPE      = "MSP"
OBSERVATION_ID        = 16#00002798#
MRO:OBSERVATION_NUMBER = 16#01#
MRO:ACTIVITY_ID       = "SC211"
MRO:SENSOR_ID         = "S"
PRODUCT_VERSION_ID    = "0"
PRODUCER_INSTITUTION_NAME = "JOHNS HOPKINS UNIVERSITY
                            APPLIED PHYSICS LABORATORY"
SOFTWARE_NAME         = "pipe_edrslice"
SOFTWARE_VERSION_ID   = "3.5"

/* EDR Instrument and Observation Parameters */
/* for first frame */
TARGET_CENTER_DISTANCE = NULL <KM>
SOLAR_DISTANCE         = NULL <KM>
SHUTTER_MODE_ID        = OPEN
LIGHT_SOURCE_NAME      = "NONE"
CALIBRATION_LAMP_STATUS = "OFF"
CALIBRATION_LAMP_LEVEL = "N/A"
PIXEL_AVERAGING_WIDTH = 10
INSTRUMENT_POINTING_MODE = "FIXED POINTING"
SCAN_MODE_ID           = "N/A"
MRO:FRAME_RATE         = 15.00 <HZ>
MRO:EXPOSURE_PARAMETER = 425
SAMPLING_MODE_ID       = "MULTISPEC"
COMPRESSION_TYPE       = "NONE"
MRO:WAVELENGTH_FILTER = 1
```

```

MRO:WAVELENGTH_FILE_NAME = "CDR6_1_0000000000_WV_S_1.TAB"
MRO:PIXEL_PROC_FILE_NAME = "CDR6_1_0000000000_PP_S_1.TAB"
MRO:LOOKUP_TABLE_FILE_NAME = "CDR6_1_0000000000_LK_J_0.TAB"

/* This EDR label describes two data files. The first file contains */
/* the first two objects and the second file contains the third: */
/* 1. A multiple-band image file containing uncalibrated EDR data, */
/* 2. A binary table of selected image row numbers from detector, */
/* 3. A table of ancillary and housekeeping data. */
/* Description of EDR IMAGE file */

OBJECT = FILE
^IMAGE = "MSP00002798_01_SC211S_EDR0.IMG"
^ROWNUM_TABLE = ("MSP00002798_01_SC211S_EDR0.IMG", 4051)
RECORD_TYPE = FIXED_LENGTH
RECORD_BYTES = 128
FILE_RECORDS = 4051

OBJECT = IMAGE
LINES = 225
LINE_SAMPLES = 64
SAMPLE_TYPE = MSB_UNSIGNED_INTEGER
SAMPLE_BITS = 16
BANDS = 18
BAND_STORAGE_TYPE = LINE_INTERLEAVED
MISSING_CONSTANT = 65535
CHECKSUM = "NULL"
END_OBJECT = IMAGE

OBJECT = ROWNUM_TABLE
NAME = "SELECTED ROWS FROM DETECTOR"
INTERCHANGE_FORMAT = "BINARY"
ROWS = 18
COLUMNS = 1
ROW_BYTES = 2
DESCRIPTION = "The detector is subsampled in the spectral direction
by selecting specific rows to be downlinked. This
table provides a list of the rows selected for all
frames in this multidimensional image cube."

OBJECT = COLUMN
NAME = DETECTOR_ROW_NUMBER
DATA_TYPE = MSB_UNSIGNED_INTEGER
BIT_MASK = 2#0000000111111111#
START_BYTE = 1
BYTES = 2
MISSING_CONSTANT = 65535
DESCRIPTION = "Detector row number from which the data was taken."
END_OBJECT = COLUMN

END_OBJECT = ROWNUM_TABLE

END_OBJECT = FILE

/* Description of EDR HOUSEKEEPING TABLE file */

OBJECT = FILE
^EDR_HK_TABLE = "MSP00002798_01_SC211S_HKP0.TAB"
RECORD_TYPE = FIXED_LENGTH
RECORD_BYTES = 1047
FILE_RECORDS = 225

```

```
OBJECT = EDR_HK_TABLE
  NAME           = "EDR HOUSEKEEPING TABLE"
  INTERCHANGE_FORMAT = "ASCII"
  ROWS           = 225
  COLUMNS       = 233
  ROW_BYTES      = 1047

/* Columns in the table are described in this external file: */
  ^STRUCTURE     = "EDRHK.FMT"

END_OBJECT = EDR_HK_TABLE

END_OBJECT = FILE
END
```

## APPENDIX B. DDR LABEL

```

PDS_VERSION_ID           = PDS3
LABEL_REVISION_NOTE      = "2004-11-22, S. Slavney (GEO);"
                          "2006-04-05, S. Murchie (JHU/APL);"

/*( NOTE: Comments in this label that are delimited with parentheses,      )*/
/*( for example:                                                    )*/
/*(     /*( comment )*/                                           )*/
/*( are notes to the data provider. These comments should be removed      )*/
/*( from the final label. Comments without parentheses, for example:     )*/
/*(     /* comment */                                           )*/
/*( are intended to be part of the final label.                        )*/

/* DDR Identification */

DATA_SET_ID              = "MRO-M-CRISM-6-DDR-V1.0"
PRODUCT_ID               = "EPF00000411_00_DE156S_DDR0"
/* cccnnnnnnnnn_xx_ooaaaas_DDRv          */
/* ccc = Class Type                      */
/* nnnnnnnnn = Observation ID (hex)      */
/* xx = counter this observation (hex)   */
/* ooaaa = obs type, macro number       */
/* s = sensor ID (S or L)               */
/* v = version number                   */

INSTRUMENT_HOST_NAME    = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID           = MRO
INSTRUMENT_NAME         = "COMPACT RECONNAISSANCE IMAGING
                          SPECTROMETER FOR MARS"

INSTRUMENT_ID           = CRISM
TARGET_NAME             = MARS
PRODUCT_TYPE            = DDR
PRODUCT_CREATION_TIME   = 2006-01-05T15:50:24.945
START_TIME              = 2007-12-19T06:01:46.816
STOP_TIME               = 2007-12-19T06:01:50.816
SPACECRAFT_CLOCK_START_COUNT = "2/0882511324:47630"
SPACECRAFT_CLOCK_STOP_COUNT  = "2/0882511328:47630"

ORBIT_NUMBER            = 0
OBSERVATION_TYPE        = "EPF" /*( ClassType from product ID )*/
OBSERVATION_ID          = 16#00000411 /*( Obs ID (hex) )*/
MRO:OBSERVATION_NUMBER  = 16#00 /*( Counter (hex) )*/
MRO:ACTIVITY_ID         = "DE156" /*( Activity from product ID )*/
MRO:SENSOR_ID           = "S" /*( or L, Sensor ID from product ID )*/
PRODUCT_VERSION_ID     = "0" /*( version number from product ID )*/
SOURCE_PRODUCT_ID       = {"tbd1", "tbd2",
                          "tbd3", "tbd4"} /*( as many as needed )*/

PRODUCER_INSTITUTION_NAME = "APPLIED PHYSICS LABORATORY"
SOFTWARE_NAME             = "fake_ddr_generator"
SOFTWARE_VERSION_ID       = "tbd"

/* DDR Instrument and Observation Parameters */

```

```

TARGET_CENTER_DISTANCE      = tbd <KM>
                             /* distance to Mars center at first frame */
SOLAR_DISTANCE              = tbd <KM>
SOLAR_LONGITUDE             = tbd <DEGREES>
MRO:FRAME_RATE              = 3.75 <HZ>
PIXEL_AVERAGING_WIDTH      = 10
MRO:INSTRUMENT_POINTING_MODE = "DYNAMIC POINTING" /*( or FIXED POINTING)*/
SCAN_MODE_ID                = "EPF" /*( or LONG or SHORT          )*/

/* This DDR label describes one data file:                                     */
/* 1. A multiple-band backplane image file with wavelength-independent,      */
/*    spatial pixel-dependent geometric and timing information.                */

/* See the CRISM Data Products SIS for more detailed description.            */

OBJECT                      = FILE
  ^IMAGE                    = "EPF00000411_00_DE156S_DDR0.IMG"
  RECORD_TYPE               = FIXED_LENGTH
  RECORD_BYTES              = 3584
  FILE_RECORDS              = 15

OBJECT                      = IMAGE
  LINES                     = 15
  LINE_SAMPLES              = 64
  SAMPLE_TYPE               = PC_REAL
  SAMPLE_BITS               = 32
  BANDS                     = 14
  BAND_STORAGE_TYPE        = BAND_SEQUENTIAL
  BAND_NAME                 = ("INA at areoid, deg",
                              "EMA at areoid, deg",
                              "Phase angle, deg",
                              "Latitude, areocentric, deg N",
                              "Longitude, areocentric, deg E",
                              "INA at surface from MOLA, deg",
                              "EMA at surface from MOLA, deg",
                              "Slope magnitude from MOLA, deg",
                              "MOLA slope azimuth, deg clkwise from N",
                              "Elevation, meters relative to MOLA",
                              "Thermal inertia, J m^-2 K^-1 s^-0.5",
                              "Bolometric albedo",
                              "Local solar time, hours",
                              "Spare")

  END_OBJECT                = IMAGE

END_OBJECT                  = FILE

END

```

## APPENDIX C1. TRDR LABEL (RADIANCE IMAGE + LISTFILE)

```

PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE    = "2004-11-22, S. Slavney (GEO);
                          2005-12-20, H. Taylor (JHU/APL);
                          2006-04-05, S. Murchie (JHU/APL);
                          2006-07-24, P. Cavender (JHU/APL);
                          2006-09-25, S. Murchie (JHU/APL)"
DATA_SET_ID             = "MRO-M-CRISM-3-RDR-TARGETED-V1.0"
PRODUCT_ID             = "MSW00000FDE_01_RA191S_TRR0"

/* cccnnnnnnnnn_xx_ooaaas_TRRv          */
/* ccc = Class Type                      */
/* nnnnnnnn = Observation ID, hexadecimal */
/* ooaaaa = Image type, Macro number     */
/* s = Sensor ID (S or L)                */
/* v = Version number                    */

INSTRUMENT_HOST_NAME   = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID          = MRO
INSTRUMENT_NAME        = "COMPACT RECONNAISSANCE IMAGING
                          SPECTROMETER FOR MARS"

INSTRUMENT_ID          = CRISM
TARGET_NAME            = MARS
PRODUCT_TYPE           = TARGETED_RDR
PRODUCT_CREATION_TIME  = 2006-08-17T19:35:26
START_TIME              = 2007-06-18T10:07:51.437
STOP_TIME               = 2007-06-18T10:08:06.406
SPACECRAFT_CLOCK_START_COUNT = "2/0866628488.17437"
SPACECRAFT_CLOCK_STOP_COUNT  = "2/0866628503.15389"
ORBIT_NUMBER           = "NULL"
OBSERVATION_TYPE       = "MSW"
OBSERVATION_ID         = "16#00000FDE#"
MRO:OBSERVATION_NUMBER = 16#01#
MRO:ACTIVITY_ID        = "RA191"
MRO:SENSOR_ID          = "S"
MRO:DETECTOR_TEMPERATURE = 184.229
MRO:OPTICAL_BENCH_TEMPERATURE = -260.240
MRO:SPECTROMETER_HOUSING_TEMP = 223.059
MRO:SPHERE_TEMPERATURE = -260.365
MRO:FPE_TEMPERATURE    = 222.556
PRODUCT_VERSION_ID     = "0"
SOURCE_PRODUCT_ID      = {
    "MSW00000FDE_01_SC191S_EDR0",
    "CDR6_1_0000000000_LI_J_0",
    "CDR6_1_0803692813_PP_S_0",
    "CDR6_1_0000000000_GH_S_0",
    "CDR6_1_0000000000_LC_S_1",
    "CDR410000000000_DM0000000S_1",
    "CDR6_1_0000000000_AS_S_0",
    "CDR6_1_0000000000_VL_S_0",
    "CDR6_2_0866591701_ST_J_0",
    "CDR6_1_0000000000_HK_J_1",
    "CDR6_1_0000000000_HD_J_1",
    "CDR6_1_0000000000_HV_J_1",
    "CDR6_1_0000000000_DB_S_0",
    "CDR6_1_0000000000_EB_S_0",
    "CDR410000000000_SH0000000S_0",
    "CDR410000000000_SS0000002S_0",
    "CDR410000000000_TD0000000S_0",

```

```

        "CDR410000000000_NU00000000S_0",
        "CDR410803692813_SF00000000S_0",
        "CDR420866628484_BI4242530S_0",
        "CDR420866628484_UB4242530S_0",
        "CDR420866628506_BI4242530S_0",
        "CDR420866628506_UB4242530S_0",
        "CDR420866628488_BF4242510S_0",
        "CDR420866639891_BF0042500S_0",
        "CDR420866639891_SP0042500S_0"
    }
PRODUCER_INSTITUTION_NAME      = "JOHNS HOPKINS UNIVERSITY
                                APPLIED PHYSICS LABORATORY"
SOFTWARE_NAME                   = "crism_imagecal"
SOFTWARE_VERSION_ID             = "0.9.1"

/* Targeted RDR Instrument and Observation Parameters */

TARGET_CENTER_DISTANCE         = "NULL" <KM>
SOLAR_DISTANCE                 = 206874845.925904 <KM>
SOLAR_LONGITUDE               = 259.879794
SHUTTER_MODE_ID               = "OPEN"
LIGHT_SOURCE_NAME              = "NONE"
MRO:CALIBRATION_LAMP_STATUS   = "OFF"
MRO:CALIBRATION_LAMP_LEVEL    = "N/A"
PIXEL_AVERAGING_WIDTH         = 5
MRO:INSTRUMENT_POINTING_MODE  = "FIXED POINTING"
SCAN_MODE_ID                   = "N/A"
MRO:FRAME_RATE                = 30.00 <HZ>
MRO:EXPOSURE_PARAMETER        = 425
SAMPLING_MODE_ID              = "MULTISPEC"
COMPRESSION_TYPE               = "NONE"
MRO:WAVELENGTH_FILTER         = "1"
MRO:WAVELENGTH_FILE_NAME      = "CDR6_1_0000000000_WV_S_1.TAB"
MRO:PIXEL_PROC_FILE_NAME      = "CDR6_1_0000000000_PP_S_1.TAB"
MRO:INV_LOOKUP_TABLE_FILE_NAME = "CDR6_1_0000000000_LI_J_0.LBL"
MRO:INVALID_PIXEL_LOCATION    = "NULL"
MRO:ATMO_CORRECTION_FLAG      = "OFF"
MRO:THERMAL_CORRECTION_MODE    = "OFF"
MRO:PHOTOCLIN_CORRECTION_FLAG = "OFF"
MRO:SPATIAL_RESAMPLING_FLAG   = "OFF"
MRO:SPATIAL_RESAMPLING_FILE   = "N/A"
MRO:SPATIAL_RESCALING_FLAG    = "OFF"
MRO:SPATIAL_RESCALING_FILE    = "N/A"
MRO:SPECTRAL_RESAMPLING_FLAG   = "OFF"
MRO:SPECTRAL_RESAMPLING_FILE  = "N/A"
/* This Targeted RDR label describes two data files.  The first file */
/* contains the first two objects and the second file contains the */
/* third: */
/* 1. A multiple-band image file containing calibrated RDR data, */
/*    in units of radiance, */
/* 2. A binary table of selected image row numbers from detector, */
/* 3. A table of ancillary and housekeeping data converted to */
/*    engineering units. */

OBJECT          = FILE
  ^IMAGE        = "MSW00000FDE_01_RA191S_TRR0.IMG"
  ^ROWNUM_TABLE = ("MSW00000FDE_01_RA191S_TRR0.IMG", 8101 )
  RECORD_TYPE   = FIXED_LENGTH
  RECORD_BYTES  = 512
  FILE_RECORDS  = 8101

OBJECT          = IMAGE
  LINES         = 450

```

```

LINE_SAMPLES      = 128
SAMPLE_TYPE      = PC_REAL
SAMPLE_BITS      = 32
UNIT             = "W / (m**2 micrometer sr)"
BANDS           = 18
BAND_STORAGE_TYPE = LINE_INTERLEAVED
END_OBJECT = IMAGE

OBJECT           = ROWNUM_TABLE
NAME            = "SELECTED ROWS FROM DETECTOR"
INTERCHANGE_FORMAT = "BINARY"
ROWS           = 18
COLUMNS       = 1
ROW_BYTES      = 2
DESCRIPTION    = "The detector is subsampled in the spectral direction
                  by selecting specific rows to be downlinked. This
                  table provides a list of the rows selected for all
                  frames in this multidimensional image cube."

OBJECT = COLUMN
NAME      = DETECTOR_ROW_NUMBER
DATA_TYPE = MSB_UNSIGNED_INTEGER
COLUMN_NUMBER = 1
BIT_MASK  = 2#0000000111111111#
START_BYTE = 1
BYTES      = 2
DESCRIPTION = "Detector row number from which the data was taken."
END_OBJECT = COLUMN
END_OBJECT = ROWNUM_TABLE

END_OBJECT = FILE

OBJECT = FILE
^TRDR_HK_TABLE      = "MSW00000FDE_01_RA191S_HKP0.TAB"
RECORD_TYPE        = FIXED_LENGTH
RECORD_BYTES       = 1221
FILE_RECORDS       = 450
OBJECT             = TRDR_HK_TABLE
NAME               = "TARGETED RDR HOUSEKEEPING TABLE"
INTERCHANGE_FORMAT = ASCII
ROWS              = 450
COLUMNS          = 233
ROW_BYTES         = 1221
^STRUCTURE        = "TRDRHK.FMT"
END_OBJECT        = TRDR_HK_TABLE
END_OBJECT = FILE
END

```

## APPENDIX C2. TRDR LABEL (I/F OR A\_L IMAGE)

```

PDS_VERSION_ID           = PDS3
LABEL_REVISION_NOTE      = "2004-11-22, S. Slavney (GEO);
                           2005-12-20, H. Taylor (JHU/APL);
                           2006-04-05, S. Murchie (JHU/APL);
                           2006-07-24, P. Cavender (JHU/APL);
                           2006-09-25, S. Murchie (JHU/APL)"
DATA_SET_ID              = "MRO-M-CRISM-3-RDR-TARGETED-V1.0"
PRODUCT_ID               = "MSW00000FDE_01_IF191S_TRR0"

/* cccnnnnnnnnn_xx_ooaaas_TRRv          */
/* ccc = Class Type                      */
/* nnnnnnnn = Observation ID, hexadecimal */
/* ooaaaa = Image type, Macro number     */
/* s = Sensor ID (S or L)                */
/* v = Version number                    */

INSTRUMENT_HOST_NAME     = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID           = MRO
INSTRUMENT_NAME         = "COMPACT RECONNAISSANCE IMAGING
                           SPECTROMETER FOR MARS"

INSTRUMENT_ID           = CRISM
TARGET_NAME             = MARS
PRODUCT_TYPE            = TARGETED_RDR
PRODUCT_CREATION_TIME   = 2006-08-17T19:35:26
START_TIME              = 2007-06-18T10:07:51.437
STOP_TIME               = 2007-06-18T10:08:06.406
SPACECRAFT_CLOCK_START_COUNT = "2/0866628488.17437"
SPACECRAFT_CLOCK_STOP_COUNT  = "2/0866628503.15389"
ORBIT_NUMBER            = "NULL"
OBSERVATION_TYPE        = "MSW"
OBSERVATION_ID          = "16#00000FDE#"
MRO:OBSERVATION_NUMBER  = 16#01#
MRO:ACTIVITY_ID         = "IF191"
MRO:SENSOR_ID           = "S"
MRO:DETECTOR_TEMPERATURE = 184.229
MRO:OPTICAL_BENCH_TEMPERATURE = -260.240
MRO:SPECTROMETER_HOUSING_TEMP = 223.059
MRO:SPHERE_TEMPERATURE  = -260.365
MRO:FPE_TEMPERATURE     = 222.556
PRODUCT_VERSION_ID      = "0"
SOURCE_PRODUCT_ID       = {
    "MSW00000FDE_01_SC191S_EDR0",
    "CDR6_1_0000000000_LI_J_0",
    "CDR6_1_0803692813_PP_S_0",
    "CDR6_1_0000000000_GH_S_0",
    "CDR6_1_0000000000_LC_S_1",
    "CDR410000000000_DM0000000S_1",
    "CDR6_1_0000000000_AS_S_0",
    "CDR6_1_0000000000_VL_S_0",
    "CDR6_2_0866591701_ST_J_0",
    "CDR6_1_0000000000_HK_J_1",
    "CDR6_1_0000000000_HD_J_1",
    "CDR6_1_0000000000_HV_J_1",
    "CDR6_1_0000000000_DB_S_0",
    "CDR6_1_0000000000_EB_S_0",
    "CDR410000000000_SH0000000S_0",
    "CDR410000000000_SS0000002S_0",
    "CDR410000000000_TD0000000S_0",

```

```

        "CDR410000000000_NU00000000S_0",
        "CDR410803692813_SF00000000S_0",
        "CDR420866628484_BI4242530S_0",
        "CDR420866628484_UB4242530S_0",
        "CDR420866628506_BI4242530S_0",
        "CDR420866628506_UB4242530S_0",
        "CDR420866628488_BP4242510S_0",
        "CDR420866639891_BP0042500S_0",
        "CDR420866639891_SP0042500S_0"
    }
PRODUCER_INSTITUTION_NAME      = "JOHNS HOPKINS UNIVERSITY
                                APPLIED PHYSICS LABORATORY"
SOFTWARE_NAME                   = "crism_imagecal"
SOFTWARE_VERSION_ID             = "0.9.1"

/* Targeted RDR Instrument and Observation Parameters */

TARGET_CENTER_DISTANCE         = "NULL" <KM>
SOLAR_DISTANCE                 = 206874845.925904 <KM>
SOLAR_LONGITUDE               = 259.879794
SHUTTER_MODE_ID               = "OPEN"
LIGHT_SOURCE_NAME             = "NONE"
MRO:CALIBRATION_LAMP_STATUS   = "OFF"
MRO:CALIBRATION_LAMP_LEVEL    = "N/A"
PIXEL_AVERAGING_WIDTH         = 5
MRO:INSTRUMENT_POINTING_MODE  = "FIXED POINTING"
SCAN_MODE_ID                  = "N/A"
MRO:FRAME_RATE                = 30.00 <HZ>
MRO:EXPOSURE_PARAMETER        = 425
SAMPLING_MODE_ID              = "MULTISPEC"
COMPRESSION_TYPE              = "NONE"
MRO:WAVELENGTH_FILTER         = "1"
MRO:WAVELENGTH_FILE_NAME      = "CDR6_1_0000000000_WV_S_1.TAB"
MRO:PIXEL_PROC_FILE_NAME      = "CDR6_1_0000000000_PP_S_1.TAB"
MRO:INV_LOOKUP_TABLE_FILE_NAME = "CDR6_1_0000000000_LI_J_0.TAB"
MRO:INVALID_PIXEL_LOCATION    = "NULL"
MRO:ATMO_CORRECTION_FLAG      = "OFF"
MRO:THERMAL_CORRECTION_MODE   = "OFF"
MRO:PHOTOCLIN_CORRECTION_FLAG = "OFF"
MRO:SPATIAL_RESAMPLING_FLAG   = "OFF"
MRO:SPATIAL_RESAMPLING_FILE   = "N/A"
MRO:SPATIAL_RESCALING_FLAG    = "OFF"
MRO:SPATIAL_RESCALING_FILE    = "N/A"
MRO:SPECTRAL_RESAMPLING_FLAG   = "OFF"
MRO:SPECTRAL_RESAMPLING_FILE  = "N/A"
/* This Targeted RDR label describes two data files.  The first file */
/* contains the first two objects and the second file contains the */
/* third: */
/* 1. A multiple-band image file containing calibrated RDR data, */
/*    in units of I / F, */
/* 2. A binary table of selected image row numbers from detector, */
/* 3. A table of ancillary and housekeeping data converted to */
/*    engineering units. */

OBJECT          = FILE
  ^IMAGE        = "MSW00000FDE_01_IF191S_TRR0.IMG"
  ^ROWNUM_TABLE = ("MSW00000FDE_01_IF191S_TRR0.IMG", 8101 )
  RECORD_TYPE   = FIXED_LENGTH
  RECORD_BYTES  = 512
  FILE_RECORDS  = 8101

OBJECT          = IMAGE
  LINES         = 450

```

```

LINE_SAMPLES      = 128
SAMPLE_TYPE      = PC_REAL
SAMPLE_BITS      = 32
UNIT             = "I_OVER_F"
BANDS            = 18
BAND_STORAGE_TYPE = LINE_INTERLEAVED
END_OBJECT = IMAGE

OBJECT           = ROWNUM_TABLE
NAME            = "SELECTED ROWS FROM DETECTOR"
INTERCHANGE_FORMAT = "BINARY"
ROWS           = 18
COLUMNS       = 1
ROW_BYTES      = 2
DESCRIPTION    = "The detector is subsampled in the spectral direction
                  by selecting specific rows to be downlinked.  This
                  table provides a list of the rows selected for all
                  frames in this multidimensional image cube."

OBJECT = COLUMN
NAME      = DETECTOR_ROW_NUMBER
DATA_TYPE = MSB_UNSIGNED_INTEGER
COLUMN_NUMBER = 1
BIT_MASK  = 2#0000000111111111#
START_BYTE = 1
BYTES      = 2
DESCRIPTION = "Detector row number from which the data was taken."
END_OBJECT = COLUMN
END_OBJECT = ROWNUM_TABLE

END_OBJECT = FILE

END

```

## APPENDIX C3. TRDR LABEL (SUMMARY PRODUCT IMAGE)

```

PDS_VERSION_ID           = PDS3
LABEL_REVISION_NOTE     = "2004-11-22, S. Slavney (GEO);
                          "2005-12-20, H. Taylor (JHU/APL);"
                          "2006-04-05, S. Murchie (JHU/APL);"
                          "2006-09-25, S. Murchie (JHU/APL)"
DATA_SET_ID              = "MRO-M-CRISM-3-RDR-TARGETED-V1.0"
PRODUCT_ID               = "MSW00000FDE_01_SU191S_TRR0"

```

```

/* cccnnnnnnnnn_xx_ooaaa TRRv          */
/* ccc = Class Type                    */
/* nnnnnnnn = Observation ID, hexadecimal*/
/* xx = counter within this observation */
/* oaaaa = image type, macro number     */
/* s = sensor ID (S or L)              */
/* v = version number                  */

```

```

INSTRUMENT_HOST_NAME     = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID            = MRO
INSTRUMENT_NAME          = "COMPACT RECONNAISSANCE IMAGING
                          SPECTROMETER FOR MARS"
INSTRUMENT_ID            = CRISM
TARGET_NAME              = MARS
PRODUCT_TYPE             = TARGETED_RDR
PRODUCT_CREATION_TIME    = 2006-08-17T19:35:26
START_TIME                = 2007-06-18T10:07:51.437
STOP_TIME                 = 2007-06-18T10:08:06.406
SPACECRAFT_CLOCK_START_COUNT = "2/0866628488.17437"
SPACECRAFT_CLOCK_STOP_COUNT  = "2/0866628503.15389"
ORBIT_NUMBER              = "NULL"
OBSERVATION_TYPE         = "MSW"
OBSERVATION_ID           = "16#00000FDE#"
MRO:OBSERVATION_NUMBER   = 16#01#

```

```

MRO:ACTIVITY_ID          = "SU191"
MRO:SENSOR_ID            = "S"
MRO:DETECTOR_TEMPERATURE = 184.229
MRO:OPTICAL_BENCH_TEMPERATURE = -260.240
MRO:SPECTROMETER_HOUSING_TEMP = 223.059
MRO:SPHERE_TEMPERATURE  = -260.365
MRO:FPE_TEMPERATURE      = 222.556
PRODUCT_VERSION_ID       = "0"
SOURCE_PRODUCT_ID        = {
    "MSW00000FDE_01_SC191S_EDR0",
    "CDR6_1_0000000000_LI_J_0",
    "CDR6_1_0803692813_PP_S_0",
    "CDR6_1_0000000000_GH_S_0",
    "CDR6_1_0000000000_LC_S_1",
    "CDR410000000000_DM0000000S_1",
    "CDR6_1_0000000000_AS_S_0",
    "CDR6_1_0000000000_VL_S_0",
    "CDR6_2_0866591701_ST_J_0",
    "CDR6_1_0000000000_HK_J_1",
    "CDR6_1_0000000000_HD_J_1",
    "CDR6_1_0000000000_HV_J_1",
    "CDR6_1_0000000000_DB_S_0",
    "CDR6_1_0000000000_EB_S_0",
    "CDR410000000000_SH0000000S_0",

```

```

"CDR410000000000_SS0000002S_0",
"CDR410000000000_TD0000000S_0",
"CDR410000000000_NU0000000S_0",
"CDR410803692813_SF0000000S_0",
"CDR420866628484_BI4242530S_0",
"CDR420866628484_UB4242530S_0",
"CDR420866628506_BI4242530S_0",
"CDR420866628506_UB4242530S_0",
"CDR420866628488_BP4242510S_0",
"CDR420866639891_BP0042500S_0",
"CDR420866639891_SP0042500S_0"
}
PRODUCER_INSTITUTION_NAME = "JOHNS HOPKINS UNIVERSITY
                              APPLIED PHYSICS LABORATORY"
SOFTWARE_NAME = "crism_imagecal"
SOFTWARE_VERSION_ID = "0.9.1"

/* Targeted RDR Instrument and Observation Parameters */

TARGET_CENTER_DISTANCE = "NULL" <KM>
SOLAR_DISTANCE = 206874845.925904 <KM>
SOLAR_LONGITUDE = 259.879794
SHUTTER_MODE_ID = "OPEN"
LIGHT_SOURCE_NAME = "NONE"
MRO:CALIBRATION_LAMP_STATUS = "OFF"
MRO:CALIBRATION_LAMP_LEVEL = "N/A"
PIXEL_AVERAGING_WIDTH = 5
MRO:INSTRUMENT_POINTING_MODE = "FIXED POINTING"
SCAN_MODE_ID = "N/A"
MRO:FRAME_RATE = 30.00 <HZ>
MRO:EXPOSURE_PARAMETER = 425
SAMPLING_MODE_ID = "MULTISPEC"
COMPRESSION_TYPE = "NONE"
MRO:WAVELENGTH_FILTER = "1"
MRO:WAVELENGTH_FILE_NAME = "CDR6_1_0000000000_WV_S_1.TAB"
MRO:PIXEL_PROC_FILE_NAME = "CDR6_1_0000000000_PP_S_1.TAB"
MRO:INV_LOOKUP_TABLE_FILE_NAME = "CDR6_1_0000000000_LI_J_0.LBL"
MRO:INVALID_PIXEL_LOCATION = "NULL"
MRO:ATMO_CORRECTION_FLAG = "OFF"
MRO:THERMAL_CORRECTION_MODE = "OFF"
MRO:PHOTOCLIN_CORRECTION_FLAG = "OFF"
MRO:SPATIAL_RESAMPLING_FLAG = "OFF"
MRO:SPATIAL_RESAMPLING_FILE = "N/A"
MRO:SPATIAL_RESCALING_FLAG = "OFF"
MRO:SPATIAL_RESCALING_FILE = "N/A"
MRO:SPECTRAL_RESAMPLING_FLAG = "OFF"
MRO:SPECTRAL_RESAMPLING_FILE = "N/A"
/* This Targeted RDR label describes one data file: */
/* 1. A multiple-band backplane image file of computed parameters, */
/* See the CRISM Data Products SIS for more detailed description. */

/* Description of TARGETED RDR BACKPLANE IMAGE file */

OBJECT = FILE
  ^IMAGE = "MSW00000FDE_01_SU191S_TRR0.IMG"
  RECORD_TYPE = FIXED_LENGTH
  RECORD_BYTES = 512
  FILE_RECORDS = 8101

OBJECT = IMAGE
  LINES = 15
  LINE_SAMPLES = 64
  SAMPLE_TYPE = PC_REAL

```

```

SAMPLE_BITS          = 32
BANDS                = 45
BAND_STORAGE_TYPE   = LINE_INTERLEAVED
BAND_NAME           = ("R770",
                       "RBR",
                       "BD530",
                       "SH600",
                       "BD640",
                       "BD860",
                       "BD920",
                       "RPEAK1",
                       "BDI1000VIS",
                       "BDI1000IR",
                       "IRAC",
                       "OLINDEX",
                       "LCPINDEX",
                       "HCPXINDEX",
                       "VAR",
                       "ISLOPE1",
                       "BD1435",
                       "BD1500",
                       "ICER1",
                       "BD1750",
                       "BD1900",
                       "BDI2000",
                       "BD2100",
                       "BD2210",
                       "BD2290",
                       "D2300",
                       "SINDEX",
                       "BDCARB",
                       "BD3000",
                       "BD3100",
                       "BD3200",
                       "BD3400",
                       "CINDEX",
                       "R440",
                       "IRR1",
                       "BD127002",
                       "BD1400H2O",
                       "BD2000CO2",
                       "BD2350",
                       "BD2600",
                       "IRR2",
                       "R2700",
                       "BD2700",
                       "IRR3")
END_OBJECT          = IMAGE
END_OBJECT          = FILE
END

```

## APPENDIX D1. MRDR LABEL (I/F IMAGE)

```

PDS_VERSION_ID           = PDS3
LABEL_REVISION_NOTE      = "2003-11-19, S. Slavney (GEO);
                          2005-09-25, S. Murchie (JHU/APL)"

/* Map-projected Multispectral RDR Identification */

DATA_SET_ID              = "MRO-M-CRISM-5-RDR-MULTISPECTRAL-V1.0"
PRODUCT_ID               = "T0123_MRRRA_10N355_0256_0"
                          /*( Tnnnn_MRRss_xxdyyy_rrrr_v                )*/
                          /*( nnnn = tile number                       )*/
                          /*( ss = subtype of image product           )*/
                          /*( xx = latitude of tile center            )*/
                          /*( d = N or S for north or south latitude  )*/
                          /*( yyy = east longitude of tile center     )*/
                          /*( rrrr = resolution in pixels/degree      )*/
                          /*( v = version number                       )*/

INSTRUMENT_HOST_NAME     = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID            = MRO
INSTRUMENT_NAME          = "COMPACT RECONNAISSANCE IMAGING
                          SPECTROMETER FOR MARS"

INSTRUMENT_ID            = CRISM
TARGET_NAME              = MARS
PRODUCT_TYPE             = MAP_PROJECTED_MULTISPECTRAL_RDR
PRODUCT_CREATION_TIME    = 2006-06-17T13:03:07.234
START_TIME               = "N/A"
STOP_TIME                = "N/A"
SPACECRAFT_CLOCK_START_COUNT = "N/A"
SPACECRAFT_CLOCK_STOP_COUNT = "N/A"
PRODUCT_VERSION_ID       = "0" /*( version number from product ID )*/
PRODUCER_INSTITUTION_NAME = "APPLIED PHYSICS LABORATORY"
SOFTWARE_NAME            = "tbd"
SOFTWARE_VERSION_ID      = "tbd"
MRO:WAVELENGTH_FILE_NAME = "T0123_MRRWV_10N355_0256_0.TAB"

/* This Map Projected Multispectral RDR label describes one data file: */
/* 1. A multiple-band image file of calibrated RDR data in I/F,      */
/* This RDR represents one latitude-longitude bin in a global map.   */
/* See the Map Projection Object below for bin coordinates and resolution.*/
/* See the CRISM Data Products SIS for more detailed description.    */

/* Description of MAP PROJECTED MULTISPECTRAL RDR I/F IMAGE file */

OBJECT                    = FILE
  ^IMAGE                  = "T0123_MRRRA_10N355_0256_0.IMG"
  RECORD_TYPE             = FIXED_LENGTH
  RECORD_BYTES            = 5120
  FILE_RECORDS            = 92160

OBJECT                    = IMAGE
  LINES                   = 1280
  LINE_SAMPLES            = 1280
  SAMPLE_TYPE             = PC_REAL
  SAMPLE_BITS             = 32
  UNIT                    = "W / (m**2 micrometer sr)"
  BANDS                   = 72
  BAND_STORAGE_TYPE       = LINE_INTERLEAVED
  END_OBJECT              = IMAGE

```

```

END_OBJECT = FILE

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

OBJECT = IMAGE_MAP_PROJECTION
^DATA_SET_MAP_PROJECTION = "MRR_MAP.CAT"
MAP_PROJECTION_TYPE = "EQUIRECTANGULAR"
/* ( or POLAR STEREOGRAPHIC )*/
A_AXIS_RADIUS = 3393.4 <KM>
B_AXIS_RADIUS = 3393.4 <KM>
C_AXIS_RADIUS = 3375.7 <KM>
FIRST_STANDARD_PARALLEL = "N/A"
SECOND_STANDARD_PARALLEL = "N/A"
POSITIVE_LONGITUDE_DIRECTION = "EAST"
CENTER_LATITUDE = 5.0 <DEGREE>
/* ( for this tile only center latitude )*/
/* ( of projection, the low-latitude edge )*/
/* ( of the tile )*/
CENTER_LONGITUDE = 0.0 <DEGREE>
REFERENCE_LATITUDE = "N/A"
REFERENCE_LONGITUDE = "N/A"
LINE_FIRST_PIXEL = 1
/* ( line number of N edge of this tile )*/
LINE_LAST_PIXEL = 1280
/* ( line number of S edge of this tile )*/
SAMPLE_FIRST_PIXEL = 1
/* ( sample number of W edge of this tile )*/
SAMPLE_LAST_PIXEL = 1280
/* ( sample number of E edge of this tile )*/
MAP_PROJECTION_ROTATION = 0.0
MAP_RESOLUTION = 256 <PIXEL/DEGREE>
MAP_SCALE = 0.23 <KM/PIXEL>
/* ( this is average over the planet)*/
MAXIMUM_LATITUDE = 10.0 <DEGREE>
/* ( for this tile only)*/
MINIMUM_LATITUDE = 5.0 <DEGREE>
/* ( for this tile only)*/
WESTERNMOST_LONGITUDE = 355.0 <DEGREE>
/* ( for this tile only)*/
EASTERNMOST_LONGITUDE = 0.0 <DEGREE>
/* ( for this tile only)*/
LINE_PROJECTION_OFFSET = 2560
/* ( for this tile only; number of )*/
/* ( pixels from equator to first pixel )*/
/* ( of map tile )*/
SAMPLE_PROJECTION_OFFSET = -1280
/* ( for this tile only; number of )*/
/* ( pixels from 0 degrees longitude )*/
/* ( to first pixel of map tile )*/
COORDINATE_SYSTEM_TYPE = "BODY-FIXED ROTATING"
COORDINATE_SYSTEM_NAME = "PLANETOCENTRIC"
END_OBJECT = IMAGE_MAP_PROJECTION

END

```

## APPENDIX D2. MRDR LABEL (LAMBERT ALBEDO IMAGE)

```

PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE    = "2003-11-19, S. Slavney (GEO);
                        2005-09-25, S. Murchie (JHU/APL)"

/* Map-projected Multispectral RDR Identification */

DATA_SET_ID             = "MRO-M-CRISM-5-RDR-MULTISPECTRAL-V1.0"
PRODUCT_ID              = "T0123_MRRAL_10N355_0256_0"
                        /*( Tnnnn_MRRss_xxdyyy_rrrr_v                )*/
                        /*( nnnn = tile number                       )*/
                        /*( ss = subtype of imagbe product          )*/
                        /*( xx = latitude of tile center            )*/
                        /*( d = N or S for north or south latitude  )*/
                        /*( yyy = east longitude of tile center     )*/
                        /*( rrrr = resolution in pixels/degree      )*/
                        /*( v = version number                       )*/

INSTRUMENT_HOST_NAME    = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID           = MRO
INSTRUMENT_NAME         = "COMPACT RECONNAISSANCE IMAGING
                        SPECTROMETER FOR MARS"

INSTRUMENT_ID           = CRISM
TARGET_NAME             = MARS
PRODUCT_TYPE            = MAP_PROJECTED_MULTISPECTRAL_RDR
PRODUCT_CREATION_TIME   = 2006-06-17T13:03:07.234
START_TIME              = "N/A"
STOP_TIME               = "N/A"
SPACECRAFT_CLOCK_START_COUNT = "N/A"
SPACECRAFT_CLOCK_STOP_COUNT = "N/A"
PRODUCT_VERSION_ID      = "0" /*( version number from product ID )*/
PRODUCER_INSTITUTION_NAME = "APPLIED PHYSICS LABORATORY"
SOFTWARE_NAME           = "tbd"
SOFTWARE_VERSION_ID     = "tbd"
MRO:WAVELENGTH_FILE_NAME = "T0123_MRRWV_10N355_0256_0.TAB"

/* This Map Projected Multispectral RDR label describes one data file: */
/* 2. A multiple-band image file of Lambert albedo with */
/* atmospheric, photometric, and thermal emission corrections */
/* applied */
/* This RDR represents one latitude-longitude bin in a global map. */
/* See the Map Projection Object below for bin coordinates and resolution.*/
/* See the CRISM Data Products SIS for more detailed description. */

/* Description of MAP PROJECTED MULTISPECTRAL RDR I/F IMAGE file */

OBJECT                  = FILE
  ^IMAGE                = "T0123_MRRAL_10N355_0256_0.IMG"
  RECORD_TYPE           = FIXED_LENGTH
  RECORD_BYTES          = 5120
  FILE_RECORDS          = 92160

OBJECT                  = IMAGE
  LINES                 = 1280
  LINE_SAMPLES          = 1280
  SAMPLE_TYPE           = PC_REAL
  SAMPLE_BITS           = 32
  UNIT                  = "LAMBERT_ALBEDO"
  BANDS                 = 72

```

```

    BAND_STORAGE_TYPE      = LINE_INTERLEAVED
    END_OBJECT             = IMAGE

END_OBJECT                = FILE

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

OBJECT                    = IMAGE_MAP_PROJECTION
  ^DATA_SET_MAP_PROJECTION = "MRR_MAP.CAT"
  MAP_PROJECTION_TYPE      = "EQUIRECTANGULAR"
                          /* ( or POLAR STEREOGRAPHIC ) */
  A_AXIS_RADIUS            = 3393.4 <KM>
  B_AXIS_RADIUS            = 3393.4 <KM>
  C_AXIS_RADIUS            = 3375.7 <KM>
  FIRST_STANDARD_PARALLEL = "N/A"
  SECOND_STANDARD_PARALLEL = "N/A"
  POSITIVE_LONGITUDE_DIRECTION = "EAST"
  CENTER_LATITUDE         = 5.0 <DEGREE>
                          /* ( for this tile only center latitude ) */
                          /* ( of projection, the low-latitude edge ) */
                          /* ( of the tile ) */
  CENTER_LONGITUDE        = 0.0 <DEGREE>
  REFERENCE_LATITUDE      = "N/A"
  REFERENCE_LONGITUDE     = "N/A"
  LINE_FIRST_PIXEL        = 1
                          /* ( line number of N edge of this tile ) */
  LINE_LAST_PIXEL         = 1280
                          /* ( line number of S edge of this tile ) */
  SAMPLE_FIRST_PIXEL      = 1
                          /* ( sample number of W edge of this tile ) */
  SAMPLE_LAST_PIXEL       = 1280
                          /* ( sample number of E edge of this tile ) */
  MAP_PROJECTION_ROTATION = 0.0
  MAP_RESOLUTION          = 256 <PIXEL/DEGREE>
  MAP_SCALE                = 0.23 <KM/PIXEL>
                          /* ( this is average over the planet ) */
  MAXIMUM_LATITUDE        = 10.0 <DEGREE>
                          /* ( for this tile only ) */
  MINIMUM_LATITUDE        = 5.0 <DEGREE>
                          /* ( for this tile only ) */
  WESTERNMOST_LONGITUDE   = 355.0 <DEGREE>
                          /* ( for this tile only ) */
  EASTERNMOST_LONGITUDE   = 0.0 <DEGREE>
                          /* ( for this tile only ) */
  LINE_PROJECTION_OFFSET  = 2560
                          /* ( for this tile only; number of ) */
                          /* ( pixels from equator to first pixel ) */
                          /* ( of map tile ) */
  SAMPLE_PROJECTION_OFFSET = -1280
                          /* ( for this tile only; number of ) */
                          /* ( pixels from 0 degrees longitude ) */
                          /* ( to first pixel of map tile ) */
  COORDINATE_SYSTEM_TYPE  = "BODY-FIXED ROTATING"
  COORDINATE_SYSTEM_NAME  = "PLANETOCENTRIC"
END_OBJECT                = IMAGE_MAP_PROJECTION

END

```

## APPENDIX D3. MRDR LABEL (DERIVED DATA IMAGE)

```

PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE     = "2003-11-19, S. Slavney (GEO);
                          2005-09-25, S. Murchie (JHU/APL)"

/* Map-projected Multispectral RDR Identification */

DATA_SET_ID              = "MRO-M-CRISM-5-RDR-MULTISPECTRAL-V1.0"
PRODUCT_ID               = "T0123_MRRDE_10N355_0256_0"
                          /*( Tnnnn_MRRss_xxdyyy_rrrr_v          )*/
                          /*( nnnn = tile number                 )*/
                          /*( ss = subtype of image product     )*/
                          /*( xx = latitude of tile center      )*/
                          /*( d = N or S for north or south latitude )*/
                          /*( yyy = east longitude of tile center )*/
                          /*( rrrr = resolution in pixels/degree )*/
                          /*( v = version number                 )*/

INSTRUMENT_HOST_NAME     = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID            = MRO
INSTRUMENT_NAME          = "COMPACT RECONNAISSANCE IMAGING
                          SPECTROMETER FOR MARS"

INSTRUMENT_ID            = CRISM
TARGET_NAME              = MARS
PRODUCT_TYPE             = MAP_PROJECTED_MULTISPECTRAL_RDR
PRODUCT_CREATION_TIME    = 2006-06-17T13:03:07.234
START_TIME               = "N/A"
STOP_TIME                = "N/A"
SPACECRAFT_CLOCK_START_COUNT = "N/A"
SPACECRAFT_CLOCK_STOP_COUNT = "N/A"
PRODUCT_VERSION_ID       = "0" /*( version number from product ID )*/
PRODUCER_INSTITUTION_NAME = "APPLIED PHYSICS LABORATORY"
SOFTWARE_NAME            = "tbd"
SOFTWARE_VERSION_ID      = "tbd"
MRO:WAVELENGTH_FILE_NAME = "N/A"

/* This Map Projected Multispectral RDR label describes one data file: */
/* 3. A multiple-band backplane file of geometric and timing data, */
/* This RDR represents one latitude-longitude bin in a global map. */
/* See the Map Projection Object below for bin coordinates and resolution.*/
/* See the CRISM Data Products SIS for more detailed description. */

/* Description of MP MULTISPECTRAL GEOMETRIC/TIMING BACKPLANE file */

OBJECT                    = FILE
  ^IMAGE                  = "T0123_MRRDE_10N355_0256_0.IMG"
  RECORD_TYPE             = FIXED_LENGTH
  RECORD_BYTES            = 5120
  FILE_RECORDS            = 30720

OBJECT                    = IMAGE
  LINES                   = 1280
  LINE_SAMPLES            = 1280
  SAMPLE_TYPE             = PC_REAL
  SAMPLE_BITS             = 32
  BANDS                   = 24
  BAND_STORAGE_TYPE       = BAND_SEQUENTIAL
  BAND_NAME                = ("Solar longitude, deg",
                             "Solar distance, AU",

```

```

"Observation ID, VNIR",
"Observation ID, IR",
"Ordinal counter, VNIR",
"Ordinal counter, IR",
"Column number, VNIR",
"Column number, IR",
"Line, or frame number, VNIR",
"Line, or frame number, IR",
"INA at areoid, deg",
"EMA at areoid, deg",
"Phase angle, deg",
"Latitude, areocentric, deg N",
"Longitude, areocentric, deg E",
"INA at surface from MOLA, deg",
"EMA at surface from MOLA, deg",
"Slope magnitude from MOLA, deg",
"MOLA slope azimuth, deg clkwise from N",
"Elevation, meters relative to MOLA",
"Thermal inertia, J m^-2 K^-1 s^-0.5",
"Bolometric albedo",
"Local solar time, hours",
"Spare")
END_OBJECT = IMAGE
END_OBJECT = FILE

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

OBJECT = IMAGE_MAP_PROJECTION
^DATA_SET_MAP_PROJECTION = "MRR_MAP.CAT"
MAP_PROJECTION_TYPE = "EQUIRECTANGULAR"
/*( or POLAR STEREOGRAPHIC )*/
A_AXIS_RADIUS = 3393.4 <KM>
B_AXIS_RADIUS = 3393.4 <KM>
C_AXIS_RADIUS = 3375.7 <KM>
FIRST_STANDARD_PARALLEL = "N/A"
SECOND_STANDARD_PARALLEL = "N/A"
POSITIVE_LONGITUDE_DIRECTION = "EAST"
CENTER_LATITUDE = 5.0 <DEGREE>
/*( for this tile only center latitude )*/
/*( of projection, the low-latitude edge )*/
/*( of the tile )*/
CENTER_LONGITUDE = 0.0 <DEGREE>
REFERENCE_LATITUDE = "N/A"
REFERENCE_LONGITUDE = "N/A"
LINE_FIRST_PIXEL = 1
/*( line number of N edge of this tile )*/
LINE_LAST_PIXEL = 1280
/*( line number of S edge of this tile )*/
SAMPLE_FIRST_PIXEL = 1
/*( sample number of W edge of this tile )*/
SAMPLE_LAST_PIXEL = 1280
/*( sample number of E edge of this tile )*/
MAP_PROJECTION_ROTATION = 0.0
MAP_RESOLUTION = 256 <PIXEL/DEGREE>
MAP_SCALE = 0.23 <KM/PIXEL>
/*( this is average over the planet)*/
MAXIMUM_LATITUDE = 10.0 <DEGREE>
/*( for this tile only)*/
MINIMUM_LATITUDE = 5.0 <DEGREE>
/*( for this tile only)*/
WESTERNMOST_LONGITUDE = 355.0 <DEGREE>

```

```

                                /*( for this tile only)*/
EASTERNMOST_LONGITUDE         = 0.0 <DEGREE>
                                /*( for this tile only)*/
LINE_PROJECTION_OFFSET        = 2560
                                /*( for this tile only; number of )*/
                                /*( pixels from equator to first pixel )*/
                                /*( of map tile )*/
SAMPLE_PROJECTION_OFFSET      = -1280
                                /*( for this tile only; number of )*/
                                /*( pixels from 0 degrees longitude )*/
                                /*( to first pixel of map tile )*/
COORDINATE_SYSTEM_TYPE        = "BODY-FIXED ROTATING"
COORDINATE_SYSTEM_NAME        = "PLANETOCENTRIC"
END_OBJECT                     = IMAGE_MAP_PROJECTION

END

```

## APPENDIX D4. MRDR LABEL (SUMMARY PRODUCT IMAGE)

```

PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE     = "2003-11-19, S. Slavney (GEO);
                          2005-09-25, S. Murchie (JHU/APL)"

/* Map-projected Multispectral RDR Identification */

DATA_SET_ID             = "MRO-M-CRISM-5-RDR-MULTISPECTRAL-V1.0"
PRODUCT_ID              = "T0123_MRRSU_10N355_0256_0"
                          /*( Tnnnn_MRRss_xxdyyy_rrrr_v          )*/
                          /*( nnnn = tile number                 )*/
                          /*( ss = subtype of image product     )*/
                          /*( xx = latitude of tile center      )*/
                          /*( d = N or S for north or south latitude )*/
                          /*( yyy = east longitude of tile center )*/
                          /*( rrrr = resolution in pixels/degree )*/
                          /*( v = version number                 )*/

INSTRUMENT_HOST_NAME    = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID           = MRO
INSTRUMENT_NAME         = "COMPACT RECONNAISSANCE IMAGING
                          SPECTROMETER FOR MARS"

INSTRUMENT_ID           = CRISM
TARGET_NAME             = MARS
PRODUCT_TYPE            = MAP_PROJECTED_MULTISPECTRAL_RDR
PRODUCT_CREATION_TIME   = 2006-06-17T13:03:07.234
START_TIME              = "N/A"
STOP_TIME               = "N/A"
SPACECRAFT_CLOCK_START_COUNT = "N/A"
SPACECRAFT_CLOCK_STOP_COUNT = "N/A"
PRODUCT_VERSION_ID      = "0" /*( version number from product ID )*/
PRODUCER_INSTITUTION_NAME = "APPLIED PHYSICS LABORATORY"
SOFTWARE_NAME           = "tbd"
SOFTWARE_VERSION_ID     = "tbd"
MRO:WAVELENGTH_FILE_NAME = "N/A"

/* This Map Projected Multispectral RDR label describes one data file: */
/* 4. A multiple-band backplane file of computed summary parameters. */
/* This RDR represents one latitude-longitude bin in a global map. */
/* See the Map Projection Object below for bin coordinates and resolution.*/
/* See the CRISM Data Products SIS for more detailed description. */

/* Description of MP MULTISPECTRAL SUMMARY PARAMETERS BACKPLANE file */

OBJECT                  = FILE
  ^IMAGE                = "T0123_MRRSU_10N355_0256_0.IMG"
  RECORD_TYPE           = FIXED_LENGTH
  RECORD_BYTES          = 5120
  FILE_RECORDS          = 56320

OBJECT                  = IMAGE
  LINES                 = 1280
  LINE_SAMPLES          = 1280
  SAMPLE_TYPE           = PC_REAL
  SAMPLE_BITS           = 32
  BANDS                 = 45
  BAND_STORAGE_TYPE     = LINE_INTERLEAVED
  BAND_NAME              = ("R770",
                          "R770",

```

```

"RBR",
"BD530",
"SH600",
"BD640",
"BD860",
"BD920",
"RPEAK1",
"BDI1000VIS",
"BDI1000IR",
"IRAC",
"OLINDEX",
"LCPINDEX",
"HCPXINDEX",
"VAR",
"ISLOPE1",
"BD1435",
"BD1500",
"ICER1",
"BD1750",
"BD1900",
"BDI2000",
"BD2100",
"BD2210",
"BD2290",
"D2300",
"SINDEX",
"ICER2",
"BDCARB",
"BD3000",
"BD3100",
"BD3200",
"BD3400",
"CINDEX",
"R440",
"IRR1",
"BD127002",
"BD1400H2O",
"BD2000CO2",
"BD2350",
"BD2600",
"IRR2",
"R2700",
"BD2700",
"IRR3")
END_OBJECT = IMAGE
END_OBJECT = FILE
/* Map projection information about this RDR is in the IMAGE_MAP_PROJECTION */
/* object below. */
OBJECT = IMAGE_MAP_PROJECTION
^DATA_SET_MAP_PROJECTION = "MRR_MAP.CAT"
MAP_PROJECTION_TYPE = "EQUIRECTANGULAR"
/* ( or POLAR STEREOGRAPHIC )*/

```

```

A_AXIS_RADIUS           = 3393.4 <KM>
B_AXIS_RADIUS           = 3393.4 <KM>
C_AXIS_RADIUS           = 3375.7 <KM>
FIRST_STANDARD_PARALLEL = "N/A"
SECOND_STANDARD_PARALLEL = "N/A"
POSITIVE_LONGITUDE_DIRECTION = "EAST"
CENTER_LATITUDE         = 5.0 <DEGREE>
                        /*( for this tile only center latitude )*/
                        /*( of projection, the low-latitude edge )*/
                        /*( of the tile )*/

CENTER_LONGITUDE        = 0.0 <DEGREE>
REFERENCE_LATITUDE      = "N/A"
REFERENCE_LONGITUDE     = "N/A"
LINE_FIRST_PIXEL        = 1
                        /*( line number of N edge of this tile )*/
LINE_LAST_PIXEL         = 1280
                        /*( line number of S edge of this tile )*/
SAMPLE_FIRST_PIXEL      = 1
                        /*( sample number of W edge of this tile )*/
SAMPLE_LAST_PIXEL       = 1280
                        /*( sample number of E edge of this tile )*/

MAP_PROJECTION_ROTATION = 0.0
MAP_RESOLUTION          = 256 <PIXEL/DEGREE>
MAP_SCALE               = 0.23 <KM/PIXEL>
                        /*( this is average over the planet)*/
MAXIMUM_LATITUDE        = 10.0 <DEGREE>
                        /*( for this tile only)*/
MINIMUM_LATITUDE        = 5.0 <DEGREE>
                        /*( for this tile only)*/
WESTERNMOST_LONGITUDE   = 355.0 <DEGREE>
                        /*( for this tile only)*/
EASTERNMOST_LONGITUDE   = 0.0 <DEGREE>
                        /*( for this tile only)*/
LINE_PROJECTION_OFFSET  = 2560
                        /*( for this tile only; number of )*/
                        /*( pixels from equator to first pixel )*/
                        /*( of map tile )*/
SAMPLE_PROJECTION_OFFSET = -1280
                        /*( for this tile only; number of )*/
                        /*( pixels from 0 degrees longitude )*/
                        /*( to first pixel of map tile )*/

COORDINATE_SYSTEM_TYPE  = "BODY-FIXED ROTATING"
COORDINATE_SYSTEM_NAME  = "PLANETOCENTRIC"
END_OBJECT              = IMAGE_MAP_PROJECTION

END

```

## APPENDIX D5. MRDR LABEL (LIST OF TARGET ID AND METAKERNELS)

```

PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE     = "2003-11-19, S. Slavney (GEO);
                          2005-09-25, S. Murchie (JHU/APL)"

/* Map-projected Multispectral RDR Identification */

DATA_SET_ID             = "MRO-M-CRISM-5-RDR-MULTISPECTRAL-V1.0"
PRODUCT_ID              = "T0123_MRRSP_10N355_0256_0"
                          /*( Tnnnn_MRRss_xxdyyy_rrrr_v                )*/
                          /*( nnnn = tile number                       )*/
                          /*( ss = subtype of imagbe product          )*/
                          /*( xx = latitude of tile center            )*/
                          /*( d = N or S for north or south latitude  )*/
                          /*( yyy = east longitude of tile center     )*/
                          /*( rrrr = resolution in pixels/degree      )*/
                          /*( v = version number                       )*/

INSTRUMENT_HOST_NAME    = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID           = MRO
INSTRUMENT_NAME         = "COMPACT RECONNAISSANCE IMAGING
                          SPECTROMETER FOR MARS"

INSTRUMENT_ID           = CRISM
TARGET_NAME             = MARS
PRODUCT_TYPE            = MAP_PROJECTED_MULTISPECTRAL_RDR
PRODUCT_CREATION_TIME   = 2006-06-17T13:03:07.234
START_TIME              = "N/A"
STOP_TIME               = "N/A"
SPACECRAFT_CLOCK_START_COUNT = "N/A"
SPACECRAFT_CLOCK_STOP_COUNT = "N/A"
PRODUCT_VERSION_ID     = "0" /*( version number from product ID )*/
PRODUCER_INSTITUTION_NAME = "APPLIED PHYSICS LABORATORY"
SOFTWARE_NAME          = "tbd"
SOFTWARE_VERSION_ID    = "tbd"
MRO:WAVELENGTH_FILE_NAME = "N/A"

/* This Map Projected Multispectral RDR label describes four data files: */
/* 5. A listfile including observation IDs and SPICE metakernels used. */
/* This RDR represents one latitude-longitude bin in a global map. */
/* See the Map Projection Object below for bin coordinates and resolution.*/
/* See the CRISM Data Products SIS for more detailed description. */

/* Description of MAP PROJECTED MULTISPECTRAL RDR LISTFILE */

OBJECT                  = FILE
  ^TABLE                = "T0123_MRRSP_10N355_0256_0.TAB"
  RECORD_TYPE           = FIXED_LENGTH
  RECORD_BYTES         = 37
  FILE_RECORDS         = tbd

/* The number of records may increment each time the image is modified */

OBJECT                  = TABLE
  NAME                  = "CRISM MRDR METAKERNEL TABLE"
  INTERCHANGE_FORMAT    = "ASCII"
  ROWS                  = tbd

/* The number of rows may increment each time the image is modified */

```

```

COLUMNS = 2
ROW_BYTES = 37
DESCRIPTION = "Table of row numbers and center
              wavelengths for the I/F and
              Lambert albedo images in this MRDR."

OBJECT = COLUMN
  COLUMN_NUMBER = 1
  NAME = OBSERVATION_ID
  DATA_TYPE = CHARACTER
  START_BYTE = 1
  BYTES = 8
  DESCRIPTION = "Target ID of the CRISM observation as a
                hexadecimal number"
END_OBJECT = COLUMN

OBJECT = COLUMN
  COLUMN_NUMBER = 2
  NAME = METAKERNEL_FILE_NAME
  DATA_TYPE = CHARACTER
  START_BYTE = 9
  BYTES = 28
  DESCRIPTION = "Name of the SPICE metakernel that lists
                the SPICE kernels to use, in order of
                loading, for this OBSERVATION_ID."
  UNIT = "NM"
END_OBJECT = COLUMN

END_OBJECT = TABLE
END_OBJECT = FILE

END

```

## APPENDIX D6. MRDR LABEL (WAVELENGTH FILE)

```

PDS_VERSION_ID           = PDS3
LABEL_REVISION_NOTE      = "2003-11-19, S. Slavney (GEO);
                          2006-09-25, S. Murchie (JHU/APL)
                          2006-09-27, S. Murchie (JHU/APL)"

/* Map-projected Multispectral RDR Identification */

DATA_SET_ID              = "MRO-M-CRISM-5-RDR-MULTISPECTRAL-V1.0"
PRODUCT_ID               = "T0123_MRRWV_10N355_0256_0"
                          /*( Tnnnn_MRRss_xxdyyy_rrrr_v                )*/
                          /*( nnnn = tile number                       )*/
                          /*( ss = subtype of imagbe product          )*/
                          /*( xx = latitude of tile center            )*/
                          /*( d = N or S for north or south latitude  )*/
                          /*( yyy = east longitude of tile center     )*/
                          /*( rrrr = resolution in pixels/degree      )*/
                          /*( v = version number                       )*/

INSTRUMENT_HOST_NAME     = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID            = MRO
INSTRUMENT_NAME          = "COMPACT RECONNAISSANCE IMAGING
                          SPECTROMETER FOR MARS"

INSTRUMENT_ID           = CRISM
TARGET_NAME              = MARS
PRODUCT_TYPE             = MAP_PROJECTED_MULTISPECTRAL_RDR
PRODUCT_CREATION_TIME    = 2006-06-17T13:03:07.234
START_TIME               = "N/A"
STOP_TIME                = "N/A"
SPACECRAFT_CLOCK_START_COUNT = "N/A"
SPACECRAFT_CLOCK_STOP_COUNT = "N/A"
PRODUCT_VERSION_ID       = "0" /*( version number from product ID )*/
PRODUCER_INSTITUTION_NAME = "APPLIED PHYSICS LABORATORY"
SOFTWARE_NAME            = "tbd"
SOFTWARE_VERSION_ID      = "tbd"
MRO:WAVELENGTH_FILE_NAME = "N/A"

/* This Map Projected Multispectral RDR label describes four data files: */
/* 6. A listfile including detector row numbers and wavelengths in the */
/* I.F and Lambert albedo images. */
/* This RDR represents one latitude-longitude bin in a global map. */
/* See the Map Projection Object below for bin coordinates and resolution.*/
/* See the CRISM Data Products SIS for more detailed description. */

/* Description of MAP PROJECTED MULTISPECTRAL RDR LISTFILE */

OBJECT                    = FILE
  ^TABLE                  = "T0123_MRRWV_10N355_0256_0.TAB"
  RECORD_TYPE             = FIXED_LENGTH
  RECORD_BYTES            = 12
  FILE_RECORDS            = 72

/* The number of records may increment each time the image is modified */

OBJECT                    = TABLE
  NAME                    = "CRISM MRDR WAVELENGTH TABLE"
  INTERCHANGE_FORMAT      = "ASCII"
  ROWS                     = 72

```

```

COLUMNS                = 3
ROW_BYTES               = 14
DESCRIPTION              = "CRISM MRDR wavelength table "

OBJECT                  = COLUMN
  COLUMN_NUMBER         = 1
  NAME                  = SPECT_ID
  DATA_TYPE            = ASCII_INTEGER
  START_BYTE           = 214
  BYTES                 = 1
  DESCRIPTION           = "Spectrometer identifier; 0 = IR; 1 = VNIR"
END_OBJECT              = COLUMN

OBJECT                  = COLUMN
  COLUMN_NUMBER         = 2
  NAME                  = ROWNUM
  DATA_TYPE            = ASCII_INTEGER
  START_BYTE           = 3
  BYTES                 = 3
  DESCRIPTION           = "detector row number (0-479) "
END_OBJECT              = COLUMN

OBJECT                  = COLUMN
  COLUMN_NUMBER         = 3
  NAME                  = SAMPL_WAV
  DATA_TYPE            = ASCII_REAL
  START_BYTE           = 7
  BYTES                 = 8
  DESCRIPTION           = "Standard sampling center wavelength in nm"
  UNIT                  = "NM"
END_OBJECT              = COLUMN

  END_OBJECT           = TABLE
END_OBJECT              = FILE

END

```

## **APPENDIX E. MTRDR LABEL**

TBD

## APPENDIX F. LEVEL 6 CDR LABEL

```
PDS_VERSION_ID           = PDS3
LABEL_REVISION_NOTE      = "2005-12-13, S. Murchie"

/* Level 6 CDR (Calibration Data Record) Identification */

DATA_SET_ID              = "MRO-M-CRISM-6-CDR-V1.0"
/* The time string in the product ID will increment if there is a change in */
/* the VNIR detector 14-bit DN valid limit */
PRODUCT_ID               = "CDR6_1_0000000000_VL_S_0"
/* CDR6_P_tttttttttt_pp_s_v */
/* P = sclk partition */
/* tttttttttt = sclk start or mean time */
/* pp = product type from SIS */
/* s = sensor ID: S, L, or J */
/* v = version */
PRODUCT_TYPE             = CDR
SPACECRAFT_ID            = MRO
INSTRUMENT_ID           = CRISM
/* The start time field will increment if there is a change in */
/* the VNIR detector 14-bit DN valid limit */

START_TIME               = 1980-01-01T00:00:00
STOP_TIME                = NULL
/* The start clock count field will increment if there is a change in */
/* the VNIR detector 14-bit DN valid limit */

SPACECRAFT_CLOCK_START_COUNT = "1/0000000000"
SPACECRAFT_CLOCK_STOP_COUNT = NULL
/* The creation time field will increment when a new version is issued */
PRODUCT_CREATION_TIME    = 2005-12-13T14:00:00
MRO:SENSOR_ID            = "S" /* or L OR J, Sensor ID from product ID */
PRODUCT_VERSION_ID       = "0" /* version number from product ID */

/* CRISM VNIR 14-bit DN Valid Limit File */
/*
/* This file gives the 14-bit DN at which the VNIR detector - ON AVERAGE - is
/* saturated. It is used together with the predicted limiting case expected
/* 14-bit scene DN levels (product ID CDR6_1_0000000000_AS_S_0) to produce
/* bad pixel maps. The 14-bit DN unsaturated limit is also used in routine
/* calibration to flag saturated pixels.
/*
/* Results from 1, 3.75, 5, and 15 Hz are from a test series designated as
/* VRD7, taken at the detector level on 2 Feb 2004. These data show both
/* quadrant and frame rate dependence. No saturated data were obtained at
/* 30 Hz so these values are replicated from 1 Hz which show the lowest
/* 14-bit saturated DNs.
/*
/* This file also gives three additional values that are applicable to
/* production of bad pixel maps. (a) The decimal fraction of saturation below
/* which response is near-linear, as described in product ID
/* CDR6_0_0000000000_LC_S_0. This was derived from the same test data
/* sequence but is known only approximately. (b) The 14-bit DN threshold of
/* noise in bias images at which a pixel is declared bad. This noise behaves
/* like an enhanced read noise and has a large effect on SNR. (c) The decimal
/* fraction of the average 14-bit dark-, bias-, and linearity-corrected DN in
/* a row of an internal integrating sphere image below which a detector
/* element is assigned to be a bad pixel."
/*
/* The values given here are used to generate bad pixel masks. The bad
```

```

/* pixel mask is defined as an image product containing values of 0, except 1 */
/* where any of the four following conditions is satisfied: */
/* */
/* - In a bias measurement, a 12-bit value of 4095 is observed. */
/* */
/* - In a bias measurement expanded to 14 bits, the per-pixel standard */
/* deviation at the appropriate combination of frame rate and exposure time */
/* is more than 5x (TBR) the read noise in the data, or approximately 15 14- */
/* bit DNs. */
/* */
/* - From the bias measurement, at a combination of frame rate and exposure */
/* time, the sum of the maximum predicted scene DN and the predicted dark DN */
/* is greater than 93% (TBR) of the 14-bit saturation DN (approximately 10000 */
/* VNIR, 9000 IR. */
/* */
/* - From the sphere measurement accompanying the bias measurement, dark- */
/* removed sphere 14-bit DN is <5% (TBR) of the maximum predicted DN at 1 Hz */
/* at that row. */
/* */
/* This combination flags (a) pixels that are saturated in dark measurements, */
/* (b) noisy pixels, (c) pixels that are expected to saturate during a scene */
/* measurement, and (d) pixels that are nearly or totally unresponsive to */
/* light. */

```

```

OBJECT = FILE
/* The time string in the file name will increment if there is a change in */
/* the VNIR detector 14-bit DN valid limit */

```

```

^TABLE = "CDR6_1_0000000000_VL_S_0.TAB"
RECORD_TYPE = FIXED_LENGTH
FILE_RECORDS = 16
RECORD_BYTES = 27

```

```

OBJECT = TABLE
NAME = "CRISM VNIR 14-bit DN Valid Limit File"
INTERCHANGE_FORMAT = "ASCII"
ROWS = 20
COLUMNS = 6
ROW_BYTES = 27
DESCRIPTION = "CRISM VNIR 14-bit DN Valid Limit File"

```

```

OBJECT = COLUMN
COLUMN_NUMBER = 1
NAME = RATE
DATA_TYPE = ASCII_INTEGER
START_BYTE = 1
BYTES = 1
DESCRIPTION = "Rate of frame acquisition; 0 = 1 Hz; 1 = 3.75
Hz; 2 = 5 Hz; 3 = 15 Hz; 4 = 30 Hz; specified
separately for each detector"
END_OBJECT = COLUMN

```

```

OBJECT = COLUMN
COLUMN_NUMBER = 2
NAME = QUADRANT
DATA_TYPE = ASCII_INTEGER
START_BYTE = 3
BYTES = 1
DESCRIPTION = "Quadrant of the detector. For no binning,
quadrant 1 = columns 0-159, quadrant 2 =
columns 160-319, quadrant 3 = columns
320-479, quadrant 4 = columns 480-639"
END_OBJECT = COLUMN

```

```

OBJECT                = COLUMN
  COLUMN_NUMBER      = 3
  NAME                = VNIR_14_BIT_LIMIT
  DATA_TYPE         = ASCII_INTEGER
  START_BYTE         = 5
  BYTES               = 5
  DESCRIPTION        = "14-bit DN at which saturation occurs"
END_OBJECT           = COLUMN

OBJECT                = COLUMN
  COLUMN_NUMBER      = 4
  NAME                = VNIR_LINEARITY_LIMIT
  DATA_TYPE         = ASCII_REAL
  START_BYTE         = 11
  BYTES               = 4
  DESCRIPTION        = "The decimal fraction of saturation 14-bit DN
                        below which detector element response to
                        light is adequately described by the
                        nonlinearity correction."
END_OBJECT           = COLUMN

OBJECT                = COLUMN
  COLUMN_NUMBER      = 5
  NAME                = VNIR_NOISE_LIMIT
  DATA_TYPE         = ASCII_INTEGER
  START_BYTE         = 16
  BYTES               = 5
  DESCRIPTION        = "The 14-bit DN value which is the noise
                        threshold for assigning a bad pixel value.
                        Noise is assessed using dark measurements
                        (for the VNIR, activity = DF) or bias
                        measurements (for the IR, activity = BI)."
END_OBJECT           = COLUMN

OBJECT                = COLUMN
  COLUMN_NUMBER      = 6
  NAME                = VNIR_SENSITIVITY_LIMIT
  DATA_TYPE         = ASCII_REAL
  START_BYTE         = 22
  BYTES               = 4
  DESCRIPTION        = "The decimal fraction of the average 14-bit
                        dark-, bias-, and linearity-corrected DN
                        in a row of an internal integrating sphere
                        image below which a detector element is
                        assigned to be a bad pixel."
END_OBJECT           = COLUMN

END_OBJECT           = TABLE

END_OBJECT           = FILE

END

```

## APPENDIX G. LEVEL 4 CDR LABEL

```

PDS_VERSION_ID           = PDS3
LABEL_REVISION_NOTE     = "2006-04-11 D. Humm (APL), modified"

/* Level 4 CDR (Calibration Data Record) Identification */

DATA_SET_ID              = "MRO-M-CRISM-4-CDR-V1.0"
PRODUCT_ID               = "CDR410803692813_WA0000000L_0"

/*( CDR4Ptttttttttt_pprbeeewsn_v           )*/
/*( P = partition of sclk time              )*/
/*( tttttttttt = s/c start or mean time    )*/
/*( pp = calib. type from SIS table 2-8    )*/
/*( r = frame rate identifier, 0-4         )*/
/*( b = binning identifier, 0-3           )*/
/*( eee = exposure time parameter, 0-480  )*/
/*( w = wavelength filter, 0-3           )*/
/*( s = side: 1 or 2, or 0 if N/A         )*/
/*( n = sensor ID: S, L, or J             )*/
/*( v = version                            )*/

PRODUCT_TYPE             = CDR
SPACECRAFT_ID            = MRO
INSTRUMENT_ID            = CRISM
START_TIME                = 2005-06-19T23:59:59.999
STOP_TIME                 = NULL
SPACECRAFT_CLOCK_START_COUNT = "1/0803692813"
SPACECRAFT_CLOCK_STOP_COUNT = NULL
OBSERVATION_TIME         = NULL
PRODUCT_CREATION_TIME    = 2006-04-24T21:00:00.000

OBSERVATION_TYPE         = NULL
OBSERVATION_ID           = NULL
MRO:OBSERVATION_NUMBER   = NULL
MRO:ACTIVITY_ID          = NULL
SOURCE_PRODUCT_ID        = NULL
MRO:SENSOR_ID            = "L"
PRODUCT_VERSION_ID       = "0"

/* CDR Instrument and Observation Parameters */

SAMPLING_MODE_ID         = "HYPERSPEC"
MRO:WAVELENGTH_FILE_NAME = "CDR410803692813_WA0000000L_0.IMG"
MRO:DETECTOR_TEMPERATURE = NULL
MRO:OPTICAL_BENCH_TEMPERATURE = NULL
MRO:SPECTROMETER_HOUSING_TEMP = NULL
MRO:SPHERE_TEMPERATURE  = NULL
MRO:FPE_TEMPERATURE     = NULL
SHUTTER_MODE_ID         = "OPEN"
LIGHT_SOURCE_NAME        = "NONE"
MRO:CALIBRATION_LAMP_STATUS = "OFF"
MRO:CALIBRATION_LAMP_LEVEL = 0
MRO:FRAME_RATE          = NULL
PIXEL_AVERAGING_WIDTH   = 1 /*( pixel bin size, across track ) */

```

```

MRO:EXPOSURE_PARAMETER      = NULL
MRO:WAVELENGTH_FILTER       = "0"

/* This Level 4 CDR label describes one calibration data file. The file */
/* is a single-band image file derived from ground data. It consists of */
/* a binary image followed by a list of row numbers corresponding to the */
/* wavelength filter. */

/* The WA level 4 CDR gives the center wavelength in nm of each pixel, */
/* assuming a given spatial binning and wavelength filter. */

/* Description of CDR IMAGE file */

OBJECT      = FILE
  ^IMAGE    = "CDR410803692813_WA0000000L_0.IMG"

/* offset is in file records, which is just (imgbands*imglines) + 1 */
^ROWNUM_TABLE = ("CDR410803692813_WA0000000L_0.IMG",439 )

RECORD_TYPE  = FIXED_LENGTH
RECORD_BYTES = 2560 /* one row now, not one frame to save space in table */
FILE_RECORDS = 439 /* compute by ROUND ((imgbands * imglines *
/*                               line_samples * samplebits/8 +
/*                               tablerows * tablerowbytes) /
/*                               record_bytes + 0.5 ) */

OBJECT      = IMAGE
  LINES     = 1
  LINE_SAMPLES = 640
  SAMPLE_TYPE = PC_REAL
  SAMPLE_BITS = 32
  BANDS      = 438
  BAND_NAME  = NULL
  BAND_STORAGE_TYPE = LINE_INTERLEAVED
  DESCRIPTION = "Center wavelength in nm for each
                detector pixel"

END_OBJECT  = IMAGE

/* be sure to pad this object to a full record (2560/bin bytes here)
*/

OBJECT = ROWNUM_TABLE
  NAME      = "SELECTED ROWS FROM DETECTOR"
  INTERCHANGE_FORMAT = "BINARY"
  ROWS      = 438
  COLUMNS  = 1
  ROW_BYTES = 2
  DESCRIPTION = "The detector is subsampled in the spectral direction
                by selecting specific rows to be downlinked. This
                table provides a list of the rows selected for all
                frames in this multidimensional image cube."

OBJECT = COLUMN
  NAME      = DETECTOR_ROW_NUMBER
  DATA_TYPE = MSB_UNSIGNED_INTEGER
  BIT_MASK  = 2#0000000111111111#
  START_BYTE = 1
  BYTES     = 2
  DESCRIPTION = "Detector row number from which the data was taken."

```

```
END_OBJECT = COLUMN
END_OBJECT = ROWNUM_TABLE
END_OBJECT = FILE
END
```

## APPENDIX H. ADR LABEL

```

PDS_VERSION_ID          = PDS3

LABEL_REVISION_NOTE     = "2006-04-29, P. McGuire,
                          2006-05-01, S. Murchie"

DATA_SET_ID             = "MRO-M-CRISM-6-ADR-V1.0"
PRODUCT_ID              = "ADR_AC_nnnn_0_0000000000_0"
                          /*( ADR_pp_nnnn_P_tttttttttt_v          )*/
                          /*( pp = ADR type from SIS section 3.8  )*/
                          /*( nnnn = wavelength in nanometers    )*/
                          /*( P = partition of sclk time          )*/
                          /*( tttttttttt = s/c start time        )*/
                          /*( v = version                          )*/

PRODUCT_TYPE            = ADR
INSTRUMENT_HOST_NAME   = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID          = MRO
INSTRUMENT_NAME        = "COMPACT RECONNAISSANCE IMAGING SPECTROMETER
                          FOR MARS"

INSTRUMENT_ID          = CRISM
TARGET_NAME            = MARS
START_TIME             = NULL
STOP_TIME              = NULL
SPACECRAFT_CLOCK_START_COUNT = NULL
SPACECRAFT_CLOCK_STOP_COUNT  = NULL
PRODUCT_CREATION_TIME  = 2006-03-30T11:11:00.000
PRODUCER_INSTITUTION_NAME = "Space Science Institute"
SOFTWARE_NAME          = "disort_multi"
SOFTWARE_VERSION_ID    = NULL
PRODUCT_VERSION_ID     = "0"

OBJECT                  = FILE
  ^ARRAY                = "ADR_AC_0000_0_0000000000_0.DAT"
  RECORD_TYPE           = FIXED_LENGTH
  RECORD_BYTES         = 4
  FILE_RECORDS         = 62660

OBJECT                  = ARRAY
  AXIS_ORDER_TYPE      = FIRST_INDEX_FASTEST
  SAMPLE_BITS          = 32
  SAMPLE_TYPE          = PC_REAL
  INTERCHANGE_FORMAT   = BINARY

START_BYTE             = 161
AXES                   = 9
NAME                   = I_OVER_F
UNIT                   = N/A          /* I_OVER_F */
AXIS_NAME              = {MU,
                          PHI,
                          MU0,
                          ALB,
                          TAUd,
                          TAUi,
                          SURFTEMP,
                          SURFPRES,
                          SOLAR_FLUX}

AXIS_ITEMS             = {5,          /* MU */
                          5,          /* PHI */

```

```

5,          /* MU0 */
5,          /* ALB */
5,          /* TAUd */
5,          /* TAUi */
1,          /* SURFTEMP */
1,          /* SURFPRES */
1}         /* SOLAR_FLUX */

  AXIS_START    = {0.100,      /* MU */
                  0.0,        /* PHI */
                  0.100,      /* MU0 */
                  0.00,       /* ALB */
                  0.00,       /* TAUd */
                  0.0,        /* TAUi */
                  270.0,      /* SURFTEMP */
                  6.1,        /* SURFPRES */
                  3.141593}   /* SOLAR_FLUX */

  AXIS_STOP     = {1.000,      /* MU */
                  180.0,      /* PHI */
                  1.000,      /* MU0 */
                  0.60,       /* ALB */
                  1.00,       /* TAUd */
                  0.4,        /* TAUi */
                  270.0,      /* SURFTEMP */
                  6.1,        /* SURFPRES */
                  3.141593}   /* SOLAR_FLUX */

  AXIS_INTERVAL = {0.225,      /* MU */
                  45.0,       /* PHI */
                  0.225,      /* MU0 */
                  0.15,       /* ALB */
                  0.25,       /* TAUd */
                  0.1,        /* TAUi */
                  0.0,        /* SURFTEMP */
                  0.0,        /* SURFPRES */
                  0.000000}   /* SOLAR_FLUX */

  AXIS_NAME     = {N/A,        /* MU */
                  DEGREES,    /* PHI */
                  N/A,        /* MU0 */
                  N/A,        /* ALB */
                  N/A,        /* TAUd */
                  N/A,        /* TAUi */
                  KELVIN,      /* SURFTEMP */
                  MILLIBARS,   /* SURFPRES */
                  SOL_CONST;F=PI} /* SOLAR_FLUX */

  END_OBJECT = ARRAY

  END_OBJECT = FILE

  END

```

## APPENDIX I1. EDR BROWSE PRODUCT HTML FILE LABEL

```
PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE     = "2006-02-25, S.Murchie (APL)"

/* This browse product provides an overview of the MRO CRISM EDRs */
/* from a single observation */

^HTML_DOCUMENT          = "FUN000027B0_BROWSE_EDR0.HTML"

DATA_SET_ID             = "MRO-M-CRISM-2-EDR-V1.0"
PRODUCT_ID              = "FUN000027B0_BROWSE_EDR0"
/* EDR browse product          */
/* cccnnnnnnnn_BROWSE_EDRv    */
/* ccc = Class Type           */
/* nnnnnnnnn = Observation ID (hex) */
/* v = Version number         */

INSTRUMENT_HOST_NAME    = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID           = MRO
INSTRUMENT_NAME         = "COMPACT RECONNAISSANCE IMAGING
                          SPECTROMETER FOR MARS"
INSTRUMENT_ID           = CRISM
TARGET_NAME             = MARS
PRODUCT_TYPE            = BROWSE
PRODUCT_CREATION_TIME   = 2006-09-25T13:13:10.583
PRODUCER_INSTITUTION_NAME = "JOHNS HOPKINS UNIVERSITY
                          APPLIED PHYSICS LABORATORY"
SOFTWARE_NAME           = "pipe_crism_create_browse"
SOFTWARE_VERSION_ID     = "1.0"

/* The following information is relevant to an entire observation */

ORBIT_NUMBER            = NULL
OBSERVATION_TYPE        = "FUN"
OBSERVATION_ID          = "16#000027B0#"
PRODUCT_VERSION_ID      = "0"
SOLAR_DISTANCE          = NULL <KM>

/* These times are from the beginning of the first EDR of the observation */
/* to the end of the last EDR of the observation */

START_TIME              = 2006-09-25T15:45:25.756879
STOP_TIME               = 2006-09-25T15:46:57.053571
SPACECRAFT_CLOCK_START_COUNT = "2/0843666344.27976"
SPACECRAFT_CLOCK_STOP_COUNT  = "2/0843666435.47420"

OBJECT                  = HTML_DOCUMENT
  DOCUMENT_NAME          = "EDR_BROWSE OVERVIEW"
  RECORD_TYPE            = UNDEFINED
  PUBLICATION_DATE       = 2006-09-25
  DOCUMENT_TOPIC_TYPE    = "HTML NAVIGATION"
  INTERCHANGE_FORMAT     = ASCII
  DOCUMENT_FORMAT        = HTML
  DESCRIPTION            = "This document provides an overview of the MRO
                          CRISM EDRs from a single observation."
END_OBJECT              = HTML_DOCUMENT

END
```



## APPENDIX I2. EDR BROWSE PRODUCT PNG FILE LABEL

```
PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE    = "2003-11-19, S. Slavney (GEO);
                        2005-02-01, C. Hash (ACT);
                        2006-01-04, C. Hash (ACT);"

/* EDR Identification */

DATA_SET_ID             = "MRO-M-CRISM-2-EDR-V1.0"
PRODUCT_ID             = "FUN000027B0_00_T3245L_RAW0"
/* cccnnnnnnnnn_xx_ooaaaas_RAWv          */
/* ccc = Class Type                       */
/* nnnnnnnnn = Observation ID (hex)       */
/* xx = counter within observation (hex)  */
/* oaaaa = obs type, macro number        */
/* s = sensor ID (S or L)                 */
/* v = version number                     */

INSTRUMENT_HOST_NAME   = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID          = MRO
INSTRUMENT_NAME        = "COMPACT RECONNAISSANCE IMAGING
                        SPECTROMETER FOR MARS"

INSTRUMENT_ID          = CRISM
TARGET_NAME            = MARS
PRODUCT_TYPE           = BROWSE
PRODUCT_CREATION_TIME  = 2006-09-25T13:13:10
START_TIME              = 2006-09-25T15:45:25.756879
STOP_TIME               = 2006-09-25T15:45:34.756879
SPACECRAFT_CLOCK_START_COUNT = "2/0843666344.27976"
SPACECRAFT_CLOCK_STOP_COUNT  = "2/0843666353.27976"
ORBIT_NUMBER           = "NULL"
OBSERVATION_TYPE       = "FUN"
OBSERVATION_ID         = "16#000027B0#"
MRO:OBSERVATION_NUMBER = 16#00#
MRO:ACTIVITY_ID        = "T3245"
MRO:SENSOR_ID          = "L"
PRODUCT_VERSION_ID     = "0"
PRODUCER_INSTITUTION_NAME = "JOHNS HOPKINS UNIVERSITY
                        APPLIED PHYSICS LABORATORY"

SOFTWARE_NAME          = "pipe_edrslice"
SOFTWARE_VERSION_ID    = "3.9"

/* EDR Instrument and Observation Parameters */
/* for first frame */
TARGET_CENTER_DISTANCE = NULL <KM>
SOLAR_DISTANCE         = NULL <KM>
SHUTTER_MODE_ID        = CLOSED
LIGHT_SOURCE_NAME      = "NONE"
MRO:CALIBRATION_LAMP_STATUS = "OFF"
MRO:CALIBRATION_LAMP_LEVEL = "N/A"
PIXEL_AVERAGING_WIDTH = 1
MRO:INSTRUMENT_POINTING_MODE = "FIXED POINTING"
SCAN_MODE_ID           = "N/A"
MRO:FRAME_RATE         = 1.00 <HZ>
MRO:EXPOSURE_PARAMETER = 27
SAMPLING_MODE_ID       = "HYPERSPEC"
COMPRESSION_TYPE       = "NONE"
MRO:WAVELENGTH_FILTER = 0
```

```
MRO:WAVELENGTH_FILE_NAME = "CDR6_1_0000000000_WV_L_1.TAB"
MRO:PIXEL_PROC_FILE_NAME = "CDR6_1_0000000000_PP_L_1.TAB"
MRO:LOOKUP_TABLE_FILE_NAME = "CDR6_1_0000000000_LK_J_0.TAB"
```

```
/* These parameters describe the browse image as a PDS document. */
```

```
^DOCUMENT          = "FUN000027B0_00_T3245L_RAW0.PNG"
OBJECT             = DOCUMENT
  DOCUMENT_NAME    = "FUN000027B0_00_T3245L_RAW0"
  DOCUMENT_FORMAT  = PNG
  DOCUMENT_TOPIC_TYPE = "BROWSE IMAGE"
  INTERCHANGE_FORMAT = BINARY
  PUBLICATION_DATE = 2006-09-25
  SOURCE_PRODUCT_ID = "FUN000027B0_00_T3245L_EDR0"
  LINES            = 10
  LINE_SAMPLES     = 640
  SAMPLE_TYPE      = MSB_UNSIGNED_INTEGER
  SAMPLE_BITS      = 8
  DERIVED_MINIMUM  = 0
  DERIVED_MAXIMUM  = 250
  OFFSET           = -26.274
  SCALING_FACTOR   = 0.067
  MISSING_CONSTANT = 255
  DESCRIPTION      = "This file is a scaled median image of raw DN level
                    in a CRISM EDR. The x-y coordinates of the image
                    are spatial and in sensor space (not map-
                    projected), where x = detector column and y = frame
                    number within an EDR. The encoded 8-bit value at
                    each x-y location is the scaled median of the
                    values at all wavelengths."
END_OBJECT        = DOCUMENT
END
```

## APPENDIX J1. DDR BROWSE PRODUCT HTML FILE LABEL

```
PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE     = "2006-09-27, S. Murchie (APL)"

/* This browse product provides an overview of the MRO CRISM DDRs */
/* from a single observation */

DATA_SET_ID             = "MRO-M-CRISM-6-DDR-V1.0"
PRODUCT_ID              = "EPF00000411_BROWSE_DDR0"
/* TRDR browse product */
/* cccnnnnnnnn_BROWSE_TRRv */
/* ccc = Class Type */
/* nnnnnnnn = Observation ID (hex) */
/* v = Version number */

INSTRUMENT_HOST_NAME    = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID           = MRO
INSTRUMENT_NAME         = "COMPACT RECONNAISSANCE IMAGING
                          SPECTROMETER FOR MARS"
INSTRUMENT_ID           = CRISM
TARGET_NAME             = MARS
PRODUCT_TYPE            = BROWSE
PRODUCT_CREATION_TIME   = 2006-01-19T20:06:14
PRODUCER_INSTITUTION_NAME = "JOHNS HOPKINS UNIVERSITY
                          APPLIED PHYSICS LABORATORY"
SOFTWARE_NAME           = "tbd"
SOFTWARE_VERSION_ID     = "tbd"

/* The following information is relevant to an entire observation */

ORBIT_NUMBER            = 0
OBSERVATION_TYPE        = "EPF" /*( ClassType from product ID )*/
OBSERVATION_ID          = 16#00000411 /*( Obs ID (hex) )*/
PRODUCT_VERSION_ID     = "0"
SOLAR_DISTANCE          = NULL <KM>

/* These times are from the beginning of the first EDR of the observation */
/* to the end of the last EDR of the observation */

START_TIME              = 2007-12-19T06:01:46.816
STOP_TIME               = 2007-12-19T06:01:50.816
SPACECRAFT_CLOCK_START_COUNT = "2/0882511324:47630"
SPACECRAFT_CLOCK_STOP_COUNT  = "2/0882511328:47630"

OBJECT                  = HTML_DOCUMENT
^HTML_DOCUMENT          = "EPF00000411_BROWSE_DER0.HTML"
RECORD_TYPE             = UNDEFINED
PUBLICATION_DATE        = 2006-09-18
DOCUMENT_TOPIC_TYPE     = "HTML NAVIGATION"
INTERCHANGE_FORMAT      = ASCII
DOCUMENT_FORMAT         = HTML
DESCRIPTION              = "This document provides an overview of the MRO
                          CRISM summary products derived from the DDRs
                          from a single observation."
END_OBJECT              = HTML_DOCUMENT

END
```



## APPENDIX J2. DDR BROWSE PRODUCT PNG FILE LABEL

```

PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE    = "2006-09-27, S. Murchie (APL)"

/* This browse product consists of a synoptic image representing one */
/* MRO CRISM DDR */

DATA_SET_ID             = "MRO-M-CRISM-6-DDR-V1.0"
PRODUCT_ID              = "EPF00000411_00_DE156S_DER0"
/* cccnnnnnnnn_xx_IFaaas_TRUv */
/* ccc = Class Type */
/* nnnnnnnnn = Observation ID (hex) */
/* xx = counter within observation (hex) */
/* DE = derived from a DDR */
/* aaa = macro number */
/* s = sensor ID (S or L) */
/* v = version number */

INSTRUMENT_HOST_NAME    = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID           = MRO
INSTRUMENT_NAME         = "COMPACT RECONNAISSANCE IMAGING
                          SPECTROMETER FOR MARS"

INSTRUMENT_ID           = CRISM
TARGET_NAME             = MARS
PRODUCT_TYPE            = BROWSE
PRODUCT_CREATION_TIME   = 2006-01-05T15:50:24.945
START_TIME              = 2007-12-19T06:01:46.816
STOP_TIME               = 2007-12-19T06:01:50.816
SPACECRAFT_CLOCK_START_COUNT = "2/0882511324:47630"
SPACECRAFT_CLOCK_STOP_COUNT  = "2/0882511328:47630"

ORBIT_NUMBER            = 0
OBSERVATION_TYPE        = "EPF" /*( ClassType from product ID )*/
OBSERVATION_ID          = 16#00000411 /*( Obs ID (hex) )*/
MRO:OBSERVATION_NUMBER  = 16#00 /*( Counter (hex) )*/
MRO:ACTIVITY_ID         = "DE156" /*( Activity from product ID )*/
MRO:SENSOR_ID           = "S" /*( or L, Sensor ID from product ID )*/
PRODUCT_VERSION_ID      = "0" /*( version number from product ID )*/
PRODUCER_INSTITUTION_NAME = "APPLIED PHYSICS LABORATORY"
SOFTWARE_NAME           = "tbd"
SOFTWARE_VERSION_ID     = "tbd"

/* DDR Instrument and Observation Parameters */

TARGET_CENTER_DISTANCE  = tbd <KM>
                          /* distance to Mars center at first frame */
SOLAR_DISTANCE          = tbd <KM>
SOLAR_LONGITUDE         = tbd <DEGREES>
MRO:FRAME_RATE          = 3.75 <HZ>
PIXEL_AVERAGING_WIDTH   = 10
MRO:INSTRUMENT_POINTING_MODE = "DYNAMIC POINTING" /*( or FIXED POINTING)*/
SCAN_MODE_ID            = "EPF" /*( or LONG or SHORT )*/

/* These parameters describe the browse image as a PDS document. */

^DOCUMENT                = "EPF00000411_00_DE156S_DDR0.PNG"
OBJECT                   = DOCUMENT
  DOCUMENT_NAME          = "EPF00000411_00_DE156S_DDR0"

```

```

DOCUMENT_FORMAT          = PNG
DOCUMENT_TOPIC_TYPE     = "BROWSE IMAGE"
INTERCHANGE_FORMAT      = BINARY
PUBLICATION_DATE        = 2006-01-19
SOURCE_PRODUCT_ID       = ("EPF00000411_00_DE156S_DDR0")
RECORD_BYTES            = 64
FILE_RECORDS            = 15
SAMPLE_TYPE             = LSB_UNSIGNED_INTEGER
SAMPLE_BITS             = 8
BANDS                   = 3
BAND_SEQUENCE           = ("RED", "GREEN", "BLUE")
BAND_NAME               = ("INA at areoid, deg",
                          "Elevation, meters relative to MOLA",
                          "EMA at areoid, deg")

/* The following information to scale from real numbers to an */
/* 8-bit integer is hard-coded for this type of browse image. */

DERIVED_MINIMUM         = (0,0,0)
DERIVED_MAXIMUM         = (250,250,250)
OFFSET                  = (0,-9000,0)
SCALING_FACTOR          = (-0.36,144,0.36)  MISSING_CONSTANT      =
(255,255,255)
DESCRIPTION             = "This browse product 3-color composite with
                          red = solar incidence angle at the areoid
                          in degrees, scaled 90-0 to 0-250,
                          green = elevation in meters relative to
                          MOLA datum, scaled -9000 - 27,000 to 0-250,
                          blue = emission angle at the areoid in
                          degrees, scaled 0-90 to 0-250."

END_OBJECT              = DOCUMENT

END

```

## APPENDIX K1. TRDR BROWSE PRODUCT HTML FILE LABEL

```
PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE     = "2006-02-26, S. Murchie (APL)
                          2006-09-18, S. Murchie (APL)"

/* This browse product provides an overview of the MRO CRISM EDRs */
/* from a single observation */

DATA_SET_ID             = "MRO-M-CRISM-2-TRDR-V1.0"
PRODUCT_ID              = "MSP00002798_BROWSE_TRR0"
/* TRDR browse product */
/* cccnnnnnnnn_BROWSE_TRRv */
/* ccc = Class Type */
/* nnnnnnnn = Observation ID (hex) */
/* v = Version number */

INSTRUMENT_HOST_NAME    = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID           = MRO
INSTRUMENT_NAME         = "COMPACT RECONNAISSANCE IMAGING
                          SPECTROMETER FOR MARS"
INSTRUMENT_ID           = CRISM
TARGET_NAME             = MARS
PRODUCT_TYPE            = BROWSE
PRODUCT_CREATION_TIME   = 2006-01-19T20:06:14
PRODUCER_INSTITUTION_NAME = "JOHNS HOPKINS UNIVERSITY
                          APPLIED PHYSICS LABORATORY"
SOFTWARE_NAME           = "pipe_edrslice"
SOFTWARE_VERSION_ID     = "3.5"

/* The following information is relevant to an entire observation */

ORBIT_NUMBER            = "NULL"
OBSERVATION_TYPE        = "MSP"
OBSERVATION_ID          = 00002798
PRODUCT_VERSION_ID      = "0"
SOLAR_DISTANCE          = NULL <KM>

/* These times are from the beginning of the first EDR of the observation */
/* to the end of the last EDR of the observation */

START_TIME              = 2006-01-19T18:42:39.459758
STOP_TIME               = 2006-01-19T18:42:58.529979
SPACECRAFT_CLOCK_START_COUNT = "2/822163378:9273"
SPACECRAFT_CLOCK_STOP_COUNT = "2/822163397:13875"

OBJECT                  = HTML_DOCUMENT
^HTML_DOCUMENT          = "MSP00002798_BROWSE_TRR0.HTML"
RECORD_TYPE             = UNDEFINED
PUBLICATION_DATE        = 2006-09-18
DOCUMENT_TOPIC_TYPE     = "HTML NAVIGATION"
INTERCHANGE_FORMAT      = ASCII
DOCUMENT_FORMAT         = HTML
DESCRIPTION              = "This document provides an overview of the MRO
                          CRISM summary products derived from the TRDRs
                          from a single observation."
END_OBJECT              = HTML_DOCUMENT

END
```

## APPENDIX K2. TRDR BROWSE PRODUCT 'TRU' PNG FILE LABEL

```
PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE     = "2006-02-26, S.Murchie (APL);
                          2006-03-02, S. Slavney (GEO);
                          2006-09-18, S. Murchie (APL)"

/* This browse product consists of a synoptic image representing one */
/* MRO CRISM TRDR */

DATA_SET_ID             = "MRO-M-CRISM-2-TRDR-V1.0"
PRODUCT_ID              = "MSP00002798_01_IF211S_TRU0"
/* cccnnnnnnnn_xx_IFaaas_TRUv          */
/* ccc = Class Type                    */
/* nnnnnnnn = Observation ID (hex)     */
/* xx = counter within observation (hex) */
/* IF = derived from I_OVER_F image    */
/* aaa = macro number                  */
/* s = sensor ID (S or L)              */
/* v = version number                  */

INSTRUMENT_HOST_NAME    = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID           = MRO
INSTRUMENT_NAME         = "COMPACT RECONNAISSANCE IMAGING
                          SPECTROMETER FOR MARS"

INSTRUMENT_ID           = CRISM
TARGET_NAME             = MARS
PRODUCT_TYPE            = BROWSE
PRODUCT_CREATION_TIME   = 2006-01-19T20:06:14
PRODUCT_VERSION_ID      = "0"
PRODUCER_INSTITUTION_NAME = "JOHNS HOPKINS UNIVERSITY
                          APPLIED PHYSICS LABORATORY"

SOFTWARE_NAME           = "pipe_edrslice"
SOFTWARE_VERSION_ID     = "3.5"

/* The following information is relevant to an entire observation */

ORBIT_NUMBER            = "NULL"
OBSERVATION_TYPE        = "MSP"
OBSERVATION_ID          = 00002798

/* The following information is particular to one TRDR in the observation. */
/* The times are from the beginning of a TRDR to the end of the TRDR.      */

START_TIME              = 2006-01-19T18:42:43.592479
STOP_TIME               = 2006-01-19T18:42:58.529979
SPACECRAFT_CLOCK_START_COUNT = "2/822163382:17971"
SPACECRAFT_CLOCK_STOP_COUNT = "2/822163397:13875"
MRO:OBSERVATION_NUMBER  = 1
MRO:ACTIVITY_ID         = "IF211"
MRO:SENSOR_ID           = "S"
SHUTTER_MODE_ID        = OPEN
LIGHT_SOURCE_NAME       = "NONE"
MRO:CALIBRATION_LAMP_STATUS = "OFF"
MRO:CALIBRATION_LAMP_LEVEL = "N/A"
PIXEL_AVERAGING_WIDTH   = 10
MRO:INSTRUMENT_POINTING_MODE = "FIXED POINTING"
SCAN_MODE_ID            = "N/A"
MRO:FRAME_RATE          = 15.00 <HZ>
```

```

MRO:EXPOSURE_PARAMETER = 425
SAMPLING_MODE_ID       = "MULTISPEC"
COMPRESSION_TYPE       = "NONE"
MRO:WAVELENGTH_FILTER  = 1
MRO:WAVELENGTH_FILE_NAME = "CDR400000000000_WA0300010S_0.IMG"
MRO:PIXEL_PROC_FILE_NAME = "CDR6_1_0000000000_PP_S_1.TAB"
MRO:INV_LOOKUP_TABLE_FILE_NAME = "CDR6_1_0000000000_LI_J_0.TAB"
MRO:ATMO_CORRECTION_FLAG = "OFF"
MRO:THERMAL_CORRECTION_MODE = "OFF"
MRO:PHOTOCLIN_CORRECTION_FLAG = "OFF"
MRO:SPATIAL_RESAMPLING_FLAG = "OFF"
MRO:SPATIAL_RESAMPLING_FILE = "N/A"
MRO:SPATIAL_RESCALING_FLAG = "OFF"
MRO:SPATIAL_RESCALING_FILE = "N/A"
MRO:SPECTRAL_RESAMPLING_FLAG = "OFF"
MRO:SPECTRAL_RESAMPLING_FILE = "N/A"

/* These parameters describe the browse image as a PDS document. */

^DOCUMENT              = "MSP00002798_01_IF211S_TRU0.PNG"
OBJECT                 = DOCUMENT
  DOCUMENT_NAME        = "MSP00002798_01_IF211S_TRU0"
  DOCUMENT_FORMAT      = PNG
  DOCUMENT_TOPIC_TYPE  = "BROWSE IMAGE"
  INTERCHANGE_FORMAT   = BINARY
  PUBLICATION_DATE     = 2006-01-19

/* The DDR file cited in SOURCE_PRODUCT_ID can be used to */
/* map-project the PNG file. */

SOURCE_PRODUCT_ID     = ("MSP00002798_01_IF211S_TRR0",
                        "MSP00002798_01_DE211S_DDR0")
RECORD_BYTES          = 64
FILE_RECORDS          = 225
SAMPLE_TYPE           = LSB_UNSIGNED_INTEGER
SAMPLE_BITS           = 8
BANDS                 = 3
BAND_SEQUENCE         = ("RED", "GREEN", "BLUE")
BAND_NAME              = ("592 nm", "533 nm", "442 nm")

/* The following information to scale from real numbers to an */
/* 8-bit integer is hard-coded for this type of browse image. */

DERIVED_MINIMUM       = (0,0,0)
DERIVED_MAXIMUM       = (250,250,250)
OFFSET                = (0,0,0)
SCALING_FACTOR        = (0.0024,0.0024,0.0024)
MISSING_CONSTANT      = (255,255,255)
DESCRIPTION           = "This file is a true color VNIR image assembled
                        from calibrated radiance, solar distance, and
                        solar flux as sampled in the wavelength filter
                        and binning state being used: radiance_factor =
                        I*D^2/(pi*F) where I = spectral radiance,
                        D = solar distance in AU, and F = solar flux at
                        1 AU. Subsequently a correction was made for
                        atmospheric and photometric effects either
                        predictively from climatology or after the fact
                        from CRISM measurements."
END_OBJECT            = DOCUMENT

END

```

## APPENDIX K3. TRDR BROWSE PRODUCT 'FEM' PNG FILE LABEL

```
PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE     = "2006-02-26, S. Murchie (APL);
                          2006-03-02, S. Slavney (GEO);
                          2006-09-18, S. Murchie (APL)"

/* This browse product consists of a synoptic image representing one */
/* MRO CRISM TRDR */

DATA_SET_ID             = "MRO-M-CRISM-2-TRDR-V1.0"
PRODUCT_ID              = "MSP00002798_01_SU211S_FEM0"
/* cccnnnnnnnnn_xx_SUaaaS_TRUV          */
/* ccc = Class Type                      */
/* nnnnnnnnn = Observation ID (hex)      */
/* xx = counter within observation (hex) */
/* SU = derived from summary product image */
/* aaa = macro number                    */
/* s = sensor ID (S or L)                */
/* v = version number                     */

INSTRUMENT_HOST_NAME    = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID           = MRO
INSTRUMENT_NAME         = "COMPACT RECONNAISSANCE IMAGING
                          SPECTROMETER FOR MARS"

INSTRUMENT_ID           = CRISM
TARGET_NAME             = MARS
PRODUCT_TYPE            = BROWSE
PRODUCT_CREATION_TIME   = 2006-01-19T20:06:14
PRODUCT_VERSION_ID      = "0"
PRODUCER_INSTITUTION_NAME = "JOHNS HOPKINS UNIVERSITY
                              APPLIED PHYSICS LABORATORY"

SOFTWARE_NAME           = "pipe_edrslice"
SOFTWARE_VERSION_ID     = "3.5"

/* The following information is relevant to an entire observation */

ORBIT_NUMBER            = "NULL"
OBSERVATION_TYPE        = "MSP"
OBSERVATION_ID          = 00002798

/* The following information is particular to one TRDR in the observation. */
/* The times are from the beginning of a TRDR to the end of the TRDR.      */

START_TIME              = 2006-01-19T18:42:43.592479
STOP_TIME               = 2006-01-19T18:42:58.529979
SPACECRAFT_CLOCK_START_COUNT = "2/822163382:17971"
SPACECRAFT_CLOCK_STOP_COUNT = "2/822163397:13875"
MRO:OBSERVATION_NUMBER  = 1
MRO:ACTIVITY_ID         = "SU211"
MRO:SENSOR_ID           = "S"
SHUTTER_MODE_ID         = OPEN
LIGHT_SOURCE_NAME       = "NONE"
MRO:CALIBRATION_LAMP_STATUS = "OFF"
MRO:CALIBRATION_LAMP_LEVEL = "N/A"
PIXEL_AVERAGING_WIDTH   = 10
MRO:INSTRUMENT_POINTING_MODE = "FIXED POINTING"
SCAN_MODE_ID            = "N/A"
MRO:FRAME_RATE          = 15.00 <HZ>
```

```

MRO:EXPOSURE_PARAMETER = 425
SAMPLING_MODE_ID       = "MULTISPEC"
COMPRESSION_TYPE       = "NONE"
MRO:WAVELENGTH_FILTER  = 1
MRO:WAVELENGTH_FILE_NAME = "CDR400000000000_WA0300010S_0.IMG"
MRO:PIXEL_PROC_FILE_NAME = "CDR6_1_0000000000_PP_S_1.TAB"
MRO:LOOKUP_TABLE_FILE_NAME = "CDR6_1_0000000000_LK_J_0.TAB"
MRO:INV_LOOKUP_TABLE_FILE_NAME = "CDR6_1_0000000000_LI_J_0.TAB"
MRO:ATMO_CORRECTION_FLAG = "OFF"
MRO:THERMAL_CORRECTION_MODE = "OFF"
MRO:PHOTOCLIN_CORRECTION_FLAG = "OFF"
MRO:SPATIAL_RESAMPLING_FLAG = "OFF"
MRO:SPATIAL_RESAMPLING_FILE = "N/A"
MRO:SPATIAL_RESCALING_FLAG = "OFF"
MRO:SPATIAL_RESCALING_FILE = "N/A"
MRO:SPECTRAL_RESAMPLING_FLAG = "OFF"
MRO:SPECTRAL_RESAMPLING_FILE = "N/A"

/* These parameters describe the browse image as a PDS document. */

^DOCUMENT              = "MSP00002798_01_SU211S_FEM0.PNG"
OBJECT                 = DOCUMENT
  DOCUMENT_NAME        = "MSP00002798_01_SU211S_FEM0"
  DOCUMENT_FORMAT      = PNG
  DOCUMENT_TOPIC_TYPE  = "BROWSE IMAGE"
  INTERCHANGE_FORMAT   = BINARY
  PUBLICATION_DATE     = 2006-01-19

/* The DDR file cited in SOURCE_PRODUCT_ID can be used to */
/* map-project the PNG file. */

SOURCE_PRODUCT_ID      = ("MSP00002798_01_SU211S_TRR0",
                          "MSP00002798_01_DE211S_DDR0")
RECORD_BYTES           = 192
FILE_RECORDS           = 225
SAMPLE_TYPE            = LSB_UNSIGNED_INTEGER
SAMPLE_BITS            = 8
BANDS                  = 3
BAND_SEQUENCE          = ("RED", "GREEN", "BLUE")
BAND_NAME              = ("BD530", "SH600", "BDI1000VIS")

/* The following information to scale from real numbers to an */
/* 8-bit integer is hard-coded for this type of browse image. */

DERIVED_MINIMUM        = (0,0,0)
DERIVED_MAXIMUM        = (250,250,250)
OFFSET                 = (0,1.1,0)
SCALING_FACTOR         = (0.0006,0.0004,0.00016)
MISSING_CONSTANT       = (255,255,255)
DESCRIPTION             = "This file is a false color VNIR image assembled
                          from calibrated radiance, solar distance, and
                          solar flux as sampled in the wavelength filter
                          and binning state being used: radiance_factor =
                          I*D^2/(pi*F) where I = spectral radiance,
                          D = solar distance in AU, and F = solar flux at
                          1 AU. Subsequently a correction was made for
                          atmospheric and photometric effects either
                          predictively from climatology or after the fact
                          from CRISM measurements. Finally the data were
                          used to derive synthetic spectral parameters that
                          encode spectral variance in the data due to Fe
                          minerals. B D530 is depth of the 530-nm band in
                          ferric materials. SH600 is strength of the

```

shoulder that is present in some ferric minerals near 600 nm. BDI1000VIS is the integrated area in the 1-micron band due to ferric and ferrous iron minerals."

END\_OBJECT

= DOCUMENT

END

## APPENDIX K4. TRDR BROWSE PRODUCT 'IRA' PNG FILE LABEL

```
PDS_VERSION_ID      = PDS3
LABEL_REVISION_NOTE = "2006-02-26, S. Murchie (APL);
                      2006-03-02, S. Slavney (GEO);
                      2006-09-19, S. Murchie (APL)"

/* This browse product consists of a synoptic image representing one */
/* MRO CRISM EDR */

DATA_SET_ID         = "MRO-M-CRISM-2-EDR-V1.0"
PRODUCT_ID          = "MSP00002798_01_IF211L_IRA0"
/* cccnnnnnnnn_xx_IFaaas_IRAv          */
/* ccc = Class Type                    */
/* nnnnnnnn = Observation ID (hex)     */
/* xx = counter within observation (hex) */
/* SU = derived from summary product image */
/* aaa = macro number                  */
/* s = sensor ID (S or L)              */
/* v = version number                  */

INSTRUMENT_HOST_NAME = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID        = MRO
INSTRUMENT_NAME      = "COMPACT RECONNAISSANCE IMAGING
                      SPECTROMETER FOR MARS"

INSTRUMENT_ID        = CRISM
TARGET_NAME          = MARS
PRODUCT_TYPE         = BROWSE
PRODUCT_CREATION_TIME = 2006-01-19T20:06:14
PRODUCT_VERSION_ID   = "0"
PRODUCER_INSTITUTION_NAME = "JOHNS HOPKINS UNIVERSITY
                              APPLIED PHYSICS LABORATORY"

SOFTWARE_NAME        = "pipe_edrslice"
SOFTWARE_VERSION_ID  = "3.5"

/* The following information is relevant to an entire observation */

ORBIT_NUMBER         = "NULL"
OBSERVATION_TYPE     = "MSP"
OBSERVATION_ID       = 00002798

/* The following information is particular to one EDR in the observation. */
/* The times are from the beginning of an EDR to the end of the EDR.      */

START_TIME           = 2006-01-19T18:42:43.592479
STOP_TIME            = 2006-01-19T18:42:58.529979
SPACECRAFT_CLOCK_START_COUNT = "2/822163382:17971"
SPACECRAFT_CLOCK_STOP_COUNT = "2/822163397:13875"
MRO:OBSERVATION_NUMBER = 1
MRO:ACTIVITY_ID        = "IF211"
MRO:SENSOR_ID          = "L"
SHUTTER_MODE_ID       = OPEN
LIGHT_SOURCE_NAME     = "NONE"
MRO:CALIBRATION_LAMP_STATUS = "OFF"
MRO:CALIBRATION_LAMP_LEVEL = "N/A"
PIXEL_AVERAGING_WIDTH = 10
MRI:INSTRUMENT_POINTING_MODE = "FIXED POINTING"
SCAN_MODE_ID          = "N/A"
MRO:FRAME_RATE        = 15.00 <HZ>
```

```

MRO:EXPOSURE_PARAMETER = 425
SAMPLING_MODE_ID       = "MULTISPEC"
COMPRESSION_TYPE       = "NONE"
MRO:WAVELENGTH_FILTER  = 1
MRO:WAVELENGTH_FILE_NAME = "CDR6_1_0000000000_WV_L_1.TAB"
MRO:PIXEL_PROC_FILE_NAME = "CDR6_1_0000000000_PP_L_1.TAB"
MRO:INV_LOOKUP_TABLE_FILE_NAME = "CDR6_1_0000000000_LI_J_0.TAB"
MRO:ATMO_CORRECTION_FLAG = "OFF"
MRO:THERMAL_CORRECTION_MODE = "OFF"
MRO:PHOTOCLIN_CORRECTION_FLAG = "OFF"
MRO:SPATIAL_RESAMPLING_FLAG = "OFF"
MRO:SPATIAL_RESAMPLING_FILE = "N/A"
MRO:SPATIAL_RESCALING_FLAG = "OFF"
MRO:SPATIAL_RESCALING_FILE = "N/A"
MRO:SPECTRAL_RESAMPLING_FLAG = "OFF"
MRO:SPECTRAL_RESAMPLING_FILE = "N/A"

^DOCUMENT                = "MSP00002798_01_IF211L_IRA0.PNG"
OBJECT                   = DOCUMENT
  DOCUMENT_NAME          = "MSP00002798_01_IF211L_IRA0"
  DOCUMENT_FORMAT        = PNG
  DOCUMENT_TOPIC_TYPE    = "BROWSE IMAGE"
  INTERCHANGE_FORMAT     = BINARY
  PUBLICATION_DATE       = 2006-01-19

/* The DDR file cited in SOURCE_PRODUCT_ID can be used to */
/* map-project the PNG file. */

SOURCE_PRODUCT_ID        = ("MSP00002798_01_IF211L_TRR0",
                           "MSP00002798_01_DE211L_DDR0")
RECORD_BYTES             = 64
FILE_RECORDS             = 225
SAMPLE_TYPE              = LSB_UNSIGNED_INTEGER
SAMPLE_BITS              = 8
BANDS                    = 1
BAND_NAME                = "1330nm"

/* The following information to scale from real numbers to an */
/* 8-bit integer is hard-coded for this type of browse image. */

DERIVED_MINIMUM          = 0
DERIVED_MAXIMUM          = 250
OFFSET                   = 0
SCALING_FACTOR           = 0.0024
MISSING_CONSTANT         = 255
DESCRIPTION               = "This file is a scaled 1330 nm I/F image assembled
                             from calibrated radiance, solar distance, and
                             solar flux as sampled in the wavelength filter
                             and binning state being used: radiance_factor =
                             I*D^2/(pi*F) where I = spectral radiance,
                             D = solar distance in AU, and F = solar flux at
                             1 AU. Subsequently a correction was made for
                             atmospheric and photometric effects either
                             predictively from climatology or after the fact
                             from CRISM measurements."
END_OBJECT               = DOCUMENT

END

```

## APPENDIX K5. TRDR BROWSE PRODUCT 'MAF' PNG FILE LABEL

```
PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE     = "2006-02-26, S.Murchie (APL);
                          2006-03-02, S. Slavney (GEO);
                          2006-09-18, S. Murchie (APL)"

/* This browse product consists of a synoptic image representing one */
/* MRO CRISM EDR */

DATA_SET_ID             = "MRO-M-CRISM-2-TRDR-V1.0"
PRODUCT_ID              = "MSP00002798_01_SU211L_MAF0"
/* cccnnnnnnnn_xx_ooaaas_RAWv          */
/* ccc = Class Type                    */
/* nnnnnnnn = Observation ID (hex)     */
/* xx = counter within observation (hex) */
/* SU = derived from summary product image */
/* ooaaa = obs type, macro number     */
/* s = sensor ID (S or L)             */
/* v = version number                  */

INSTRUMENT_HOST_NAME    = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID           = MRO
INSTRUMENT_NAME         = "COMPACT RECONNAISSANCE IMAGING
                          SPECTROMETER FOR MARS"

INSTRUMENT_ID           = CRISM
TARGET_NAME             = MARS
PRODUCT_TYPE            = BROWSE
PRODUCT_CREATION_TIME   = 2006-01-19T20:06:14
PRODUCT_VERSION_ID      = "0"
PRODUCER_INSTITUTION_NAME = "JOHNS HOPKINS UNIVERSITY
                          APPLIED PHYSICS LABORATORY"

SOFTWARE_NAME           = "pipe_edrslice"
SOFTWARE_VERSION_ID     = "3.5"

/* The following information is relevant to an entire observation */

ORBIT_NUMBER            = "NULL"
OBSERVATION_TYPE        = "MSP"
OBSERVATION_ID          = 00002798

/* The following information is particular to one EDR in the observation. */
/* The times are from the beginning of an EDR to the end of the EDR.      */

START_TIME              = 2006-01-19T18:42:43.592479
STOP_TIME               = 2006-01-19T18:42:58.529979
SPACECRAFT_CLOCK_START_COUNT = "2/822163382:17971"
SPACECRAFT_CLOCK_STOP_COUNT = "2/822163397:13875"
MRO:OBSERVATION_NUMBER  = 1
MRO:ACTIVITY_ID         = "SU211"
MRO:SENSOR_ID           = "L"
SHUTTER_MODE_ID         = OPEN
LIGHT_SOURCE_NAME       = "NONE"
MRO:CALIBRATION_LAMP_STATUS = "OFF"
MRO:CALIBRATION_LAMP_LEVEL = "N/A"
PIXEL_AVERAGING_WIDTH   = 10
MRI:INSTRUMENT_POINTING_MODE = "FIXED POINTING"
SCAN_MODE_ID            = "N/A"
MRO:FRAME_RATE          = 15.00 <HZ>
```

```

MRO:EXPOSURE_PARAMETER = 425
SAMPLING_MODE_ID       = "MULTISPEC"
COMPRESSION_TYPE       = "NONE"
MRO:WAVELENGTH_FILTER  = 1
MRO:WAVELENGTH_FILE_NAME = "CDR400000000000_WA0300010L_0.IMG"
MRO:PIXEL_PROC_FILE_NAME = "CDR6_1_0000000000_PP_L_1.TAB"
MRO:INV_LOOKUP_TABLE_FILE_NAME = "CDR6_1_0000000000_LI_J_0.TAB"
MRO:ATMO_CORRECTION_FLAG = "OFF"
MRO:THERMAL_CORRECTION_MODE = "OFF"
MRO:PHOTOCLIN_CORRECTION_FLAG = "OFF"
MRO:SPATIAL_RESAMPLING_FLAG = "OFF"
MRO:SPATIAL_RESAMPLING_FILE = "N/A"
MRO:SPATIAL_RESCALING_FLAG = "OFF"
MRO:SPATIAL_RESCALING_FILE = "N/A"
MRO:SPECTRAL_RESAMPLING_FLAG = "OFF"
MRO:SPECTRAL_RESAMPLING_FILE = "N/A"

```

```

^DOCUMENT              = "MSP00002798_01_SU211L_MAF0.PNG"
OBJECT                 = DOCUMENT
  DOCUMENT_NAME        = "MSP00002798_01_SU211L_MAF0"
  DOCUMENT_FORMAT      = PNG
  DOCUMENT_TOPIC_TYPE  = "BROWSE IMAGE"
  INTERCHANGE_FORMAT   = BINARY
  PUBLICATION_DATE     = 2006-01-19

```

```

/* The DDR file cited in SOURCE_PRODUCT_ID can be used to */
/* map-project the PNG file. */

```

```

SOURCE_PRODUCT_ID      = ("MSP00002798_01_SU211L_TRR0",
                          "MSP00002798_01_DE211L_DDR0")
RECORD_BYTES           = 192
FILE_RECORDS           = 225
SAMPLE_TYPE            = LSB_UNSIGNED_INTEGER
SAMPLE_BITS            = 8
BANDS                  = 3
BAND_SEQUENCE          = ("RED", "GREEN", "BLUE")
BAND_NAME              = ("OLINDEX", "LCPINDEX", "HCPINDEX")

```

```

/* The following information to scale from real numbers to an */
/* 8-bit integer is hard-coded for this type of browse image. */

```

```

DERIVED_MINIMUM        = (0,0,0)
DERIVED_MAXIMUM        = (250,250,250)
OFFSET                 = (0,0,0)
SCALING_FACTOR         = (0.001,0.000016,0.000024)
MISSING_CONSTANT       = (255,255,255)
DESCRIPTION             = "This file is a false color IR image assembled
                          from calibrated radiance, solar distance, and
                          solar flux as sampled in the wavelength filter
                          and binning state being used: radiance_factor =
                          I*D^2/(pi*F) where I = spectral radiance,
                          D = solar distance in AU, and F = solar flux at
                          1 AU. Subsequently a correction was made for
                          atmospheric and photometric effects either
                          predictively from climatology or after the fact
                          from CRISM measurements. Finally the data were
                          used to derive synthetic spectral parameters that
                          encode spectral variance in the data due to Fe
                          minerals. OLINDEX is a measure of reflectance
                          near 1700 nm relative to that at shorter
                          wavelengths, where values >>1 are suggestive of
                          olivine. LCPINDEX is a measure of peakedness
                          of the spectrum near 1330 nm, with values >>0

```

```
    suggestive of low-calcium pyroxene. HCPINDEX
    is a measure of peakedness of the spectrum
    near 1470 nm, with values >>0 suggestive of
    high-calcium pyroxene."
END_OBJECT      = DOCUMENT
END
```

## APPENDIX K6. TRDR BROWSE PRODUCT 'HYD' PNG FILE LABEL

```
PDS_VERSION_ID      = PDS3
LABEL_REVISION_NOTE = "2006-02-26, S.Murchie (APL);
                      2006-03-02, S. Slavney (GEO);
                      2006-09-18, S. Murchie (APL)"

/* This browse product consists of a synoptic image representing one */
/* MRO CRISM EDR */

DATA_SET_ID         = "MRO-M-CRISM-2-TRDR-V1.0"
PRODUCT_ID          = "MSP00002798_01_SU211L_HYD0"
/* cccnnnnnnnn_xx_ooaaas_RAWv          */
/* ccc = Class Type                    */
/* nnnnnnnn = Observation ID (hex)     */
/* xx = counter within observation (hex) */
/* IF = derived from summary product image */
/* ooaaa = obs type, macro number     */
/* s = sensor ID (S or L)            */
/* v = version number                 */

INSTRUMENT_HOST_NAME = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID        = MRO
INSTRUMENT_NAME      = "COMPACT RECONNAISSANCE IMAGING
                      SPECTROMETER FOR MARS"

INSTRUMENT_ID        = CRISM
TARGET_NAME          = MARS
PRODUCT_TYPE         = BROWSE
PRODUCT_CREATION_TIME = 2006-01-19T20:06:14
PRODUCT_VERSION_ID   = "0"
PRODUCER_INSTITUTION_NAME = "JOHNS HOPKINS UNIVERSITY
                             APPLIED PHYSICS LABORATORY"

SOFTWARE_NAME        = "pipe_edrslice"
SOFTWARE_VERSION_ID  = "3.5"

/* The following information is relevant to an entire observation */

ORBIT_NUMBER         = "NULL"
OBSERVATION_TYPE     = "MSP"
OBSERVATION_ID       = 00002798

/* The following information is particular to one EDR in the observation. */
/* The times are from the beginning of an EDR to the end of the EDR.      */

START_TIME           = 2006-01-19T18:42:43.592479
STOP_TIME            = 2006-01-19T18:42:58.529979
SPACECRAFT_CLOCK_START_COUNT = "2/822163382:17971"
SPACECRAFT_CLOCK_STOP_COUNT = "2/822163397:13875"
MRO:OBSERVATION_NUMBER = 1
MRO:ACTIVITY_ID        = "SU211"
MRO:SENSOR_ID          = "L"
SHUTTER_MODE_ID       = OPEN
LIGHT_SOURCE_NAME     = "NONE"
MRO:CALIBRATION_LAMP_STATUS = "OFF"
MRO:CALIBRATION_LAMP_LEVEL = "N/A"
PIXEL_AVERAGING_WIDTH = 10
MRO:INSTRUMENT_POINTING_MODE = "FIXED POINTING"
SCAN_MODE_ID          = "N/A"
MRO:FRAME_RATE        = 15.00 <HZ>
```

```

MRO:EXPOSURE_PARAMETER = 425
SAMPLING_MODE_ID       = "MULTISPEC"
COMPRESSION_TYPE       = "NONE"
MRO:WAVELENGTH_FILTER  = 1
MRO:WAVELENGTH_FILE_NAME = "CDR400000000000_WA0300010L_0.IMG"
MRO:PIXEL_PROC_FILE_NAME = "CDR6_1_0000000000_PP_L_1.TAB"
MRO:INV_LOOKUP_TABLE_FILE_NAME = "CDR6_1_0000000000_LI_J_0.TAB"
MRO:ATMO_CORRECTION_FLAG = "OFF"
MRO:THERMAL_CORRECTION_MODE = "OFF"
MRO:PHOTOCLIN_CORRECTION_FLAG = "OFF"
MRO:SPATIAL_RESAMPLING_FLAG = "OFF"
MRO:SPATIAL_RESAMPLING_FILE = "N/A"
MRO:SPATIAL_RESCALING_FLAG = "OFF"
MRO:SPATIAL_RESCALING_FILE = "N/A"
MRO:SPECTRAL_RESAMPLING_FLAG = "OFF"
MRO:SPECTRAL_RESAMPLING_FILE = "N/A"

/* These parameters describe the browse image as a PDS document. */

^DOCUMENT              = "MSP00002798_01_SU211L_HYD0.PNG"
OBJECT                 = DOCUMENT
  DOCUMENT_NAME        = "MSP00002798_01_SU211L_HYD0"
  DOCUMENT_FORMAT      = PNG
  DOCUMENT_TOPIC_TYPE  = "BROWSE IMAGE"
  INTERCHANGE_FORMAT   = BINARY
  PUBLICATION_DATE     = 2006-01-19

/* The DDR file cited in SOURCE_PRODUCT_ID can be used to */
/* map-project the PNG file. */

SOURCE_PRODUCT_ID     = ("MSP00002798_01_SU211L_TRR0",
                        "MSP00002798_01_SU211L_TRR0")
RECORD_BYTES          = 192
FILE_RECORDS          = 225
SAMPLE_TYPE           = LSB_UNSIGNED_INTEGER
SAMPLE_BITS           = 8
BANDS                  = 3
BAND_SEQUENCE         = ("RED", "GREEN", "BLUE")
BAND_NAME              = ("SINDEX", "BD2100", "BD1900")

/* The following information to scale from real numbers to an */
/* 8-bit integer is hard-coded for this type of browse image. */

DERIVED_MINIMUM        = (0,0,0)
DERIVED_MAXIMUM        = (250,250,250)
OFFSET                 = (1,0,0)
SCALING_FACTOR         = (0.0004,0.0002,0.0002)
MISSING_CONSTANT       = (255,255,255)
DESCRIPTION            = "This file is a false color IR image assembled
                          from calibrated radiance, solar distance, and
                          solar flux as sampled in the wavelength filter
                          and binning state being used: radiance_factor =
                          I*D^2/(pi*F) where I = spectral radiance,
                          D = solar distance in AU, and F = solar flux at
                          1 AU. Subsequently a correction was made for
                          atmospheric and photometric effects either
                          predictively from climatology or after the fact
                          from CRISM measurements. Finally the data were
                          used to derive synthetic spectral parameters that
                          encode spectral variance in the data due to
                          hydrated minerals.
                          SINDEX is a measure of the wing
                          of the 3000-nm band due to bound water, or

```

of a 2400-nm band in some polyhydrated minerals.  
BD2100 is a measure of the depth of  
the 2100-nm band due to bound water in  
monohydrated sulfates.  
BD1900 is a measure of the depth of  
the 1900-nm band due to bound water."

END\_OBJECT

= DOCUMENT

END

## APPENDIX K7. TRDR BROWSE PRODUCT 'ICE' PNG FILE LABEL

```
PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE     = "2006-02-26, S.Murchie (APL);
                          2006-03-02, S. Slavney (GEO);
                          2006-09-18, S. Murchie (APL)"

/* This browse product consists of a synoptic image representing one */
/* MRO CRISM EDR */

DATA_SET_ID             = "MRO-M-CRISM-2-TRDR-V1.0"
PRODUCT_ID              = "MSP00002798_01_SU211L_ICE0"
/* cccnnnnnnnn_xx_ooaaas_RAWv          */
/* ccc = Class Type                    */
/* nnnnnnnn = Observation ID (hex)     */
/* xx = counter within observation (hex) */
/* IF = derived from summary product image */
/* ooaaa = obs type, macro number      */
/* s = sensor ID (S or L)              */
/* v = version number                  */

INSTRUMENT_HOST_NAME   = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID         = MRO
INSTRUMENT_NAME        = "COMPACT RECONNAISSANCE IMAGING
                          SPECTROMETER FOR MARS"

INSTRUMENT_ID         = CRISM
TARGET_NAME           = MARS
PRODUCT_TYPE          = BROWSE
PRODUCT_CREATION_TIME = 2006-01-19T20:06:14
PRODUCT_VERSION_ID    = "0"
PRODUCER_INSTITUTION_NAME = "JOHNS HOPKINS UNIVERSITY
                              APPLIED PHYSICS LABORATORY"

SOFTWARE_NAME         = "pipe_edrslice"
SOFTWARE_VERSION_ID   = "3.5"

/* The following information is relevant to an entire observation */

ORBIT_NUMBER          = "NULL"
OBSERVATION_TYPE      = "MSP"
OBSERVATION_ID        = 00002798

/* The following information is particular to one EDR in the observation. */
/* The times are from the beginning of an EDR to the end of the EDR.      */

START_TIME            = 2006-01-19T18:42:43.592479
STOP_TIME             = 2006-01-19T18:42:58.529979
SPACECRAFT_CLOCK_START_COUNT = "2/822163382:17971"
SPACECRAFT_CLOCK_STOP_COUNT = "2/822163397:13875"
MRO:OBSERVATION_NUMBER = 1
MRO:ACTIVITY_ID       = "SU211"
MRO:SENSOR_ID        = "L"
SHUTTER_MODE_ID      = OPEN
LIGHT_SOURCE_NAME     = "NONE"
MRO:CALIBRATION_LAMP_STATUS = "OFF"
MRO:CALIBRATION_LAMP_LEVEL = "N/A"
PIXEL_AVERAGING_WIDTH = 10
MRO:INSTRUMENT_POINTING_MODE = "FIXED POINTING"
SCAN_MODE_ID         = "N/A"
MRO:FRAME_RATE       = 15.00 <HZ>
```

```

MRO:EXPOSURE_PARAMETER = 425
SAMPLING_MODE_ID       = "MULTISPEC"
COMPRESSION_TYPE       = "NONE"
MRO:WAVELENGTH_FILTER  = 1
MRO:WAVELENGTH_FILE_NAME = "CDR400000000000_WA0300010L_0.IMG"
MRO:PIXEL_PROC_FILE_NAME = "CDR6_1_0000000000_PP_L_1.TAB"
MRO:INV_LOOKUP_TABLE_FILE_NAME = "CDR6_1_0000000000_LI_J_0.TAB"
MRO:ATMO_CORRECTION_FLAG = "OFF"
MRO:THERMAL_CORRECTION_MODE = "OFF"
MRO:PHOTOCLIN_CORRECTION_FLAG = "OFF"
MRO:SPATIAL_RESAMPLING_FLAG = "OFF"
MRO:SPATIAL_RESAMPLING_FILE = "N/A"
MRO:SPATIAL_RESCALING_FLAG = "OFF"
MRO:SPATIAL_RESCALING_FILE = "N/A"
MRO:SPECTRAL_RESAMPLING_FLAG = "OFF"
MRO:SPECTRAL_RESAMPLING_FILE = "N/A"

```

```

/* These parameters describe the browse image as a PDS document. */

```

```

^DOCUMENT              = "MSP00002798_01_SU211L_ICE0.PNG"
OBJECT                 = DOCUMENT
  DOCUMENT_NAME        = "MSP00002798_01_SU211L.ICE0"
  DOCUMENT_FORMAT      = PNG
  DOCUMENT_TOPIC_TYPE  = "BROWSE IMAGE"
  INTERCHANGE_FORMAT   = BINARY
  PUBLICATION_DATE     = 2006-01-19

```

```

/* The DDR file cited in SOURCE_PRODUCT_ID can be used to */
/* map-project the PNG file. */

```

```

SOURCE_PRODUCT_ID      = ("MSP00002798_01_SU211L_TRR0",
                          "MSP00002798_01_SU211L_TRR0")
RECORD_BYTES           = 192
FILE_RECORDS           = 225
SAMPLE_TYPE            = LSB_UNSIGNED_INTEGER
SAMPLE_BITS            = 8
BANDS                  = 3
BAND_SEQUENCE          = ("RED", "GREEN", "BLUE")
BAND_NAME               = ("BD1900", "BD1500", "BD1435")

```

```

/* The following information to scale from real numbers to an */
/* 8-bit integer is hard-coded for this type of browse image. */

```

```

DERIVED_MINIMUM        = (0,0,0)
DERIVED_MAXIMUM        = (250,250,250)
OFFSET                 = (0,0,0)
SCALING_FACTOR         = (0.0016,0.0016,0.0016)
MISSING_CONSTANT       = (255,255,255)
DESCRIPTION             = "This file is a false color IR image assembled
                          from calibrated radiance, solar distance, and
                          solar flux as sampled in the wavelength filter
                          and binning state being used: radiance_factor =
                          I*D^2/(pi*F) where I = spectral radiance,
                          D = solar distance in AU, amd F = solar flux at
                          1 AU. Subsequently a correction was made for
                          atmospheric and photometric effects either
                          predictively from climatology or after the fact
                          from CRISM measurements. Finally the data were
                          used to derive synthetic spectral parameters that
                          encode spectral variance in the data due to
                          water and carbon dioxide ice.
                          BD1900 is a measure of the 1900-nm band in
                          water ice."

```

```
BD1500 is a measure of the 1500-nm band in
water ice.
BD1435 is a measure of the 1435-nm band in
carbon dioxide ice."
END_OBJECT = DOCUMENT
END
```

## APPENDIX K8. TRDR BROWSE PRODUCT 'PHY' PNG FILE LABEL

```
PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE     = "2006-02-26, S.Murchie (APL);
                          2006-03-02, S. Slavney (GEO);
                          2006-09-18, S. Murchie (APL)"

/* This browse product consists of a synoptic image representing one */
/* MRO CRISM EDR */

DATA_SET_ID             = "MRO-M-CRISM-2-TRDR-V1.0"
PRODUCT_ID              = "MSP00002798_01_SU211L_PHY0"
/* cccnnnnnnnn_xx_ooaaas_RAWv          */
/* ccc = Class Type                    */
/* nnnnnnnn = Observation ID (hex)     */
/* xx = counter within observation (hex) */
/* IF = derived from summary product image */
/* ooaaa = obs type, macro number     */
/* s = sensor ID (S or L)            */
/* v = version number                 */

INSTRUMENT_HOST_NAME   = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID          = MRO
INSTRUMENT_NAME        = "COMPACT RECONNAISSANCE IMAGING
                          SPECTROMETER FOR MARS"

INSTRUMENT_ID          = CRISM
TARGET_NAME            = MARS
PRODUCT_TYPE           = BROWSE
PRODUCT_CREATION_TIME  = 2006-01-19T20:06:14
PRODUCT_VERSION_ID     = "0"
PRODUCER_INSTITUTION_NAME = "JOHNS HOPKINS UNIVERSITY
                          APPLIED PHYSICS LABORATORY"

SOFTWARE_NAME          = "pipe_edrslice"
SOFTWARE_VERSION_ID    = "3.5"

/* The following information is relevant to an entire observation */

ORBIT_NUMBER           = "NULL"
OBSERVATION_TYPE       = "MSP"
OBSERVATION_ID         = 00002798

/* The following information is particular to one EDR in the observation. */
/* The times are from the beginning of an EDR to the end of the EDR.      */

START_TIME              = 2006-01-19T18:42:43.592479
STOP_TIME               = 2006-01-19T18:42:58.529979
SPACECRAFT_CLOCK_START_COUNT = "2/822163382:17971"
SPACECRAFT_CLOCK_STOP_COUNT = "2/822163397:13875"
MRO:OBSERVATION_NUMBER  = 1
MRO:ACTIVITY_ID         = "SU211"
MRO:SENSOR_ID           = "L"
SHUTTER_MODE_ID         = OPEN
LIGHT_SOURCE_NAME       = "NONE"
MRO:CALIBRATION_LAMP_STATUS = "OFF"
MRO:CALIBRATION_LAMP_LEVEL = "N/A"
PIXEL_AVERAGING_WIDTH   = 10
MRO:INSTRUMENT_POINTING_MODE = "FIXED POINTING"
SCAN_MODE_ID            = "N/A"
MRO:FRAME_RATE          = 15.00 <HZ>
```

```

MRO:EXPOSURE_PARAMETER = 425
SAMPLING_MODE_ID       = "MULTISPEC"
COMPRESSION_TYPE       = "NONE"
MRO:WAVELENGTH_FILTER  = 1
MRO:WAVELENGTH_FILE_NAME = "CDR400000000000_WA0300010L_0.IMG"
MRO:PIXEL_PROC_FILE_NAME = "CDR6_1_0000000000_PP_L_1.TAB"
MRO:INV_LOOKUP_TABLE_FILE_NAME = "CDR6_1_0000000000_LI_J_0.TAB"
MRO:ATMO_CORRECTION_FLAG = "OFF"
MRO:THERMAL_CORRECTION_MODE = "OFF"
MRO:PHOTOCLIN_CORRECTION_FLAG = "OFF"
MRO:SPATIAL_RESAMPLING_FLAG = "OFF"
MRO:SPATIAL_RESAMPLING_FILE = "N/A"
MRO:SPATIAL_RESCALING_FLAG = "OFF"
MRO:SPATIAL_RESCALING_FILE = "N/A"
MRO:SPECTRAL_RESAMPLING_FLAG = "OFF"
MRO:SPECTRAL_RESAMPLING_FILE = "N/A"

/* These parameters describe the browse image as a PDS document. */

^DOCUMENT              = "MSP00002798_01_SU211L_PHY0.PNG"
OBJECT                 = DOCUMENT
  DOCUMENT_NAME        = "MSP00002798_01_SU211L.PHY0"
  DOCUMENT_FORMAT      = PNG
  DOCUMENT_TOPIC_TYPE  = "BROWSE IMAGE"
  INTERCHANGE_FORMAT   = BINARY
  PUBLICATION_DATE     = 2006-01-19

/* The DDR file cited in SOURCE_PRODUCT_ID can be used to */
/* map-project the PNG file. */

SOURCE_PRODUCT_ID      = ("MSP00002798_01_SU211L_TRR0",
                          "MSP00002798_01_SU211L_TRR0")
RECORD_BYTES           = 192
FILE_RECORDS           = 225
SAMPLE_TYPE            = LSB_UNSIGNED_INTEGER
SAMPLE_BITS            = 8
BANDS                  = 3
BAND_SEQUENCE          = ("RED", "GREEN", "BLUE")
BAND_NAME              = ("D2300", "BD2210", "BD1900")

/* The following information to scale from real numbers to an */
/* 8-bit integer is hard-coded for this type of browse image. */

DERIVED_MINIMUM        = (0,0,0)
DERIVED_MAXIMUM        = (250,250,250)
OFFSET                 = (0,0,0)
SCALING_FACTOR         = (0.0002,0.0002,0.0002)
MISSING_CONSTANT       = (255,255,255)
DESCRIPTION             = "This file is a false color IR image assembled
                           from calibrated radiance, solar distance, and
                           solar flux as sampled in the wavelength filter
                           and binning state being used: radiance_factor =
                           I*D^2/(pi*F) where I = spectral radiance,
                           D = solar distance in AU, and F = solar flux at
                           1 AU. Subsequently a correction was made for
                           atmospheric and photometric effects either
                           predictively from climatology or after the fact
                           from CRISM measurements. Finally the data were
                           used to derive synthetic spectral parameters that
                           encode spectral variance in the data due to
                           hydroxylated minerals.
                           D2300 is a measure of the 2300-nm band due to
                           Mg- and Fe-OH bonds in phyllosilicates."

```

BD2210 is a measure of the 2290-nm band due to Al- and Si-OH bonds in in hydrated silicates.  
BD1900 is a measure of the depth of the 1900-nm band due to bound water."  
= DOCUMENT

END\_OBJECT

END

## APPENDIX L1. MRDR BROWSE PRODUCT 'TRU' PNG FILE LABEL

```

PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE     = "2003-11-19, S. Slavney (GEO);
                          2005-09-25, S. Murchie (JHU/APL)"

/* Map-projected Multispectral RDR Identification */

DATA_SET_ID             = "MRO-M-CRISM-5-RDR-MULTISPECTRAL-V1.0"
PRODUCT_ID              = "T0123_MRRTRU_10N355_0256_0"
                          /*( Tnnnn_MRRsss_xxdyyy_rrrr_v          )*/
                          /*( nnnn = tile number                  )*/
                          /*( sss = subtype of browse product    )*/
                          /*( xx = latitude of tile center       )*/
                          /*( d = N or S for north or south latitude )*/
                          /*( yyy = east longitude of tile center )*/
                          /*( rrrr = resolution in pixels/degree  )*/
                          /*( v = version number                  )*/

INSTRUMENT_HOST_NAME    = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID           = MRO
INSTRUMENT_NAME         = "COMPACT RECONNAISSANCE IMAGING
                          SPECTROMETER FOR MARS"

INSTRUMENT_ID           = CRISM
TARGET_NAME             = MARS
PRODUCT_TYPE            = BROWSE
PRODUCT_CREATION_TIME   = 2006-06-17T13:03:07.234
START_TIME              = "N/A"
STOP_TIME               = "N/A"
SPACECRAFT_CLOCK_START_COUNT = "N/A"
SPACECRAFT_CLOCK_STOP_COUNT = "N/A"
PRODUCT_VERSION_ID      = "0" /*( version number from product ID )*/
PRODUCER_INSTITUTION_NAME = "APPLIED PHYSICS LABORATORY"
SOFTWARE_NAME           = "tbd"
SOFTWARE_VERSION_ID     = "tbd"
MRO:WAVELENGTH_FILE_NAME = "T0123_MRRWV_10N355_0256_0.TAB"

/* These parameters describe the browse image as a PDS document. */

^DOCUMENT                = "T0123_MRRTRU_10N355_0256_0.PNG"
OBJECT                   = DOCUMENT
  DOCUMENT_NAME          = "T0123_MRRTRU_10N355_0256_0"
  DOCUMENT_FORMAT        = PNG
  DOCUMENT_TOPIC_TYPE    = "BROWSE IMAGE"
  INTERCHANGE_FORMAT     = BINARY
  PUBLICATION_DATE       = 2006-01-19
  SOURCE_PRODUCT_ID      = "T0123_MRRAL_10N355_0256_0"
  RECORD_BYTES           = 3840
  FILE_RECORDS           = 1280
  SAMPLE_TYPE            = LSB_UNSIGNED_INTEGER
  SAMPLE_BITS            = 8
  BANDS                  = 3
  BAND_SEQUENCE          = ("RED", "GREEN", "BLUE")
  BAND_NAME              = ("592 nm", "532 nm", "442 nm")

/* The following information to scale from real numbers to an */
/* 8-bit integer is hard-coded for this type of browse image. */

DERIVED_MINIMUM         = (0,0,0)

```

```

DERIVED_MAXIMUM      = (250,250,250)
OFFSET               = (0,0,0)
SCALING_FACTOR       = (0.0024,0.0024,0.0024)
MISSING_CONSTANT     = (255,255,255)
DESCRIPTION          = "This file is a true color VNIR image assembled
                        from calibrated radiance, solar distance, and
                        solar flux as sampled in the wavelength filter
                        and binning state being used: radiance_factor =
                        I*D^2/(pi*F) where I = spectral radiance,
                        D = solar distance in AU, and F = solar flux at
                        1 AU. Subsequently a correction was made for
                        atmospheric and photometric effects either
                        predictively from climatology or after the fact
                        from CRISM measurements."
END_OBJECT           = DOCUMENT

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

OBJECT              = IMAGE_MAP_PROJECTION
  ^DATA_SET_MAP_PROJECTION = "MRR_MAP.CAT"
  MAP_PROJECTION_TYPE     = "EQUIRECTANGULAR"
                        /* ( or POLAR STEREOGRAPHIC ) */
  A_AXIS_RADIUS          = 3393.4 <KM>
  B_AXIS_RADIUS          = 3393.4 <KM>
  C_AXIS_RADIUS          = 3375.7 <KM>
  FIRST_STANDARD_PARALLEL = "N/A"
  SECOND_STANDARD_PARALLEL = "N/A"
  POSITIVE_LONGITUDE_DIRECTION = "EAST"
  CENTER_LATITUDE        = 5.0 <DEGREE>
                        /* ( for this tile only center latitude ) */
                        /* ( of projection, the low-latitude edge ) */
                        /* ( of the tile ) */
  CENTER_LONGITUDE        = 0.0 <DEGREE>
  REFERENCE_LATITUDE      = "N/A"
  REFERENCE_LONGITUDE     = "N/A"
  LINE_FIRST_PIXEL        = 1
                        /* ( line number of N edge of this tile ) */
  LINE_LAST_PIXEL         = 1280
                        /* ( line number of S edge of this tile ) */
  SAMPLE_FIRST_PIXEL      = 1
                        /* ( sample number of W edge of this tile ) */
  SAMPLE_LAST_PIXEL       = 1280
                        /* ( sample number of E edge of this tile ) */
  MAP_PROJECTION_ROTATION = 0.0
  MAP_RESOLUTION          = 256 <PIXEL/DEGREE>
  MAP_SCALE               = 0.23 <KM/PIXEL>
                        /* ( this is average over the planet ) */
  MAXIMUM_LATITUDE        = 10.0 <DEGREE>
                        /* ( for this tile only ) */
  MINIMUM_LATITUDE        = 5.0 <DEGREE>
                        /* ( for this tile only ) */
  WESTERNMOST_LONGITUDE   = 355.0 <DEGREE>
                        /* ( for this tile only ) */
  EASTERNMOST_LONGITUDE   = 0.0 <DEGREE>
                        /* ( for this tile only ) */
  LINE_PROJECTION_OFFSET  = 2560
                        /* ( for this tile only; number of ) */
                        /* ( pixels from equator to first pixel ) */
                        /* ( of map tile ) */
  SAMPLE_PROJECTION_OFFSET = -1280
                        /* ( for this tile only; number of ) */
                        /* ( pixels from 0 degrees longitude ) */

```

```
                                /*( to first pixel of map tile )*/
    COORDINATE_SYSTEM_TYPE      = "BODY-FIXED ROTATING"
    COORDINATE_SYSTEM_NAME     = "PLANETOCENTRIC"
    END_OBJECT                  = IMAGE_MAP_PROJECTION

END
```

## APPENDIX L2. MRDR BROWSE PRODUCT 'FEM' PNG FILE LABEL

```

PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE     = "2003-11-19, S. Slavney (GEO);
                          2005-09-25, S. Murchie (JHU/APL)"

/* Map-projected Multispectral RDR Identification */

DATA_SET_ID             = "MRO-M-CRISM-5-RDR-MULTISPECTRAL-V1.0"
PRODUCT_ID              = "T0123_MRRFEM_10N355_0256_0"
                          /*( Tnnnn_MRRsss_xxdyyy_rrrr_v          )*/
                          /*( nnnn = tile number                  )*/
                          /*( sss = subtype of browse product    )*/
                          /*( xx = latitude of tile center       )*/
                          /*( d = N or S for north or south latitude )*/
                          /*( yyy = east longitude of tile center )*/
                          /*( rrrr = resolution in pixels/degree  )*/
                          /*( v = version number                  )*/

INSTRUMENT_HOST_NAME    = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID           = MRO
INSTRUMENT_NAME         = "COMPACT RECONNAISSANCE IMAGING
                          SPECTROMETER FOR MARS"

INSTRUMENT_ID           = CRISM
TARGET_NAME             = MARS
PRODUCT_TYPE            = BROWSE
PRODUCT_CREATION_TIME   = 2006-06-17T13:03:07.234
START_TIME              = "N/A"
STOP_TIME               = "N/A"
SPACECRAFT_CLOCK_START_COUNT = "N/A"
SPACECRAFT_CLOCK_STOP_COUNT = "N/A"
PRODUCT_VERSION_ID      = "0" /*( version number from product ID )*/
PRODUCER_INSTITUTION_NAME = "APPLIED PHYSICS LABORATORY"
SOFTWARE_NAME           = "tbd"
SOFTWARE_VERSION_ID     = "tbd"
MRO:WAVELENGTH_FILE_NAME = "N/A"

/* These parameters describe the browse image as a PDS document. */

^DOCUMENT                = "T0123_MRRFEM_10N355_0256_0.PNG"
OBJECT                   = DOCUMENT
  DOCUMENT_NAME          = "T0123_MRRFEM_10N355_0256_0"
  DOCUMENT_FORMAT        = PNG
  DOCUMENT_TOPIC_TYPE    = "BROWSE IMAGE"
  INTERCHANGE_FORMAT     = BINARY
  PUBLICATION_DATE       = 2006-01-19
  SOURCE_PRODUCT_ID      = "T0123_MRRSU_10N355_0256_0"
  RECORD_BYTES           = 3840
  FILE_RECORDS           = 1280
  SAMPLE_TYPE            = LSB_UNSIGNED_INTEGER
  SAMPLE_BITS            = 8
  BANDS                  = 3
  BAND_SEQUENCE          = ("RED", "GREEN", "BLUE")
  BAND_NAME              = ("BD530", "SH600", "BDI1000VIS")

/* The following information to scale from real numbers to an */
/* 8-bit integer is hard-coded for this type of browse image. */

DERIVED_MINIMUM         = (0,0,0)

```

```

DERIVED_MAXIMUM      = (250,250,250)
OFFSET               = (0,1.1,0)
SCALING_FACTOR       = (0.0006,0.0004,0.00016)
MISSING_CONSTANT     = (255,255,255)
DESCRIPTION          = "This file is a false color VNIR image assembled
                        from calibrated radiance, solar distance, and
                        solar flux as sampled in the wavelength filter
                        and binning state being used: radiance_factor =
                        I*D^2/(pi*F) where I = spectral radiance,
                        D = solar distance in AU, and F = solar flux at
                        1 AU. Subsequently a correction was made for
                        atmospheric and photometric effects either
                        predictively from climatology or after the fact
                        from CRISM measurements. Finally the data were
                        used to derive synthetic spectral parameters that
                        encode spectral variance in the data due to Fe
                        minerals. B D530 is depth of the 530-nm band in
                        ferric materials. SH600 is strength of the
                        shoulder that is present in some ferric minerals
                        near 600 nm. BDI1000VIS is the integrated area in
                        the 1-micron band due to ferric and ferrous iron
                        minerals."
END_OBJECT           = DOCUMENT

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

OBJECT              = IMAGE_MAP_PROJECTION
^DATA_SET_MAP_PROJECTION = "MRR_MAP.CAT"
MAP_PROJECTION_TYPE  = "EQUIRECTANGULAR"
                    /* ( or POLAR STEREOGRAPHIC ) */
A_AXIS_RADIUS        = 3393.4 <KM>
B_AXIS_RADIUS        = 3393.4 <KM>
C_AXIS_RADIUS        = 3375.7 <KM>
FIRST_STANDARD_PARALLEL = "N/A"
SECOND_STANDARD_PARALLEL = "N/A"
POSITIVE_LONGITUDE_DIRECTION = "EAST"
CENTER_LATITUDE      = 5.0 <DEGREE>
                    /* ( for this tile only center latitude ) */
                    /* ( of projection, the low-latitude edge ) */
                    /* ( of the tile ) */
CENTER_LONGITUDE     = 0.0 <DEGREE>
REFERENCE_LATITUDE   = "N/A"
REFERENCE_LONGITUDE  = "N/A"
LINE_FIRST_PIXEL     = 1
                    /* ( line number of N edge of this tile ) */
LINE_LAST_PIXEL      = 1280
                    /* ( line number of S edge of this tile ) */
SAMPLE_FIRST_PIXEL   = 1
                    /* ( sample number of W edge of this tile ) */
SAMPLE_LAST_PIXEL    = 1280
                    /* ( sample number of E edge of this tile ) */
MAP_PROJECTION_ROTATION = 0.0
MAP_RESOLUTION       = 256 <PIXEL/DEGREE>
MAP_SCALE            = 0.23 <KM/PIXEL>
                    /* ( this is average over the planet ) */
MAXIMUM_LATITUDE     = 10.0 <DEGREE>
                    /* ( for this tile only ) */
MINIMUM_LATITUDE     = 5.0 <DEGREE>
                    /* ( for this tile only ) */
WESTERNMOST_LONGITUDE = 355.0 <DEGREE>
                    /* ( for this tile only ) */
EASTERNMOST_LONGITUDE = 0.0 <DEGREE>

```

```

                                /*( for this tile only)*/
LINE_PROJECTION_OFFSET        = 2560
                                /*( for this tile only; number of )*/
                                /*( pixels from equator to first pixel )*/
                                /*( of map tile )*/
SAMPLE_PROJECTION_OFFSET     = -1280
                                /*( for this tile only; number of )*/
                                /*( pixels from 0 degrees longitude )*/
                                /*( to first pixel of map tile )*/
COORDINATE_SYSTEM_TYPE       = "BODY-FIXED ROTATING"
COORDINATE_SYSTEM_NAME      = "PLANETOCENTRIC"
END_OBJECT                   = IMAGE_MAP_PROJECTION

END

```

## APPENDIX L3. MRDR BROWSE PRODUCT 'IRA' PNG FILE LABEL

```

PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE     = "2003-11-19, S. Slavney (GEO);
                          2005-09-25, S. Murchie (JHU/APL)"

/* Map-projected Multispectral RDR Identification */

DATA_SET_ID             = "MRO-M-CRISM-5-RDR-MULTISPECTRAL-V1.0"
PRODUCT_ID              = "T0123_MRRIRA_10N355_0256_0"
                          /*( Tnnnn_MRRsss_xxdyyy_rrrr_v          )*/
                          /*( nnnn = tile number                  )*/
                          /*( sss = subtype of browse product    )*/
                          /*( xx = latitude of tile center        )*/
                          /*( d = N or S for north or south latitude )*/
                          /*( yyy = east longitude of tile center )*/
                          /*( rrrr = resolution in pixels/degree  )*/
                          /*( v = version number                  )*/

INSTRUMENT_HOST_NAME    = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID           = MRO
INSTRUMENT_NAME         = "COMPACT RECONNAISSANCE IMAGING
                          SPECTROMETER FOR MARS"

INSTRUMENT_ID           = CRISM
TARGET_NAME             = MARS
PRODUCT_TYPE            = BROWSE
PRODUCT_CREATION_TIME   = 2006-06-17T13:03:07.234
START_TIME              = "N/A"
STOP_TIME               = "N/A"
SPACECRAFT_CLOCK_START_COUNT = "N/A"
SPACECRAFT_CLOCK_STOP_COUNT = "N/A"
PRODUCT_VERSION_ID     = "0" /*( version number from product ID )*/
PRODUCER_INSTITUTION_NAME = "APPLIED PHYSICS LABORATORY"
SOFTWARE_NAME           = "tbd"
SOFTWARE_VERSION_ID     = "tbd"
MRO:WAVELENGTH_FILE_NAME = "N/A"

/* These parameters describe the browse image as a PDS document. */

^DOCUMENT                = "T0123_MRRIRA_10N355_0256_0.PNG"
OBJECT                   = DOCUMENT
  DOCUMENT_NAME          = "T0123_MRRIRA_10N355_0256_0"
  DOCUMENT_FORMAT        = PNG
  DOCUMENT_TOPIC_TYPE    = "BROWSE IMAGE"
  INTERCHANGE_FORMAT     = BINARY
  PUBLICATION_DATE       = 2006-01-19
  SOURCE_PRODUCT_ID      = "T0123_MRRAL_10N355_0256_0"
  RECORD_BYTES           = 1280
  FILE_RECORDS           = 1280
  SAMPLE_TYPE            = LSB_UNSIGNED_INTEGER
  SAMPLE_BITS            = 8
  BANDS                  = 1
  BAND_NAME              = "1330nm"

/* The following information to scale from real numbers to an */
/* 8-bit integer is hard-coded for this type of browse image. */

DERIVED_MINIMUM         = 0
DERIVED_MAXIMUM         = 250

```

```

OFFSET = 0
SCALING_FACTOR = 0.0024
MISSING_CONSTANT = 255
DESCRIPTION = "This file is a scaled 1330 nm I/F image assembled
              from calibrated radiance, solar distance, and
              solar flux as sampled in the wavelength filter
              and binning state being used: radiance_factor =
              I*D^2/(pi*F) where I = spectral radiance,
              D = solar distance in AU, and F = solar flux at
              1 AU. Subsequently a correction was made for
              atmospheric and photometric effects either
              predictively from climatology or after the fact
              from CRISM measurements."
END_OBJECT = DOCUMENT

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

OBJECT = IMAGE_MAP_PROJECTION
^DATA_SET_MAP_PROJECTION = "MRR_MAP.CAT"
MAP_PROJECTION_TYPE = "EQUIRECTANGULAR"
/* ( or POLAR STEREOGRAPHIC )*/

A_AXIS_RADIUS = 3393.4 <KM>
B_AXIS_RADIUS = 3393.4 <KM>
C_AXIS_RADIUS = 3375.7 <KM>
FIRST_STANDARD_PARALLEL = "N/A"
SECOND_STANDARD_PARALLEL = "N/A"
POSITIVE_LONGITUDE_DIRECTION = "EAST"
CENTER_LATITUDE = 5.0 <DEGREE>
/* ( for this tile only center latitude )*/
/* ( of projection, the low-latitude edge )*/
/* ( of the tile )*/

CENTER_LONGITUDE = 0.0 <DEGREE>
REFERENCE_LATITUDE = "N/A"
REFERENCE_LONGITUDE = "N/A"
LINE_FIRST_PIXEL = 1
/* ( line number of N edge of this tile )*/
LINE_LAST_PIXEL = 1280
/* ( line number of S edge of this tile )*/
SAMPLE_FIRST_PIXEL = 1
/* ( sample number of W edge of this tile )*/
SAMPLE_LAST_PIXEL = 1280
/* ( sample number of E edge of this tile )*/

MAP_PROJECTION_ROTATION = 0.0
MAP_RESOLUTION = 256 <PIXEL/DEGREE>
MAP_SCALE = 0.23 <KM/PIXEL>
/* ( this is average over the planet)*/
MAXIMUM_LATITUDE = 10.0 <DEGREE>
/* ( for this tile only)*/
MINIMUM_LATITUDE = 5.0 <DEGREE>
/* ( for this tile only)*/
WESTERNMOST_LONGITUDE = 355.0 <DEGREE>
/* ( for this tile only)*/
EASTERNMOST_LONGITUDE = 0.0 <DEGREE>
/* ( for this tile only)*/
LINE_PROJECTION_OFFSET = 2560
/* ( for this tile only; number of )*/
/* ( pixels from equator to first pixel )*/
/* ( of map tile )*/
SAMPLE_PROJECTION_OFFSET = -1280
/* ( for this tile only; number of )*/
/* ( pixels from 0 degrees longitude )*/
/* ( to first pixel of map tile )*/

```

```
COORDINATE_SYSTEM_TYPE      = "BODY-FIXED ROTATING"  
COORDINATE_SYSTEM_NAME     = "PLANETOCENTRIC"  
END_OBJECT                  = IMAGE_MAP_PROJECTION  
  
END
```

## APPENDIX L4. MRDR BROWSE PRODUCT 'MAF' PNG FILE LABEL

```

PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE    = "2003-11-19, S. Slavney (GEO);
                        2005-09-25, S. Murchie (JHU/APL)"

/* Map-projected Multispectral RDR Identification */

DATA_SET_ID             = "MRO-M-CRISM-5-RDR-MULTISPECTRAL-V1.0"
PRODUCT_ID              = "T0123_MRRMAF_10N355_0256_0"
                        /*( Tnnnn_MRRsss_xxdyyy_rrrr_v          )*/
                        /*( nnnn = tile number                  )*/
                        /*( sss = subtype of browse product    )*/
                        /*( xx = latitude of tile center       )*/
                        /*( d = N or S for north or south latitude )*/
                        /*( yyy = east longitude of tile center )*/
                        /*( rrrr = resolution in pixels/degree  )*/
                        /*( v = version number                  )*/

INSTRUMENT_HOST_NAME    = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID           = MRO
INSTRUMENT_NAME         = "COMPACT RECONNAISSANCE IMAGING
                        SPECTROMETER FOR MARS"

INSTRUMENT_ID           = CRISM
TARGET_NAME             = MARS
PRODUCT_TYPE            = BROWSE
PRODUCT_CREATION_TIME   = 2006-06-17T13:03:07.234
START_TIME              = "N/A"
STOP_TIME               = "N/A"
SPACECRAFT_CLOCK_START_COUNT = "N/A"
SPACECRAFT_CLOCK_STOP_COUNT = "N/A"
PRODUCT_VERSION_ID     = "0" /*( version number from product ID )*/
PRODUCER_INSTITUTION_NAME = "APPLIED PHYSICS LABORATORY"
SOFTWARE_NAME           = "tbd"
SOFTWARE_VERSION_ID     = "tbd"
MRO:WAVELENGTH_FILE_NAME = "N/A"

/* These parameters describe the browse image as a PDS document. */

^DOCUMENT                = "T0123_MRRMAF_10N355_0256_0.PNG"
OBJECT                   = DOCUMENT
  DOCUMENT_NAME          = "T0123_MRRMAF_10N355_0256_0"
  DOCUMENT_FORMAT        = PNG
  DOCUMENT_TOPIC_TYPE    = "BROWSE IMAGE"
  INTERCHANGE_FORMAT     = BINARY
  PUBLICATION_DATE       = 2006-01-19
  SOURCE_PRODUCT_ID      = "T0123_MRRSU_10N355_0256_0"
  RECORD_BYTES           = 3840
  FILE_RECORDS           = 1280
  SAMPLE_TYPE            = LSB_UNSIGNED_INTEGER
  SAMPLE_BITS            = 8
  BANDS                  = 3
  BAND_SEQUENCE          = ("RED", "GREEN", "BLUE")
  BAND_NAME              = ("OLINDEX", "LCPINDEX", "HCPINDEX")

/* The following information to scale from real numbers to an */
/* 8-bit integer is hard-coded for this type of browse image. */

DERIVED_MINIMUM          = (0,0,0)

```

```

DERIVED_MAXIMUM      = (250,250,250)
OFFSET               = (0,0,0)
SCALING_FACTOR       = (0.001,0.000016,0.000024)
MISSING_CONSTANT     = (255,255,255)
DESCRIPTION          = "This file is a false color IR image assembled
                        from calibrated radiance, solar distance, and
                        solar flux as sampled in the wavelength filter
                        and binning state being used: radiance_factor =
                        I*D^2/(pi*F) where I = spectral radiance,
                        D = solar distance in AU, and F = solar flux at
                        1 AU. Subsequently a correction was made for
                        atmospheric and photometric effects either
                        predictively from climatology or after the fact
                        from CRISM measurements. Finally the data were
                        used to derive synthetic spectral parameters that
                        encode spectral variance in the data due to Fe
                        minerals. OLINDEX is a measure of reflectance
                        near 1700 nm relative to that at shorter
                        wavelengths, where values >>1 are suggestive of
                        olivine. LCPINDEX is a measure of peakedness
                        of the spectrum near 1330 nm, with values >>0
                        suggestive of low-calcium pyroxene. HCPINDEX
                        is a measure of peakedness of the spectrum
                        near 1470 nm, with values >>0 suggestive of
                        high-calcium pyroxene."
END_OBJECT           = DOCUMENT

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

OBJECT               = IMAGE_MAP_PROJECTION
^DATA_SET_MAP_PROJECTION = "MRR_MAP.CAT"
MAP_PROJECTION_TYPE  = "EQUIRECTANGULAR"
                    /* ( or POLAR STEREOGRAPHIC ) */
A_AXIS_RADIUS        = 3393.4 <KM>
B_AXIS_RADIUS        = 3393.4 <KM>
C_AXIS_RADIUS        = 3375.7 <KM>
FIRST_STANDARD_PARALLEL = "N/A"
SECOND_STANDARD_PARALLEL = "N/A"
POSITIVE_LONGITUDE_DIRECTION = "EAST"
CENTER_LATITUDE      = 5.0 <DEGREE>
                    /* ( for this tile only center latitude ) */
                    /* ( of projection, the low-latitude edge ) */
                    /* ( of the tile ) */
CENTER_LONGITUDE     = 0.0 <DEGREE>
REFERENCE_LATITUDE   = "N/A"
REFERENCE_LONGITUDE  = "N/A"
LINE_FIRST_PIXEL     = 1
                    /* ( line number of N edge of this tile ) */
LINE_LAST_PIXEL      = 1280
                    /* ( line number of S edge of this tile ) */
SAMPLE_FIRST_PIXEL   = 1
                    /* ( sample number of W edge of this tile ) */
SAMPLE_LAST_PIXEL    = 1280
                    /* ( sample number of E edge of this tile ) */
MAP_PROJECTION_ROTATION = 0.0
MAP_RESOLUTION       = 256 <PIXEL/DEGREE>
MAP_SCALE            = 0.23 <KM/PIXEL>
                    /* ( this is average over the planet ) */
MAXIMUM_LATITUDE     = 10.0 <DEGREE>
                    /* ( for this tile only ) */
MINIMUM_LATITUDE     = 5.0 <DEGREE>
                    /* ( for this tile only ) */

```

```

WESTERNMOST_LONGITUDE = 355.0 <DEGREE>
                        /*( for this tile only)*/
EASTERNMOST_LONGITUDE = 0.0 <DEGREE>
                        /*( for this tile only)*/
LINE_PROJECTION_OFFSET = 2560
                        /*( for this tile only; number of )*/
                        /*( pixels from equator to first pixel )*/
                        /*( of map tile )*/
SAMPLE_PROJECTION_OFFSET = -1280
                        /*( for this tile only; number of )*/
                        /*( pixels from 0 degrees longitude )*/
                        /*( to first pixel of map tile )*/
COORDINATE_SYSTEM_TYPE = "BODY-FIXED ROTATING"
COORDINATE_SYSTEM_NAME = "PLANETOCENTRIC"
END_OBJECT             = IMAGE_MAP_PROJECTION

END

```

## APPENDIX L5. MRDR BROWSE PRODUCT 'HYD' PNG FILE LABEL

```

PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE     = "2003-11-19, S. Slavney (GEO);
                          2005-09-25, S. Murchie (JHU/APL)"

/* Map-projected Multispectral RDR Identification */

DATA_SET_ID             = "MRO-M-CRISM-5-RDR-MULTISPECTRAL-V1.0"
PRODUCT_ID              = "T0123_MRRHYD_10N355_0256_0"
                          /*( Tnnnn_MRRsss_xxdyyy_rrrr_v          )*/
                          /*( nnnn = tile number                  )*/
                          /*( sss = subtype of browse product    )*/
                          /*( xx = latitude of tile center       )*/
                          /*( d = N or S for north or south latitude )*/
                          /*( yyy = east longitude of tile center )*/
                          /*( rrrr = resolution in pixels/degree  )*/
                          /*( v = version number                  )*/

INSTRUMENT_HOST_NAME    = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID           = MRO
INSTRUMENT_NAME         = "COMPACT RECONNAISSANCE IMAGING
                          SPECTROMETER FOR MARS"

INSTRUMENT_ID           = CRISM
TARGET_NAME             = MARS
PRODUCT_TYPE            = BROWSE
PRODUCT_CREATION_TIME   = 2006-06-17T13:03:07.234
START_TIME              = "N/A"
STOP_TIME               = "N/A"
SPACECRAFT_CLOCK_START_COUNT = "N/A"
SPACECRAFT_CLOCK_STOP_COUNT = "N/A"
PRODUCT_VERSION_ID     = "0" /*( version number from product ID )*/
PRODUCER_INSTITUTION_NAME = "APPLIED PHYSICS LABORATORY"
SOFTWARE_NAME           = "tbd"
SOFTWARE_VERSION_ID     = "tbd"
MRO:WAVELENGTH_FILE_NAME = "N/A"

/* These parameters describe the browse image as a PDS document. */

^DOCUMENT                = "T0123_MRRHYD_10N355_0256_0.PNG"
OBJECT                   = DOCUMENT
  DOCUMENT_NAME          = "T0123_MRRHYD_10N355_0256_0"
  DOCUMENT_FORMAT        = PNG
  DOCUMENT_TOPIC_TYPE    = "BROWSE IMAGE"
  INTERCHANGE_FORMAT     = BINARY
  PUBLICATION_DATE       = 2006-01-19
  SOURCE_PRODUCT_ID      = "T0123_MRRSU_10N355_0256_0"
  RECORD_BYTES           = 3840
  FILE_RECORDS           = 1280
  SAMPLE_TYPE            = LSB_UNSIGNED_INTEGER
  SAMPLE_BITS            = 8
  BANDS                  = 3
  BAND_SEQUENCE          = ("RED", "GREEN", "BLUE")
  BAND_NAME              = ("SINDEX", "BD2100", "BD1900")

/* The following information to scale from real numbers to an */
/* 8-bit integer is hard-coded for this type of browse image. */

DERIVED_MINIMUM          = (0,0,0)

```

```

DERIVED_MAXIMUM      = (250,250,250)
OFFSET                = (1,0,0)
SCALING_FACTOR       = (0.0004,0.0002,0.0002)
MISSING_CONSTANT     = (255,255,255)
DESCRIPTION          = "This file is a false color IR image assembled
                        from calibrated radiance, solar distance, and
                        solar flux as sampled in the wavelength filter
                        and binning state being used: radiance_factor =
                        I*D^2/(pi*F) where I = spectral radiance,
                        D = solar distance in AU, and F = solar flux at
                        1 AU. Subsequently a correction was made for
                        atmospheric and photometric effects either
                        predictively from climatology or after the fact
                        from CRISM measurements. Finally the data were
                        used to derive synthetic spectral parameters that
                        encode spectral variance in the data due to
                        hydrated minerals.
                        SINDEX is a measure of the wing
                        of the 3000-nm band due to bound water, or
                        of a 2400-nm band in some polyhydrated minerals.
                        BD2100 is a measure of the depth of
                        the 2100-nm band due to bound water in
                        monohydrated sulfates.
                        BD1900 is a measure of the depth of
                        the 1900-nm band due to bound water."
END_OBJECT           = DOCUMENT

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

OBJECT              = IMAGE_MAP_PROJECTION
^DATA_SET_MAP_PROJECTION = "MRR_MAP.CAT"
MAP_PROJECTION_TYPE = "EQUIRECTANGULAR"
                    /* ( or POLAR STEREOGRAPHIC ) */
A_AXIS_RADIUS      = 3393.4 <KM>
B_AXIS_RADIUS      = 3393.4 <KM>
C_AXIS_RADIUS      = 3375.7 <KM>
FIRST_STANDARD_PARALLEL = "N/A"
SECOND_STANDARD_PARALLEL = "N/A"
POSITIVE_LONGITUDE_DIRECTION = "EAST"
CENTER_LATITUDE    = 5.0 <DEGREE>
                    /* ( for this tile only center latitude ) */
                    /* ( of projection, the low-latitude edge ) */
                    /* ( of the tile ) */
CENTER_LONGITUDE   = 0.0 <DEGREE>
REFERENCE_LATITUDE = "N/A"
REFERENCE_LONGITUDE = "N/A"
LINE_FIRST_PIXEL   = 1
                    /* ( line number of N edge of this tile ) */
LINE_LAST_PIXEL    = 1280
                    /* ( line number of S edge of this tile ) */
SAMPLE_FIRST_PIXEL = 1
                    /* ( sample number of W edge of this tile ) */
SAMPLE_LAST_PIXEL  = 1280
                    /* ( sample number of E edge of this tile ) */
MAP_PROJECTION_ROTATION = 0.0
MAP_RESOLUTION       = 256 <PIXEL/DEGREE>
MAP_SCALE            = 0.23 <KM/PIXEL>
                    /* ( this is average over the planet ) */
MAXIMUM_LATITUDE    = 10.0 <DEGREE>
                    /* ( for this tile only ) */
MINIMUM_LATITUDE    = 5.0 <DEGREE>
                    /* ( for this tile only ) */

```

```

WESTERNMOST_LONGITUDE = 355.0 <DEGREE>
                        /*( for this tile only)*/
EASTERNMOST_LONGITUDE = 0.0 <DEGREE>
                        /*( for this tile only)*/
LINE_PROJECTION_OFFSET = 2560
                        /*( for this tile only; number of )*/
                        /*( pixels from equator to first pixel )*/
                        /*( of map tile )*/
SAMPLE_PROJECTION_OFFSET = -1280
                        /*( for this tile only; number of )*/
                        /*( pixels from 0 degrees longitude )*/
                        /*( to first pixel of map tile )*/
COORDINATE_SYSTEM_TYPE = "BODY-FIXED ROTATING"
COORDINATE_SYSTEM_NAME = "PLANETOCENTRIC"
END_OBJECT             = IMAGE_MAP_PROJECTION

END

```

## APPENDIX L6. MRDR BROWSE PRODUCT 'ICE' PNG FILE LABEL

```

PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE    = "2003-11-19, S. Slavney (GEO);
                        2005-09-25, S. Murchie (JHU/APL)"

/* Map-projected Multispectral RDR Identification */

DATA_SET_ID            = "MRO-M-CRISM-5-RDR-MULTISPECTRAL-V1.0"
PRODUCT_ID             = "T0123_MRRICE_10N355_0256_0"
                        /*( Tnnnn_MRRsss_xxdyyy_rrrr_v          )*/
                        /*( nnnn = tile number                  )*/
                        /*( sss = subtype of browse product    )*/
                        /*( xx = latitude of tile center       )*/
                        /*( d = N or S for north or south latitude )*/
                        /*( yyy = east longitude of tile center )*/
                        /*( rrrr = resolution in pixels/degree )*/
                        /*( v = version number                  )*/

INSTRUMENT_HOST_NAME   = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID          = MRO
INSTRUMENT_NAME        = "COMPACT RECONNAISSANCE IMAGING
                        SPECTROMETER FOR MARS"

INSTRUMENT_ID         = CRISM
TARGET_NAME           = MARS
PRODUCT_TYPE          = BROWSE
PRODUCT_CREATION_TIME = 2006-06-17T13:03:07.234
START_TIME            = "N/A"
STOP_TIME             = "N/A"
SPACECRAFT_CLOCK_START_COUNT = "N/A"
SPACECRAFT_CLOCK_STOP_COUNT  = "N/A"
PRODUCT_VERSION_ID    = "0" /*( version number from product ID )*/
PRODUCER_INSTITUTION_NAME = "APPLIED PHYSICS LABORATORY"
SOFTWARE_NAME         = "tbd"
SOFTWARE_VERSION_ID   = "tbd"
MRO:WAVELENGTH_FILE_NAME = "N/A"

/* These parameters describe the browse image as a PDS document. */

^DOCUMENT              = "T0123_MRRICE_10N355_0256_0.PNG"
OBJECT                 = DOCUMENT
  DOCUMENT_NAME        = "T0123_MRRICE_10N355_0256_0"
  DOCUMENT_FORMAT      = PNG
  DOCUMENT_TOPIC_TYPE  = "BROWSE IMAGE"
  INTERCHANGE_FORMAT   = BINARY
  PUBLICATION_DATE     = 2006-01-19
  SOURCE_PRODUCT_ID    = "T0123_MRRSU_10N355_0256_0"
  RECORD_BYTES        = 3840
  FILE_RECORDS        = 1280
  SAMPLE_TYPE         = LSB_UNSIGNED_INTEGER
  SAMPLE_BITS         = 8
  BAND_SEQUENCE       = ("RED", "GREEN", "BLUE")
  BAND_NAME           = ("BD1900", "BD1500", "BD1435")

/* The following information to scale from real numbers to an */
/* 8-bit integer is hard-coded for this type of browse image. */

DERIVED_MINIMUM       = (0,0,0)
DERIVED_MAXIMUM       = (250,250,250)

```

```

OFFSET                = (0,0,0)
SCALING_FACTOR        = (0.0016,0.0016,0.0016)
MISSING_CONSTANT      = (255,255,255)
DESCRIPTION            = "This file is a false color IR image assembled
                        from calibrated radiance, solar distance, and
                        solar flux as sampled in the wavelength filter
                        and binning state being used: radiance_factor =
                        I*D^2/(pi*F) where I = spectral radiance,
                        D = solar distance in AU, and F = solar flux at
                        1 AU. Subsequently a correction was made for
                        atmospheric and photometric effects either
                        predictively from climatology or after the fact
                        from CRISM measurements. Finally the data were
                        used to derive synthetic spectral parameters that
                        encode spectral variance in the data due to
                        water and carbon dioxide ice.
                        BD1900 is a measure of the 1900-nm band in
                        water ice.
                        BD1500 is a measure of the 1500-nm band in
                        water ice.
                        BD1435 is a measure of the 1435-nm band in
                        carbon dioxide ice."
END_OBJECT            = DOCUMENT

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

OBJECT                = IMAGE_MAP_PROJECTION
^DATA_SET_MAP_PROJECTION = "MRR_MAP.CAT"
MAP_PROJECTION_TYPE    = "EQUIRECTANGULAR"
                        /* ( or POLAR STEREOGRAPHIC ) */
A_AXIS_RADIUS          = 3393.4 <KM>
B_AXIS_RADIUS          = 3393.4 <KM>
C_AXIS_RADIUS          = 3375.7 <KM>
FIRST_STANDARD_PARALLEL = "N/A"
SECOND_STANDARD_PARALLEL = "N/A"
POSITIVE_LONGITUDE_DIRECTION = "EAST"
CENTER_LATITUDE        = 5.0 <DEGREE>
                        /* ( for this tile only center latitude ) */
                        /* ( of projection, the low-latitude edge ) */
                        /* ( of the tile ) */
CENTER_LONGITUDE        = 0.0 <DEGREE>
REFERENCE_LATITUDE      = "N/A"
REFERENCE_LONGITUDE     = "N/A"
LINE_FIRST_PIXEL        = 1
                        /* ( line number of N edge of this tile ) */
LINE_LAST_PIXEL         = 1280
                        /* ( line number of S edge of this tile ) */
SAMPLE_FIRST_PIXEL      = 1
                        /* ( sample number of W edge of this tile ) */
SAMPLE_LAST_PIXEL       = 1280
                        /* ( sample number of E edge of this tile ) */
MAP_PROJECTION_ROTATION = 0.0
MAP_RESOLUTION          = 256 <PIXEL/DEGREE>
MAP_SCALE               = 0.23 <KM/PIXEL>
                        /* ( this is average over the planet ) */
MAXIMUM_LATITUDE        = 10.0 <DEGREE>
                        /* ( for this tile only ) */
MINIMUM_LATITUDE        = 5.0 <DEGREE>
                        /* ( for this tile only ) */
WESTERNMOST_LONGITUDE   = 355.0 <DEGREE>
                        /* ( for this tile only ) */
EASTERNMOST_LONGITUDE   = 0.0 <DEGREE>

```

```

                                /*( for this tile only)*/
LINE_PROJECTION_OFFSET        = 2560
                                /*( for this tile only; number of )*/
                                /*( pixels from equator to first pixel )*/
                                /*( of map tile )*/
SAMPLE_PROJECTION_OFFSET     = -1280
                                /*( for this tile only; number of )*/
                                /*( pixels from 0 degrees longitude )*/
                                /*( to first pixel of map tile )*/
COORDINATE_SYSTEM_TYPE       = "BODY-FIXED ROTATING"
COORDINATE_SYSTEM_NAME       = "PLANETOCENTRIC"
END_OBJECT                    = IMAGE_MAP_PROJECTION

END

```

## APPENDIX L7. MRDR BROWSE PRODUCT 'PHY' PNG FILE LABEL

```

PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE    = "2003-11-19, S. Slavney (GEO);
                        2005-09-25, S. Murchie (JHU/APL)"

/* Map-projected Multispectral RDR Identification */

DATA_SET_ID             = "MRO-M-CRISM-5-RDR-MULTISPECTRAL-V1.0"
PRODUCT_ID              = "T0123_MRRPHY_10N355_0256_0"
                        /*( Tnnnn_MRRsss_xxdyyy_rrrr_v          )*/
                        /*( nnnn = tile number                  )*/
                        /*( sss = subtype of browse product    )*/
                        /*( xx = latitude of tile center        )*/
                        /*( d = N or S for north or south latitude )*/
                        /*( yyy = east longitude of tile center )*/
                        /*( rrrr = resolution in pixels/degree  )*/
                        /*( v = version number                  )*/

INSTRUMENT_HOST_NAME    = "MARS RECONNAISSANCE ORBITER"
SPACECRAFT_ID           = MRO
INSTRUMENT_NAME         = "COMPACT RECONNAISSANCE IMAGING
                        SPECTROMETER FOR MARS"

INSTRUMENT_ID           = CRISM
TARGET_NAME             = MARS
PRODUCT_TYPE            = BROWSE
PRODUCT_CREATION_TIME   = 2006-06-17T13:03:07.234
START_TIME              = "N/A"
STOP_TIME               = "N/A"
SPACECRAFT_CLOCK_START_COUNT = "N/A"
SPACECRAFT_CLOCK_STOP_COUNT = "N/A"
PRODUCT_VERSION_ID      = "0" /*( version number from product ID )*/
PRODUCER_INSTITUTION_NAME = "APPLIED PHYSICS LABORATORY"
SOFTWARE_NAME           = "tbd"
SOFTWARE_VERSION_ID     = "tbd"
MRO:WAVELENGTH_FILE_NAME = "N/A"

/* These parameters describe the browse image as a PDS document. */

^DOCUMENT                = "T0123_MRRPHY_10N355_0256_0.PNG"
OBJECT                   = DOCUMENT
  DOCUMENT_NAME          = "T0123_MRRPHY_10N355_0256_0"
  DOCUMENT_FORMAT        = PNG
  DOCUMENT_TOPIC_TYPE    = "BROWSE IMAGE"
  INTERCHANGE_FORMAT     = BINARY
  PUBLICATION_DATE       = 2006-01-19
  SOURCE_PRODUCT_ID      = "T0123_MRRSU_10N355_0256_0"
  RECORD_BYTES           = 3840
  FILE_RECORDS           = 1280
  SAMPLE_TYPE            = LSB_UNSIGNED_INTEGER
  SAMPLE_BITS            = 8
  BANDS                  = 3
  BAND_SEQUENCE          = ("RED", "GREEN", "BLUE")
  BAND_NAME              = ("D2300", "BD2210", "BD1900")

/* The following information to scale from real numbers to an */
/* 8-bit integer is hard-coded for this type of browse image. */

DERIVED_MINIMUM         = (0,0,0)

```

```

DERIVED_MAXIMUM      = (250,250,250)
OFFSET               = (0,0,0)
SCALING_FACTOR       = (0.0002,0.0002,0.0002)
MISSING_CONSTANT     = (255,255,255)
DESCRIPTION          = "This file is a false color IR image assembled
                        from calibrated radiance, solar distance, and
                        solar flux as sampled in the wavelength filter
                        and binning state being used: radiance_factor =
                        I*D^2/(pi*F) where I = spectral radiance,
                        D = solar distance in AU, and F = solar flux at
                        1 AU. Subsequently a correction was made for
                        atmospheric and photometric effects either
                        predictively from climatology or after the fact
                        from CRISM measurements. Finally the data were
                        used to derive synthetic spectral parameters that
                        encode spectral variance in the data due to
                        hydroxylated minerals.
                        D2300 is a measure of the 2300-nm band due to
                        Mg- and Fe-OH bonds in phyllosilicates.
                        BD2210 is a measure of the 2290-nm band due to
                        Al- and Si-OH bonds in in hydrated silicates.
                        BD1900 is a measure of the depth of
                        the 1900-nm band due to bound water."

EEND_OBJECT         = DOCUMENT

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

OBJECT              = IMAGE_MAP_PROJECTION
^DATA_SET_MAP_PROJECTION = "MRR_MAP.CAT"
MAP_PROJECTION_TYPE  = "EQUIRECTANGULAR"
                    /* ( or POLAR STEREOGRAPHIC ) */
A_AXIS_RADIUS       = 3393.4 <KM>
B_AXIS_RADIUS       = 3393.4 <KM>
C_AXIS_RADIUS       = 3375.7 <KM>
FIRST_STANDARD_PARALLEL = "N/A"
SECOND_STANDARD_PARALLEL = "N/A"
POSITIVE_LONGITUDE_DIRECTION = "EAST"
CENTER_LATITUDE     = 5.0 <DEGREE>
                    /* ( for this tile only center latitude ) */
                    /* ( of projection, the low-latitude edge ) */
                    /* ( of the tile ) */
CENTER_LONGITUDE    = 0.0 <DEGREE>
REFERENCE_LATITUDE  = "N/A"
REFERENCE_LONGITUDE = "N/A"
LINE_FIRST_PIXEL    = 1
                    /* ( line number of N edge of this tile ) */
LINE_LAST_PIXEL     = 1280
                    /* ( line number of S edge of this tile ) */
SAMPLE_FIRST_PIXEL  = 1
                    /* ( sample number of W edge of this tile ) */
SAMPLE_LAST_PIXEL   = 1280
                    /* ( sample number of E edge of this tile ) */
MAP_PROJECTION_ROTATION = 0.0
MAP_RESOLUTION      = 256 <PIXEL/DEGREE>
MAP_SCALE           = 0.23 <KM/PIXEL>
                    /* ( this is average over the planet ) */
MAXIMUM_LATITUDE    = 10.0 <DEGREE>
                    /* ( for this tile only ) */
MINIMUM_LATITUDE    = 5.0 <DEGREE>
                    /* ( for this tile only ) */
WESTERNMOST_LONGITUDE = 355.0 <DEGREE>
                    /* ( for this tile only ) */

```

```

EASTERNMOST_LONGITUDE      = 0.0 <DEGREE>
                             /*( for this tile only)*/
LINE_PROJECTION_OFFSET     = 2560
                             /*( for this tile only; number of )*/
                             /*( pixels from equator to first pixel )*/
                             /*( of map tile )*/
SAMPLE_PROJECTION_OFFSET   = -1280
                             /*( for this tile only; number of )*/
                             /*( pixels from 0 degrees longitude )*/
                             /*( to first pixel of map tile )*/
COORDINATE_SYSTEM_TYPE     = "BODY-FIXED ROTATING"
COORDINATE_SYSTEM_NAME     = "PLANETOCENTRIC"
END_OBJECT                 = IMAGE_MAP_PROJECTION

END

```

## APPENDIX M. DATA PROCESSING DETAILS

Dave Humm and Scott Murchie

6/30/2006

### 1. CALIBRATION OVERVIEW

#### 1.1 Collection of calibration data in flight

Darks will be taken bracketing every targeted measurement as part of the macro for that targeted measurement. Darks will be taken every 5 minutes in mapping mode.

Onboard integrating sphere calibration data will be taken with the IR lamp at nominally fixed intervals in time. The plan is to take sphere calibrations once every 1.5 orbits, bracketing scene observations with a dayside and nightside sphere observation. The idea is that the IR detector will be relatively warm (by a degree or so, maybe much less) on the dayside and relatively cool on the nightside. To correct the radiometric calibration for detector temperature, we interpolate in indicated detector temperature between the dayside and nightside sphere calibrations. In some cases, we will skip an extra orbit or two between the dayside and nightside due to restrictions on scheduling. The primary sphere lamp is lamp 2, the VNIR-controlled “along-slit” lamp. Integrating sphere data with lamp 1, the IR-controlled “cross-slit” lamp, will be taken once a month to look for signs of aging in lamp 2, the VNIR-controlled “along-slit” lamp.

Bias calibration data, darks with multiple integration times, will be taken at nominally fixed intervals for the IR detector only. Currently, the default is to take a bias set with every integrating sphere calibration measurement. There is a specific macro for the bias calibration.

Focal plane lamp data will be taken every month. Currently, the focal plane lamp data are not used in the calibration algorithm, so this is just for verification and engineering checkout. There is a specific macro for the focal plane lamp calibration.

A nadir-pointed hyperspectral swath of a featureless region of Mars is taken at a nominally fixed interval. Currently, the plan is to take these data monthly. These data will be used to flat-field the VNIR detector. IR data will be taken in the featureless regions, also. However, the IR data will be used only for validation. The default flat-fielding for the IR detector will come from the sphere calibration.

#### 1.2 Reduction of flight target image data using calibration data

0. Apply correction for integrating sphere temperature to ground integrating sphere radiance. This corrects the ground-measured radiance of the integrating sphere to the radiance at the temperature of the integrating sphere for the flight calibration. This correction will include the correction for temperature dependence of beamsplitter features, assuming the spectrometer temperature moves with the optical bench temperature, which is sampled by the sphere temperature. In flight, we will watch for the difference between spectrometer temperature and optical bench temperature being

different than it was in testing. Uses flight sphere temperature only to correct ground sphere radiance only. No effect on flight scene or calibration sphere images. Section 3.4.

1. Use pixel processing table and LUT tables to convert 8-bit data to 12-bit if data are 8-bit. Section 2.2.
2. Use pixel processing table to convert 12-bit data to 14-bit data. Section 2.2.
3. Subtract bias calculated from nearest available flight bias calibration data set, corrected for detector temperature and FPU board temperature. For IR only. Apply to scene images and darks. Sections 2.3 and 0.
4. Subtract darks from scene images. For VNIR only. Use a weighted average of darks taken before and after the target image, with the weighting factors derived from the relative time at which each dark was taken with respect to the scene image. Correct for detector temperature and FPU temperature dependence of bias using temperatures of scene image and weighted temperatures of dark images. Sections 2.3 and 3.2.
5. Make detector quadrant ghost correction applying coefficients from ground calibration to each quadrant within each image. For IR, apply to darks as well. Section 2.4. Replace saturated pixels with 65535.
6. Apply bad pixel mask to all images, replacing bad pixels with a linear spatial nearest-neighbor interpolation. Sections 2.5 and 0.
7. Apply cosmic ray correction to scene images, dark images, and flight calibration images. Section 2.7.
8. Apply overall detector nonlinearity correction from ground calibration to scene images. For IR, apply to darks as well. Section 2.8.
9. Divide by integration time to get counts/millisecond. Section 2.9
10. Subtract processed darks from processed scene images. Use a weighted average of darks taken before and after the scene image, with the weighting factors derived from the relative time at which each dark was taken with respect to the scene image. Correct for detector temperature dependence of bias using detector temperature of scene image and weighted detector temperature of dark images. For IR only. Sections 2.10 and 3.2.
11. Apply stray light subtraction using stray light pixels within each image. Section 2.11.
12. Apply subtraction of 2<sup>nd</sup> order leaked light in Zone 3 of IR detector using Zone 1 counts from same image and ground-derived coefficients. For IR only. Section 2.12.
13. Apply shutter mirror nonrepeatability correction to ground integrating sphere radiance. This corrects the ground-measured radiance of the integrating sphere to the shutter mirror position in the flight calibration sphere data. Counts from flight calibration sphere will be ratioed to the counts from the nominal ground sphere radiance measurement and integrated to calculate a unitless VNIR shadow movement parameter. Ground-derived correction images will be scaled to VNIR shadow movement, and ground sphere radiance multiplied by (1+scaled image) to correct it to the flight shutter position. Uses flight calibration sphere data to correct ground sphere radiance. No effect on flight scene or calibration images, but it does use data from the flight calibration image, so it must be performed in sequence after the previous calibration steps. Section 3.4.
14. Calculate spectroradiometric responsivity using nearest available flight integrating sphere data and ground sphere radiance. This spectrum is a function of wavelength pixel and spatial pixel. For VNIR, we will use an average of the N nearest flight integrating sphere data sets. N=10 baseline value. For IR, use two flight integrating sphere measurements, one dayside and one nightside. Use linear interpolation in IR detector temperature 2

- between these two integrating sphere measurements. Note that before the responsivity is calculated, the flight integrating sphere data sets should be processed using steps 1-13 above, and the ground sphere radiance must be corrected by steps 0 and 14. Section 3.5.
15. Correct responsivity for detector temperature. VNIR only. For the IR, this is taken into account by the temperature interpolation between the dayside and nightside sphere measurements. Section 2.13.
  16. Apply binning to responsivity for the different modes. Section 2.14.
  17. Divide corrected counts/second in the scene images by the binned responsivity to get radiance at the instrument aperture. Note that before the radiance is calculated, the scene data sets should be processed using steps 1-13 above. Section 2.15.
  18. Replace non-scene pixels with the value 65535.
  19. Divide radiance image by image of external flat field. VNIR only. For IR, the flat fielding done by the sphere is good enough. See section 3.3.

There is a potential for two additional steps correcting the ground sphere radiance, one for sphere lamp aging and one for sphere feedback photodiode radiation damage. Both effects will be monitored by monthly intercalibration tests. The most likely effect on the calibration algorithm above is the baseline ground sphere radiance image used will be modified daily or weekly to account for these effects. There should be very little effect on the algorithm or data flow.

## 2. CALIBRATION DESCRIPTION

### 2.1 Overview of calibration equation

Radiometric calibration to units of radiance follows the equation

$$RD_{x,\lambda} = M_{x,\lambda,Hz} ( ( K_{x,\lambda,Hz} ( D14_{\lambda} ( DN_{x,\lambda,TaV,TaW,TaI,TaJ,Ta2,Hz,t} ) - BiaT_{x,\lambda,TaV,TaW,TaI,TaJ,Hz,t} ) / t - Bkgd_{x,\lambda,TaI,Ta2,Hz} - Scat_{x,\lambda,TaV,TaI,Ta2,Hz} ) / RST_{x,\lambda,TaV,TaI,Ta2} ) / FF_{x,\lambda}$$

Subscripts include:

- $x$ , **spatial position** in a row on the focal plane, in detector elements
- $\lambda$ , **wavelength** in spectral direction on the focal plane, in detector elements or nm
- $Hz$ , **frame rate, wavelength table, and binning mode**
- $T_{aI}$ , **IR detector temperature** in K for scene measurement
- $T_{aV}$ , **VNIR detector temperature** in K for scene measurement
- $T_{a2}$ , **spectrometer housing temperature** in K
- $T_{c3}$ , **temperature of the integrating sphere** in K for flight calibration measurement
- $T_{aJ}$ , **IR focal plane board temperature** in K for scene measurement
- $T_{aW}$ , **VNIR focal plane board temperature** in K for scene measurement
- $t$ , **integration time** in seconds
- $s$ , **choice of sphere bulb**, side 1 or 2

Temperatures are given for scene measurements, bias measurements, calibration measurements, or first and second dark measurements according to the lowercase subscripts a, b, c, d, and e respectively. So, for example,  $T_{aI}$  would be the IR detector temperature for the scene image,  $T_{dI}$  would be the IR detector temperature for the “before” dark image,  $T_{eI}$  for the “after” dark image,  $T_{cI}$  would be the IR detector temperature for the associated flight calibration images, and  $T_{bI}$  would be the IR detector temperature for the associated bias measurement. The algorithm uses temperatures from the low-rate telemetry. The temperatures are taken once per second and a 10-point median smoothing is applied.

Subscripts indicate which terms in the equation are dependent on which parameters. This includes both explicit and implicit dependence, and excludes when an implicit dependence has been explicitly subtracted out. For example, the  $Bkgd_{x,\lambda,TaI,Ta2,Hz}$  term includes background from the IR glow of the inside walls of the spectrometer, so it depends on the spectrometer temperature  $T_{a2}$ .  $Bkgd_{x,\lambda,TaI,Ta2,Hz}$  is calculated from dark images with spectrometer temperatures  $T_{d2}$  and  $T_{e2}$ , but the calculation is designed to give the level of the background for the target measurement spectrometer temperature  $T_{a2}$ . The explicit dependence on  $T_{d2}$  and  $T_{e2}$  has been subtracted out, leaving an implicit dependence on  $T_{a2}$ , so  $T_{a2}$  is in the subscript.

Description of the terms of the equation:

$D14_{\lambda}()$  converts from raw DN to 14-bit DN.

$BiaT_{x,\lambda,TaV,TaW,TaI,TaJ,Hz,t}$  is the temperature-corrected detector bias (DN at zero integration time).

$K_{x,\lambda,HZ}()$  flags saturated pixels and applies the detector ghost, bad pixel, cosmic ray, and detector nonlinearity corrections.

$Bkgd_{x,\lambda,Ta1,Ta2,HZ}$  is the dark subtraction term calculated from shutter-closed measurements.

$Scat_{x,\lambda,TaV,Ta1,Ta2,HZ}$  is the stray light subtraction, including uniform glare and 2nd order light.

$RST_{x,\lambda,TaV,Ta1,Ta2}$  is the responsivity calculated from flight onboard sphere calibration images.

$M_{x,\lambda,HZ}()$  applies the detector mask.

$FF_{x,\lambda,HZ}$  is the flat field.

$RD_{x,\lambda}$  is the observed spectral radiance in  $W/(m^2 \text{ micrometer sr})$  at the instrument aperture.

Definition of the terms of the equation:

The value 65535 is treated as a flag and any pixel with that value does not receive any further processing at any step of the calibration. The value of 65535 is just passed on to the next step.

$$D14_{\lambda}(DN_{x,\lambda,TaV,Ta1,Ta2,HZ,t}) = Offset_{\lambda} + Gain_{\lambda} \cdot ILUT_{\lambda}(DN_{x,\lambda,TaV,Ta1,Ta2,HZ,t})$$

This is conversion from raw DN (raw DN has fast lossless compression undone) to 14-bit DN. See section 2.2.

$$BiaT_{x,\lambda,Ta1,TaJ,HZ,t} = Bias_{x,\lambda,TbI,TbJ,HZ} - a0I \cdot Hv(row_{\lambda}+1-(502/480) \cdot (480-integ(t))) \\ + \beta_{I,HZ} \cdot (T_{aI} - T_{bI}) - \beta_{J,HZ} \cdot (T_{aJ} - T_{bJ})$$

for IR and

$$BiaT_{x,\lambda,TaV,TaW,HZ,t} = (\alpha_{ea} \cdot Bias_{x,\lambda,TdV,TdW,HZ,t} + \alpha_{ad} \cdot Bias_{x,\lambda,TeV,TeW,HZ,t}) / (\alpha_{ad} + \alpha_{ea}) \\ + \beta_{V,HZ} \cdot [\alpha_{ea} \cdot (T_{aV} - T_{dV}) + \alpha_{ad} \cdot (T_{eV} - T_{aV})] / (\alpha_{ad} + \alpha_{ea}) \\ + \beta_{W,HZ} \cdot [\alpha_{ea} \cdot (T_{aW} - T_{dW}) + \alpha_{ad} \cdot (T_{eW} - T_{aW})] / (\alpha_{ad} + \alpha_{ea})$$

for VNIR is the temperature-corrected bias subtraction. See section 2.3 and section 0.

$K_{x,\lambda,HZ}() = F_{HZ}(C(B_{x,\lambda,HZ}(S(H))))$  applies various corrections.

$$H(DN14^a_{x,\lambda,TaV,Ta1,Ta2,HZ,t}) = DN14^a_{x,\lambda,TaV,Ta1,Ta2,HZ,t} - \sum_{n=0}^{n=3} G(DN14^a_{x0+n \cdot \delta_{\lambda},TaV,Ta1,Ta2,HZ,t})$$

applies the detector quadrant ghost correction. See section 2.4.

$S(DN14^b_{x,\lambda,TaV,Ta1,Ta2,HZ,t}) = 65565$  if  $DN14^a_{x,\lambda,TaV,Ta1,Ta2,HZ,t} > DN14^a_{maxI}$  for IR or  $DN14^a_{maxV}$  for VNIR. See section 2.5.

$B_{x,\lambda,HZ}()$  is the bad pixel removal function. See section 2.5.

$C()$  applies the cosmic ray identification function. See section 2.7.

$F_{HZ}()$  is the detector average nonlinearity function. See section 2.8.

$Bkgd_{x,\lambda,Ta1,Ta2,HZ} = Bkgd_{x,\lambda,Td1,Te1,Td2,Te2,HZ,ta1,td1,te1}$  is the dark-subtraction term. It is zero for VNIR. The parameters in the subscripts on the right-hand side are explicitly used to calculate a value of the background that should be implicitly dependent on the parameters in the subscripts on the left-hand side. See section 2.10.

$$\text{Scat}_{x,\lambda,TaV,Ta1,Ta2,Hz} = \langle \text{RT14}^h_{x1\dots xn,\lambda,TaV,Ta1,Ta2,Hz} \rangle + \sum_{n=1}^{n=4} \kappa_{x,\lambda,n,Hz} \cdot \text{RT14}^i_{x,\lambda,yx\lambda n,Hz,Ta1,Ta2,Hz}$$

comprises the stray light corrections for glare (first term), second order (second term), and optical ghost (second term). See section 2.11 and section 2.12.

$$\text{RST}_{x,\lambda,Ta1,Ta2} = ( \text{RSP}^j_{x,\lambda,Tc1,Tc2} \cdot ( T_{a1} - T_{fl} ) + \text{RSP}^j_{x,\lambda,Tfl,Tf2} \cdot ( T_{c1} - T_{a1} ) ) / ( T_{c1} - T_{fl} )$$

for IR, where  $T_{c1}$  and  $T_{fl}$  are the IR detector temperatures for the dayside and nightside sphere calibrations respectively.

$$\text{RST}_{x,\lambda,TaV,Ta2} = \text{RSP}^j_{x,\lambda,TcV,Tc2} \cdot ( \mu_{x,\lambda} + \nu_{x,\lambda} \cdot T_{aV} + \pi_{x,\lambda} \cdot T_{aV}^2 ) / ( \mu_{x,\lambda} + \nu_{x,\lambda} \cdot T_{cV} + \pi_{x,\lambda} \cdot T_{cV}^2 )$$

for VNIR is the temperature-corrected CRISM responsivity calculated from the flight onboard sphere calibration measurements. See section 3.4, section 3.5, and section 2.13.

$M_{x,\lambda,Hz}()$  replaces non-scene pixels with the value 65535.

$\text{FF}_{x,\lambda,Hz}$  is the radiance image of an external flat field, run through the whole calibration pipeline and then normalized so the scene pixels in each row average to 1. This is used for VNIR only. For IR, the flat fielding implicit in the calibration with the onboard sphere is good enough, and  $\text{FF}_{x,\lambda,Hz} = 1$  by definition. See section 3.3.

$\text{RD}_{x,\lambda}$  is the observed spectral radiance in  $\text{W}/(\text{m}^2 \text{ micrometer sr})$  at the instrument aperture for scene or EPF measurements. A solar normal incidence spectral irradiance model convolved with the CRISM instrument function  $\text{SF}_{x,\lambda}$  is supplied so the user may convert radiance to I/F. See section 2.17.

## 2.2 Uncompression and conversion to 14-bit DN

Before any calibration steps are taken, the lossless fast compression is undone, yielding **raw DN**.

The first term in the calibration equation,  $\text{DN}_{x,\lambda,Hz,t}$ , is **raw DN** for some column  $x$  and row  $\lambda$ , taken at some frame rate  $Hz$  with exposure time  $t$ . Raw DN levels are in EDRs named according to the convention `ccnnnnnnnn_xx_aaaaas_EDRv.IMG` where `ccc`=class of observation (targeted, multispectral windows, etc.), `nnnnnnnn`=observation ID in hex, `xx`=counter of EDRs within that observation, `aaaaa`=activity type, `s`=sensor ID, and `v`=version number.

Some raw DN values may be 65535. These are unphysical values used as flags for data dropout pixels. For later steps in the calibration algorithm, the value 65535 will be used to flag saturated and non-scene pixels. Whenever the value of 65535 is encountered at this or any other step, the calibration algorithm assumes it is a flag, not a true DN, and simply passes the value through rather than applying the calibration calculation to that pixel.

- Although raw DN has the lossless fast compression undone, it is still always written to an EDR compressed from a 14-bit state. This compression is performed in the DPU before

lossless fast compression. Raw DN is restored to 14 bits using a pixel processing table which has one line per detector row, with 3 elements per line. This step occurs after the EDRs are generated, as part of the conversion of the EDRs to radiance units.

The conversion needs to know:

- Which one of 8 look-up tables was used to convert 12 to 8 bits on that line, if the data are 8 bits
- An inverted version of the lookup table used for each line, to convert back to 12 bits
- A gain, by which the 12-bit DN should be divided
- An offset, which should be added to the gain-corrected DN

For 8-bit raw DN (lossy compression on), there are two steps to the conversion, converting raw DN to 12-bit DN12, and converting 12-bit DN12 to 14-bit DN14. For 12-bit raw DN (lossy compression off), the first step is skipped.

The formula for generating 12-bit DN12 with saturated pixels flagged is

$$DN12_{x,\lambda,TaV,TaW,TaI,TaJ,Ta2,HZ,t} = ILUT_{\lambda} ( DN_{x,\lambda,TaV,TaW,TaI,TaJ,Ta2,HZ,t} )$$

for 8-bit raw DN, and

$$DN12_{x,\lambda,TaV,TaW,TaI,TaJ,Ta2,HZ,t} = DN_{x,\lambda,TaV,TaW,TaI,TaJ,Ta2,HZ,t}$$

for 12-bit raw DN.  $ILUT_{\lambda}$  is the inverse of the original look-up table used by the flight DPU to perform the lossy compression.

The formula for converting 12-bit DN12 to 14-bit DN14 is

$$DN14_{x,\lambda,TaV,TaW,TaI,TaJ,Ta2,HZ,t} = Offset_{\lambda} + Gain_{\lambda} \cdot DN12_{x,\lambda,TaV,TaW,TaI,TaJ,Ta2,HZ,t}$$

The offset, gain, and lookup tables are all given row-by-row, and tables are valid over specified time ranges (although we expect them to change very infrequently if ever). As of 10/26/2005, the gain was constant for all rows of both detectors, the offset was constant for all rows of each detector but at a different value for each detector, and the LUTs were different for different rows within and between the detectors.

Which LUTs were used for each row is maintained as the last column in the level 6 pixel processing CDR, named CDR6\_#\_#####\_PP\_n\_v.TAB, where #=spacecraft time SCLK partition at the beginning time of validity of the CDR, #####=spacecraft time SCLK at the beginning time of validity of the CDR, n=sensor ID and v=version number. The LUTs themselves are maintained as CDR6\_#\_0000000000\_LK\_n\_v.TAB, and the conversion back to 14 bits uses the inverse lookup table, maintained as CDR6\_#\_0000000000\_LI\_n\_v.TAB. The gains are maintained as the second column of the level 6 pixel processing CDR, and the offsets are maintained as the third column of the level 6 pixel processing CDR.

## 2.3 Remove bias

Next the bias is removed from the data. The bias subtraction formula for the IR is

$$\text{DN14}_{x,\lambda,\text{TaI},\text{Ta2},\text{Hz},t}^a = \text{DN14}_{x,\lambda,\text{TaJ},\text{Ta2},\text{Hz},t} - \text{Bias}_{x,\lambda,\text{TbI},\text{TbJ},\text{Hz}} + a_{0I} \cdot \text{Hv}(\text{row}_\lambda + 1 - (502/480) \cdot (480 - \text{integ}(t))) - \beta_{I,\text{Hz}} \cdot (T_{aI} - T_{bI}) - \beta_{J,\text{Hz}} \cdot (T_{aJ} - T_{bJ})$$

The superscript “a” indicates the first step in the calibration algorithm has been applied, and we continue through the alphabet for subsequent steps of the calibration algorithm. As discussed earlier, any values of 65535 are treated as flags and simply passed through with no calculation performed on them.

Bias is different and more complicated for the IR detector as compared to the VNIR detector. Bias is the DN level extrapolated to zero exposure time, in image form, taken at a particular frame rate. This represents an electronics bias added to the measured signal, to prevent near-zero DNs from going negative (and being clipped) due to superimposed noise. In detector-level testing it was found that bias has a nearly fixed pattern pixel to pixel, but that its magnitude varies weakly with temperature and strongly with frame rate.

In flight, bias for the IR detector is derived from a dedicated calibration, performed periodically, in which, at each frame rate, a burst of 10 images is taken with the shutter closed at each of several short exposure times. These data are taken at IR detector temperature  $T_{bI}$ . After making a correction for a step in the bias that is a function of integration time parameter, the DN values are fit linearly on a pixel-by-pixel basis and the exposure time=0 y-intercept image is used as the bias estimate. This process is described in section 0. Note the cosmic ray correction  $C()$ , described in Section 2.7, is applied to the bias images before  $\text{Bias}_{x,\lambda,\text{TbI},\text{TbJ},\text{Hz}}$  is calculated from them.

The IR bias images  $\text{Bias}_{x,\lambda,\text{TbI},\text{TbJ},\text{Hz}}$  are corrected for the step function  $-a_{0I} \cdot \text{Hv}(\text{row}_\lambda + 1 - (502/480) \cdot (480 - \text{integ}(t)))$ . This term results from details of the readout of the image in the electronics. It is entirely predetermined, and contains the entire dependence of the bias on the integration time. The constant  $a_0$  is determined from ground calibration data,  $\text{Hv}()$  is the Heaviside function,  $\text{row}_\lambda$  is the detector row number (counting from zero), and  $\text{integ}_t$  is the integration parameter. The value of  $t$  in ms is calculated from the integration time parameter  $\text{integ}$  using the formula  $t = 1000 \cdot (502 - \text{floor}((502/480) \cdot (480 - \text{integ}))) / (502 \cdot \text{rate})$ , where  $\text{floor}()$  is the function that creates an integer from a real number by rounding down. Since the bias images  $\text{Bias}_{x,\lambda,\text{TbI},\text{TbJ},\text{Hz}}$  do not include the step function, it is subtracted explicitly in the equation above.

The IR bias images  $\text{Bias}_{x,\lambda,\text{TbI},\text{TbJ},\text{Hz}}$  are stored as level 4 calibration data records (CDRs) named  $\text{CDR4}\#\text{tttttttt\_BIrbeeewsl\_v.IMG}$ , where  $\#$ =spacecraft SCLK partition for the mean time at which that bias data was taken,  $\text{tttttttt}$ =mean spacecraft time SCLK for that bias data,  $r$ =frame rate,  $b$ =binning,  $eee$ =exposure time parameter,  $w$ =wavelength filter,  $s=0$ ,  $L$ =detector (IR), and  $v$ =version number. The calibration software uses the partition  $\#$  and the mean SCLK  $\text{tttttttt}$  to

calculate encoded SCLK for the bias measurement. It uses the SCLK given in the .TAB list file that goes with each frame of the EDR along with a partition # from the .LBL file that goes with that EDR to calculate encoded SCLK for that EDR. It then uses the CDR4 file with the value of encoded SCLK that is closest to the value of encoded SCLK for the scene measurement.

The bias calibration may be taken at an IR detector temperature  $T_{bl}$  different from that of the data being corrected,  $T_{al}$ . The term  $\beta_{I,HZ} \cdot (T_{al} - T_{bl})$  represents the scalar difference between two modeled values of averaged, temperature-dependent bias. This scalar value is intended to correct the bias image for small temperature differences between the time of its acquisition and the time of the data being corrected. The coefficients  $\beta_{I,HZ}$  are given in a level 6 CDR named CDR6\_#\_0000000000\_DB\_L\_v.TAB. Separate coefficients are defined for the 4 detector quadrants, but as of this writing (11/4/2005) the values are the same for all the quadrants so there is no subscript to represent the quadrant dependence.

The bias calibration may be taken at an IR focal plane electronics board temperature  $T_{bj}$  different from that of the data being corrected,  $T_{aj}$ . The term  $\beta_{J,HZ} \cdot (T_{aj} - T_{bj})$  represents the scalar difference between two modeled values of averaged, temperature-dependent bias. This scalar value is intended to correct the bias image for small temperature differences between the time of its acquisition and the time of the data being corrected. The coefficients  $\beta_{J,HZ}$  are given in a level 6 CDR named CDR6\_#\_0000000000\_EB\_L\_v.TAB. Separate coefficients are defined for the 4 detector quadrants, but as of this writing (11/4/2005) the values are the same for all the quadrants so there is no subscript to represent the quadrant dependence.

For the VNIR images, the dark current and thermal photons are nil, so the bias is directly and very accurately measured when the shutter is closed (the dark measurements taken before and after a scene or calibration image). For the IR, a separate bias subtraction is necessary because there is background due to dark current and thermal photons, and it is necessary to separate that background from the bias in order to make an accurate linearity correction.

The bias subtraction formula for VNIR is

$$\begin{aligned} DN14_{x,\lambda,TaV,HZ,t}^a &= DN14_{x,\lambda,HZ,TaV,TaW,t} - ( \alpha_{ea} \cdot Bias_{x,\lambda,TdV,TdW,HZ,t} + \alpha_{ad} \cdot Bias_{x,\lambda,TeV,TeW,HZ,t} ) / \\ &(\alpha_{ad} + \alpha_{ea}) \\ &- \beta_{V,HZ} \cdot [ \alpha_{ea} \cdot ( T_{aV} - T_{dV} ) + \alpha_{ad} \cdot ( T_{eV} - T_{aV} ) ] / (\alpha_{ad} + \alpha_{ea}) \\ &- \beta_{W,HZ} \cdot [ \alpha_{ea} \cdot ( T_{aW} - T_{dW} ) + \alpha_{ad} \cdot ( T_{eW} - T_{aW} ) ] / (\alpha_{ad} + \alpha_{ea}) \end{aligned}$$

The  $\alpha$  coefficients in the VNIR equation are time-weighting coefficients. The two VNIR bias images are linearly interpolated in time to the time of the scene image. The variable  $t$  represents integration time, not clock time, so a new variable,  $t_{a1}$  indicates clock time. The value of  $t_{a1}$  is the mean value of encoded SCLK for that image specifically. It is derived from the instrument timetag value in the header of each image, calculated by the CRISM instrument clock, frequently updated by the spacecraft clock, and corrected using the partition number to be encoded SCLK instead of just SCLK. Calculations on a local computer may not have the SPICE information available to convert SCLK to encoded SCLK. One may use SCLK for this calculation as long as the partition number does not change. Just like for the temperatures,  $t_{a1}$  indicates timetag for the scene image,  $t_{d1}$  and  $t_{e1}$  the dark images,  $t_{b1}$  the bias images, and  $t_{c1}$  the calibration images.

$$\alpha_{ad} = t_{a1} - t_{d1} \text{ and } \alpha_{ea} = t_{e1} - t_{a1}$$

The VNIR bias images  $Bias_{x,\lambda,TdV,TdW,HZ,t}$  and  $Bias_{x,\lambda,TeV,TeW,HZ,t}$  are stored as level 4 calibration data records (CDRs) named CDR4#ttttttttt\_BIRbeeewS\_v.IMG, where #=spacecraft SCLK partition for the beginning of time of validity of the data product, tttttttt= spacecraft time SCLK for the beginning of time of validity of the data product, r=frame rate, b=binning, eee=exposure time parameter, w=wavelength filter, s=0, S=detector (VNIR), and v=version number. The calibration software uses the partition # and the mean SCLK to calculate encoded SCLK for the bias measurement. It uses the SCLK given in the .TAB list file that goes with each frame of the EDR along with a partition # given in the .LBL file that goes with that EDR to calculate encoded SCLK for that EDR. It then uses the CDR4 file with the value of encoded SCLK that is closest to the value of encoded SCLK for the scene measurement. A description of the calculation of  $Bias_{x,\lambda,TdV,TdW,HZ,t}$  and  $Bias_{x,\lambda,TeV,TeW,HZ,t}$  is given in section 3.2.

The VNIR coefficients  $\beta_{v,HZ}$  are given in CDR6\_#\_0000000000\_DB\_n\_v.TAB, and the VNIR coefficients  $\beta_{w,HZ}$  are given in CDR6\_#\_0000000000\_EB\_n\_v.TAB. The VNIR temperature correction is with respect to the temperatures  $T_{dV}$ ,  $T_{eV}$  of the VNIR detector and  $T_{dW}$ ,  $T_{eW}$  of the VNIR focal plane electronics board during the before and after darks respectively. The images  $Bias_{x,\lambda,TdV,TdW,HZ,t}$  and  $Bias_{x,\lambda,TeV,TeW,HZ,t}$  are given in the level 4 CDRs

The above description of the bias correction applies to the scene images, which have temperatures  $T_{aI}$ ,  $T_{aJ}$  and  $T_{aV}$ ,  $T_{aW}$ . The bias correction is also applied to dark images for the IR, and the formula is the same except  $T_{aI}$ ,  $T_{aJ}$  are replaced by  $T_{dI}$ ,  $T_{dJ}$ . It is also applied to the calibration images for both IR and VNIR, and likewise  $T_{aI}$ ,  $T_{aJ}$  are replaced by  $T_{cI}$ ,  $T_{cJ}$  and  $T_{aV}$ ,  $T_{aW}$  by  $T_{cV}$ ,  $T_{cW}$ .

## 2.4 Remove detector quadrant electronics ghost

Next, electronics ghosts are removed from the data. There are two types of ghosts, each at the percent level, that add to the measured DN but do not represent real signal.

The first type of electronics ghost is a weak, negative image of any one of the four 160-column wide quadrants in each other quadrant.



Weak electronics ghost negative images of the quadrant 4 signal in each other quadrant.

Each quadrant produces the same ghost image in all 4 quadrants. We include the self-ghosting

because it makes the subsequent nonlinearity correction smaller. For VNIR, the ghost is a nonlinear function of the signal. For IR, the ghost is a linear function of the signal, but with a nonzero intercept when extrapolated to zero signal indicating that the ghost would be nonlinear at small signal levels if we had data there. For VNIR or IR, the ghost has the same function  $G(DN)$  for all 4 quadrants whether one changes the quadrant in which the source is located or the quadrant in which the ghost appears.

To remove the detector quadrant ghost, we subtract the ghost calculated from the signal in each of the 4 quadrants from each pixel. The quadrant the pixel itself is in is included, so the self-ghosting is subtracted.

$$DN14^b_{x,\lambda,TaV,HZ,t} = DN14^a_{x,\lambda,TaV,HZ,t} - \sum_{n=0}^{n=3} G_V(DN14^a_{x0+n\cdot\delta,\lambda,TaV,HZ,t})$$

for VNIR and

$$DN14^b_{x,\lambda,TaI,Ta2,HZ,t} = DN14^a_{x,\lambda,TaI,Ta2,HZ,t} - \sum_{n=0}^{n=3} G_I(DN14^a_{x0+n\cdot\delta,\lambda,TaI,Ta2,HZ,t})$$

for IR, where  $\delta$  = the width of a quadrant, and  $x0 = x$  modulo 160, the position in the first quadrant corresponding to the position of  $x$  in the current quadrant.  $G()$  is the ghost function, which is different for VNIR and IR but does not depend on frame rate or any other parameter. The coefficients in the ghost function  $G()$  are given in a level 6 CDR named CDR6\_#\_0000000000\_GH\_n\_v.TAB.

Treatment of pixels flagged with 65535 in ghost removal correction:

As always, these pixels are passed on to the next step in the calibration algorithm with no processing. For the right hand side of the equation above,  $DN14^a_{x0+n\cdot\delta,\lambda,TaI,Ta2,HZ,t}$  is set equal to zero, so these pixels have zero contribution

## 2.5 Flag saturated pixels

Saturated pixels do not represent accurate data values, so we flag them by replacing them with the value 65535. The saturated pixels are processed up to the level of the detector electronics ghost, because it is more accurate to apply the saturated value to the ghost correction than to apply zero.

**Digital saturated pixels.** The algorithm goes back to the raw images  $DN_{x,\lambda,TaV,TaW,TaI,TaJ,Ta2,HZ,t}$  from the EDR and identifies any saturated pixel values. For those pixel coordinates  $(x, \lambda)$ , it then replaces the pixel value in  $DN14^b_{x,\lambda,TaV,TaI,Ta2,HZ,t}$ , the output of the detector quadrant ghost correction, with 65535. The algorithm is basically

If (  $DN_{x,\lambda,TaV,TaW,TaI,TaJ,Ta2,HZ,t}$  eq 4095 ) then  $DN14^b_{x,\lambda,TaV,TaI,Ta2,HZ,t} = 65535$ . For 8-bit raw DN, use 255 instead of 4095.

In addition to the pixels with raw DN values pegged at 4095 (255 for 8-bit raw DN), some pixels with a smaller (but still high) value of raw DN are in a strongly nonlinear range of detector response. The former we call “digital saturated pixels”, and we have replaced them with the value 65535 in section 2.2. The latter we call “analog saturated pixels”. The analog saturation is

a function of bias-subtracted DN rather than raw DN, so we flag those pixels after the bias subtraction.

Again we have to go back to earlier data to correct current data. The analog saturated pixel criterion is based on bias-subtracted DN, so we go back to the  $DN14^a_{x,\lambda,TaV,TaI,Ta2,HZ,t}$  values to evaluate it, and we flag the  $DN14^b_{x,\lambda,TaV,TaI,Ta2,HZ,t}$  values.

The analog saturated pixel removal function replaces  $DN14^b_{x,\lambda,TaV,HZ,t}$  with the value 65535 if  $DN14^a_{x,\lambda,TaV,HZ,t} > DN14^a_{\max V,x,HZ}$  for VNIR, and replaces  $DN14^b_{x,\lambda,TaI,Ta2,HZ,t}$  with the value 65535 if  $DN14^a_{x,\lambda,TaI,Ta2,HZ,t} > DN14^a_{\max I,x,HZ}$  for IR. The values  $DN14^a_{\max V,x,HZ}$  and  $DN14^a_{\max I,x,HZ}$  are given in the level 6 CDR named CDR6\_#\_0000000000\_SL\_n\_v.TAB, where #=spacecraft time SCLK partition at the beginning time of validity of the CDR, 0000000000=spacecraft time SCLK at the beginning time of validity of the CDR, n=detector, and v=version number. There are different values for different detector quadrants and frame rates, but the values are close for a given detector.

Note 4/14/2006: We have reviewed the analog saturated pixel values and determined the digital saturated pixel removal is redundant. Any digital saturated pixels will be removed by the analog saturated pixel step anyway. Since the digital saturated pixel removal step requires going back to the 12-bit or 8-bit DN, it is somewhat awkward to implement at this point in the algorithm and we have decided to drop it.

The function S() is defined as the function that flags the saturated pixels as described above.

$$DN14^c_{x,\lambda,TaI,Ta2,HZ,t} = S( DN14^b_{x,\lambda,TaV,TaI,Ta2,HZ,t}, DN14^a_{x,\lambda,TaV,TaI,Ta2,HZ,t}, DN_{x,\lambda,TaV,TaW,TaI,TaJ,Ta2,HZ,t} )$$

Any pixels flagged with 65535 are not processed by any subsequent step in the calibration algorithm, but just passed on to the next step unchanged.

## 2.6 Apply bad pixel mask to all images

The calculation of the bad pixel mask uses the same input data as the bias subtraction, but it does not use the output of the bias subtraction. The application of the bad pixel mask to the images happens after the bias subtraction and detector ghost corrections.

The data used to generate the IR bias images  $Bias_{x,\lambda,TbI,HZ,t}$  are also used to generate the bad pixel map images for the IR detector. The VNIR darks  $Bias_{x,\lambda,TdV,TdW,HZ,t}$  are used to generate the bad pixel map images for the VNIR detector.

As described in the bias section above, the IR bias data set consists of a set of images with different integration times at each frame rate. For the IR bias calculation above, the same type of calculation is performed at each frame rate, using bias data at that same frame rate and binning. For the bad pixel map, only the unbinned 1 Hz and 3.75 Hz bias data are used, and the 3.75 Hz data are binned to apply to other frame rates. This is because detector elements hot enough to saturate may not be evident in the binned data, and other kinds of bad pixels will also be less evident in the binned data.

An offset and dark current are calculated from the 1 Hz and 3.75 Hz bias data sets. This gives the following model of the response DN14 of each detector element with the shutter closed and lamps off.

$$DN14_{x,\lambda,TbV,HZ,t} = c0_{x,\lambda,TbV,HZ} + c1_{x,\lambda,TbV,HZ} \cdot t - a0_V \cdot Hv(\text{row}_\lambda + 1 - (502/480)) \cdot (480 - \text{integ}(t))$$

for VNIR and

$$DN14_{x,\lambda,TbI,Tb2,HZ,t} = c0_{x,\lambda,TbI,HZ} + c1_{x,\lambda,TbI,Tb2,HZ} \cdot t - a0_I \cdot Hv(\text{row}_\lambda + 1 - (502/480)) \cdot (480 - \text{integ}(t))$$

for IR. Note that  $c0$  corresponds to the bias for that frame rate and integration time, and  $c1 \cdot t$  corresponds to the background signal for that frame rate and integration time. The third term is a step function resulting from details of the readout of the image in the electronics. It is entirely predetermined. The constant  $a0$  is determined from ground calibration data,  $Hv()$  is the Heaviside function, and  $\text{integ}_t$  is the integration parameter. The value of  $t$  in ms is calculated from the integration time parameter  $\text{integ}$  using the formula  $t = 1000 \cdot (502 - \text{floor}((502/480) \cdot (480 - \text{integ}))) / (502 \cdot \text{rate})$ , where  $\text{floor}()$  is the function that creates an integer from a real number by rounding down.

Note the bias images are taken at detector temperatures ( $T_{bI}$ ,  $T_{bV}$ ) and spectrometer temperature  $T_{b2}$ . These are different temperatures than the temperatures for the data being corrected, which has the a, d, or c subscripts for scene images, darks, and calibration images respectively. For the bad pixel mask, this difference is not significant and no correction is made for these temperature differences. This is in contrast to the actual bias subtraction, where a correction is made for detector temperature. See section 2.3 above.

The coefficients  $c0$  and  $c1$  are calculated from a linear fit of DN14 as a function of integration time  $t$  at each frame rate, with the data taken from the bias measurements corrected for the predetermined step function. In addition, the fit estimates the uncertainty contribution to a single DN14 from each term,  $c0$  and  $(c1 \cdot t)$ .

$$\sigma_{x,\lambda,TbI,Tb2,HZ,t} = \text{sqrt}(\sigma_{c0,x,\lambda,TbI,HZ}^2 + \sigma_{c1 \cdot t,x,\lambda,TbI,Tb2,HZ,t}^2)$$

for IR.

For VNIR, one has only the integration times used in scene and calibration measurements for each frame rate, and it is not possible to do a linear fit. For VNIR, the  $\sigma_{c1 \cdot t,x,\lambda,TbV,HZ,t}$  term does not exist, and the  $\sigma_{c0,x,\lambda,TbV,HZ}$  term is just the standard deviation of each pixel estimated from the average over the burst.

The bad pixel map identifies hot, twinkly, and dead pixels.

Hot pixels are defined as pixels having unusually high dark counts. They are identified on the basis of two criteria:

1. Potentially saturated hot pixels. The sum of the bias, background, and Mars signal gives  $DN_{12} > 4096$ . The “Mars signal” is chosen to be modestly larger than the largest signal we expect from Mars at our longest scene integration time at that frame rate. For 1 Hz, replace “Mars signal” with “flight calibration source signal”. For 15 Hz and 30 Hz, the 3.75 Hz calculation is used except with integration times appropriate for the actual frame rate, and any binned pixel that contains at least one bad unbinned pixel is declared a bad binned pixel. Note that it is necessary to convert  $DN_{12}=4096$  to the equivalent  $DN_{14}$  to apply this criterion.
2. Noisy hot pixels. The dark current is large enough to produce unacceptable noise. The criterion here is  $\sigma_{c1} \cdot t > N_{max_{x,\lambda,Hz}}$ , where  $N_{max_{x,\lambda,Hz}}$  is given for each frame rate and binning in level 4 CDR images that are determined on the ground and relatively fixed. As of 9/30/2005, we had not decided whether to reject pixels based on excessively noisy dark current, and this CDR had not yet been defined. For VNIR,  $\sigma_{c1} \cdot t$  does not exist and we have to use  $\sigma_{c0}$  instead.

Twinkly pixels are defined as pixels having an unusually high variation of bias with time. This is similar to the pixels with noisy dark current described above, except the noise is in  $c_0$  instead of  $c_1$ . The criterion is  $\sigma_{c0} > N_{twink}$ , where  $N_{twink}$  is a constant defined in a TBD level 6 CDR file. For 15 Hz and 30 Hz, if the binned pixel contains a twinkly unbinned pixel in the 3.75 Hz data, the binned pixel is defined as twinkly. For VNIR, we have to use  $\sigma_{c0}$  for the noisy hot pixels, because there is no  $\sigma_{c1}$ . Therefore, there is no distinction drawn between twinkly and noisy hot pixels for VNIR.

It is not clear whether the twinkly pixels, being a bias effect rather than a dark current effect, generate detector ghosts that twinkle along with them. It may be that we should really be getting rid of the twinkly pixels before the detector ghost subtraction, if they don't generate detector ghosts. However, the amount of twinkle is small, and the imputed ghost that gets subtracted is a small fraction of that, so applying the ghost correction with twinkly pixels still in the image would cause an insignificant error even if it is technically not correct.

Dead pixels are defined as pixels having unusually low responsivity. They are calculated from the 1 Hz integrating sphere data in closest time proximity to the bias measurement used for the given bad pixel map. If a pixel in the integrating sphere image has  $DN_{14}$  less than 5% of the expected median  $DN_{14}$ , it is defined as dead. A binned pixel is dead only if all its unbinned pixels are dead (i.e., the badness is ANDed for dead pixels, unlike the other kinds of bad pixels, where it is ORed). There are few dead unbinned pixels, and we expect to see no dead binned pixels.

Background (dark) images and calibration images will be taken more frequently than bias images. When the bad pixel mask used for scene images changes, we will force the background and calibration images used for those scene images to change as well. The bad pixel mask used for a background or calibration image will always be the same as the bad pixel mask used for the scene data that background or calibration image is applied to.

The bad pixel masks are stored as images for each frame rate in the files named

CDR4#ttttttttt\_BPrbeewsn\_v.IMG. The file CDR6\_#\_0000000000\_PD\_n\_v.TAB contains a list of the bad pixel mask image CDR4 filenames.

The bad pixel mask will be applied to a scene, dark, or calibration image by replacing each bad pixel with the average of the two pixels in adjacent columns (spatial pixels) in the same row (wavelength pixel). If two or more pixels in the same row and adjacent columns are bad, they will be replaced using a linear interpolation of the two nearest good pixels in that row. The bad pixel mask is applied after bias subtraction and detector ghost removal.

Special cases:

1. When the bad pixel is the first or last column of the scene mask, so that the nearest neighbor on one side is not a scene pixel, the bad pixel will be replaced by the neighboring pixel in the adjacent column that is part of the scene, and the neighboring pixel not part of the scene will not be used. If two or more pixels in the same row and adjacent columns are bad, including the first or last column, they will be replaced by the nearest good pixel in that row.
2. When the bad pixel is in the stray light mask, it will not be used. If all of the stray light pixels in a given row are bad (this could easily happen for the IR detector for 10x binning, where there is only one stray light pixel in a row), then they are replaced by a linear interpolation of the two pixels in adjacent rows in the same column. If two or more stray light pixels in adjacent rows are bad, they will be replaced using a linear interpolation of the two nearest good pixels in that column. See section 2.11.

In the above rules, a “good” pixel is one not in the bad pixel mask and also with a value not equal to 65535.

The scattered light pixels are columns close enough to the edge of the detector to be outside the image of the spectrometer entrance slit but far enough away from the edges of the detector to be unmasked. They sample any stray light that is uniform in character. The stray light pixels are defined as columns  $x_1 \dots x_n$  and the values are as follows: 8-27, 4-13, 2-4, and 1 for the IR detector with 1x, 2x, 5x, and 10x binning respectively. For VNIR, there are stray light columns on both sides of the detector: 12-23 and 627-639 for 1x binning, 6-11 and 314-319 for 2x binning, 3 and 126-127 for 5x binning, and 1 and 63 for 10x binning. The values are given in a level 4 calibration data record (CDR) named CDR4#0000000000\_DMrbeewsn\_v.IMG, where #=spacecraft time SCLK partition at the beginning of validity of the CDR, tttttttt=spacecraft time, r=frame rate, b=binning, eee=exposure time parameter, w=wavelength filter s=0, n=detector, and v=version number.

Applying the calculations described in the calculation above is defined as B(), the bad pixel removal function, so we have

$$DN14^d_{x,\lambda,TaV,Ta1,Ta2,HZ,t} = B_{x,\lambda,HZ}(DN14^c_{x,\lambda,TaV,Ta1,Ta2,HZ,t})$$

The bad pixel mask will never be applied to bias images, because it is calculated from the bias

images and applied after the bias subtraction.

Each RDR generated from an EDR will have ancillary information that includes the name of the bad pixel mask CDR4 file used as part of the generation of that RDR, so users who wish to reject the bad pixels entirely have the information to do so. All of the bad pixels are flagged by this method. However, the calibration algorithm will replace the bad pixels with interpolated values, not reject them.

## 2.7 Apply cosmic ray identification to all images

Short diagonal streaks and dots due to cosmic rays will appear in many images. A rough estimate of the integrated size of each hit is about 150 DN14. These features will be removed from the scene images, dark images, images used for calculating bias, and in-flight calibration images using a TBD algorithm. The function  $C()$  represents the cosmic ray identification algorithm, taking a DN14 and generating a version with the cosmic ray hits removed.

The cosmic ray identification algorithm is TBD, but will probably follow these principles:

1. For dark, bias, and calibration data, we will have multiple identical images. An easy way to remove cosmic rays is to throw out the two brightest and dimmest values in each pixel when averaging the images. The cosmic rays will not be explicitly identified, but they will be filtered out. Another part of this process will be to reject the entire burst when any pixel outside the bad pixel map has no values left when the 65535 values, digital saturated values, and the two brightest and two dimmest are thrown out. Such data will be documented in the CDR6 list files as bad, and will not generate any CDR4 images.
2. For scene images, cosmic rays will have a sharp peak spectrally, which we do not expect to see in the real spectrum, since we are looking for broad absorption peaks and we do not expect any emission peaks. The cosmic ray identification algorithm will look for peaks that are sharp in the **spectral** direction and remove the image value at each peak found, replacing it with a value linearly interpolated in the **spatial** direction, the same as for bad pixels. To the extent that there is a trade-off between throwing out good pixels and leaving in cosmic rays, the algorithm will leave in the cosmic rays. If the user has to deal with a few leftover weak cosmic rays, that's OK.
3. We will have a method for identifying those pixels replaced as part of the cosmic ray identification algorithm. As of this writing (11/9/2005), the top candidate is to define a new keyword `COSMIC_RAY_COORD` for the .LBL file that describes the TRDR generated by the scene images for which cosmic ray pixels were replaced. The keyword value would simply be a list of cube coordinates of the pixels in that TRDR that were replaced by the cosmic ray algorithm. For the dark, bias, and calibration images used for that TRDR, the cosmic ray filtering is automatic and no pixels are replaced, so no record is needed.

Applying the cosmic ray identification algorithm defines the function  $C()$ , just like  $B()$  is the bias subtraction. So, after applying these two steps, we have

$$\text{DN14}^e_{x,\lambda,\text{TaV,TaI,Ta2,HZ,t}} = C_{\text{all}}(\text{DN14}^d_{x,\lambda,\text{TaV,TaI,Ta2,HZ,t}})$$

The subscript “all” indicates that the cosmic ray correction depends on the content of each image and so can be different for each pixel of each image. It has a potential dependence on all possible parameters.

The cosmic ray identification algorithm will flag cosmic ray pixels in the .LBL file. It will handle special cases of cosmic rays at the edge of the scene or in the scattered light pixel in the same way the bad pixel algorithm does.

After the bad pixel and cosmic ray corrections are applied, one may calculate byte 1 of the data quality field. For each image (or line of the TRDR), the raw DN  $\text{DN}_{x,\lambda,\text{TaV,TaW,TaI,TaJ,Ta2,HZ,t}}$  is filtered, removing the bad pixels and the cosmic ray pixels. The remaining pixels are compared to the pixels with the same coordinates in the image  $\text{DN14}^e_{x,\lambda,\text{TaV,TaI,Ta2,HZ,t}}$ . If there are any pixels in the latter with the floating-point value 65535.0 that don't have the unsigned integer value 65535 in the former image, those are saturated pixels that aren't bad or cosmic ray pixels. If at least one such pixel is found, byte 1 of the data quality field is set equal to 1 for the line of the RDR corresponding to that image. This indicates there are some truly saturated pixels in the image, and the science team should take a look at the integration time for future images in similar regions.

## 2.8 Detector average nonlinearity correction

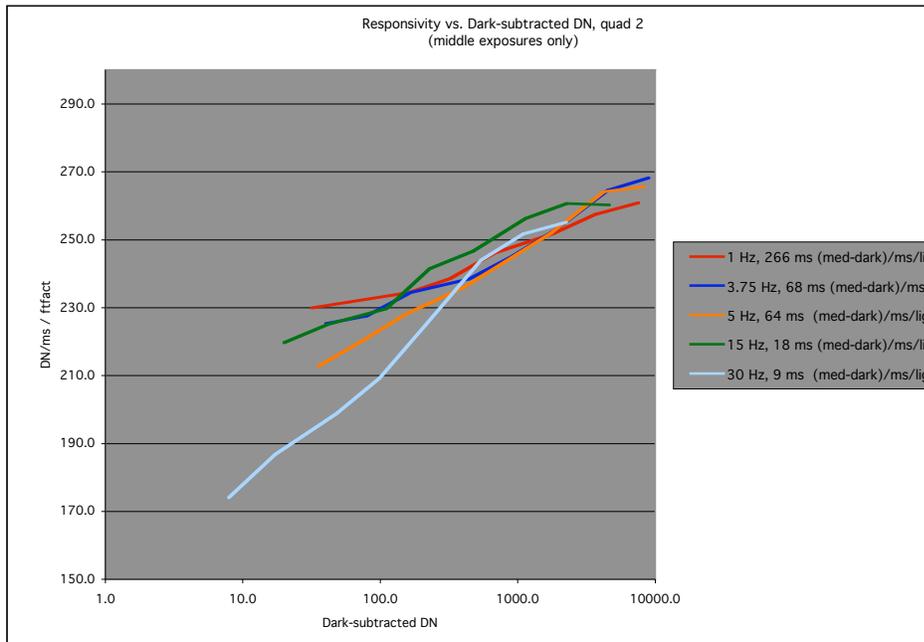
We use an empirical model of the detector nonlinearity to correct 14-bit DNs to a signal related linearly to the sum of contributions from dark current, thermal background, scattered light, and scene imaged through the slit. This is a correction for nonlinearity in the responsivity of the instrument. The source of this nonlinearity is in the detector electronics, as part of the conversion of electrons to DN. We correct for the fact that conversion efficiency of electrons to DN increases with DN. The value of DN is converted back to what it would be in an idealized case with a constant number of electrons per DN. In detector level testing it was found that, on average, conversion efficiency varies nearly linearly with the log of bias-corrected DN, and that the relationship differs slightly between frame rates. This gives the following model.

$$\text{Eff} = \text{DN} / (\text{Rate} \cdot t) = \varepsilon \cdot \log(\text{DN}) + \phi$$

where Eff is the detector conversion efficiency (DN/electrons) and Rate is the total rate of production of electrons, including source photons, background photons, and detector dark current but not including detector bias. We calculate  $\varepsilon$  and  $\phi$  from ground data  $\text{DN}_{\text{gnd}}$ , using a linear fit to  $y = \varepsilon \cdot x + \phi$  with  $y = \text{DN}_{\text{gnd}} / (\text{Rate} \cdot t)$  and  $x = \log(\text{DN}_{\text{gnd}})$  for a given data set with known dark current and background and a well-controlled radiance source with a range of radiances, using a range of integration times for our detector.

The parameters  $\varepsilon$  and  $\phi$  are calculated as averages over the whole detector, but applied to the DN level on a pixel by pixel basis. Typically, we use benchtop detector data and  $\text{DN}_{\text{gnd}}$  is an average over a region with constant filter performance and constant illumination to sample constant DN.

We can also use  $DN_{gnd}$  from data taken with the detector in the instrument, in which case it is generally an average over a row or a few rows to sample fairly constant DN. We assume that variations in the nonlinearity parameters from pixel to pixel within a row are small enough to be addressed in the flat field correction, as long as the flat field DN is roughly similar to the scene DN. For IR, the flight sphere calibration measurements are similar in DN to the scene measurements, and the flat field is taken into account when we do the sphere calibration. For VNIR, the flight sphere DN are much larger than the scene DN in some parts of the spectrum and much smaller in others, so we do a flat field correction on the radiance at the end, using averaged data from a featureless area of Mars, which does of course have similar DN to the other Mars scene data.



Nonlinear relationship of responsivity to radiance level for VNIR, measured during detector-level testing.

Then, we use the values of  $\epsilon$  and  $\phi$  from the fit to convert our flight DN back to an idealized DN which would result from a linear response. That linearized DN is proportional to  $(Rad \cdot t)$ , so we solve for  $(Rad \cdot t)$  in the model and our correction equation becomes

$$DN14_{x,\lambda,Ta1,Ta2,TaV,HZ,t}^g = F_{Hz}( DN14_{x,\lambda,Ta1,Ta2,TaV,HZ,t}^e )$$

$$F_{Hz}( DN14_{x,\lambda,Ta1,Ta2,TaV,HZ,t}^e ) = DN14_{x,\lambda,Ta1,Ta2,TaV,HZ,t}^e / ( \epsilon_{Hz} \cdot \log(DN14_{x,\lambda,Ta1,Ta2,TaV,HZ,t}^e) + \phi_{Hz} )$$

where  $DN14_{x,\lambda,Ta1,Ta2,TaV,HZ,t}^f$  is the linearized DN for our actual flight data. As shown,  $\epsilon$  and  $\phi$  are a function of frame rate. They are proportional to  $(Rate \cdot t)$  but there's an arbitrary scaling factor. We scale them so that  $F(1000)=1$ . The coefficients  $\epsilon$  and  $\phi$  are given in a level 6 CDR named `CDR6_#_0000000000_LC_n_v.TAB` where  $n$ =sensor ID and  $v$ =version number.

## 2.9 Divide by integration time to get counts/second

$$RT14_{x,\lambda,Ta1,Ta2,TaV,HZ}^g = DN14_{x,\lambda,Ta1,Ta2,TaV,HZ,t}^g / t$$

The nomenclature RT denotes rate instead of DN for data number, and the integration time is omitted to indicate that the images are nominally independent of integration time, but the rest of the subscripts are kept the same. We use t in ms, so the units of RT are counts/ms.

## 2.10 Background subtraction

The IR detector has dark current and is sensitive to IR background from the walls of the spectrometer. Now that the DN are bias-subtracted and linearized, this background must be subtracted before the scene images may be calibrated. The VNIR detector has no sensitivity to IR glow from the walls of the spectrometer, and at the  $-60^\circ$  C operating temperature there is no significant dark current, so no background subtraction is necessary for the VNIR channel.

The background is most strongly influenced by changes in the temperature of the IR detector. A spectrometer housing temperature only  $0.02^\circ$  C different from the data being corrected, at relatively warm housing temperatures near  $-78^\circ$  C, may result in a background at the longest IR wavelengths that is different by the noise-equivalent radiance. Originally, we had planned to interpolate the dark measurements using the measured spectrometer housing temperatures, but we do not expect the temperature sensors to be accurate enough. Therefore, the dark measurements are interpolated based on the time each was taken and the time of the image being background corrected. The value of  $t_{a1}$  is the mean value of encoded SCLK for that image specifically. It is derived from the instrument timetag value in the header of each image, calculated by the CRISM instrument clock, frequently updated by the spacecraft clock, and corrected using the partition number to be encoded SCLK instead of just SCLK. Calculations on a local computer may not have the SPICE information available to convert SCLK to encoded SCLK. One may use SCLK for this calculation as long as the partition number does not change. Just like for the temperatures,  $t_{a1}$  indicates timetag for the scene image,  $t_{d1}$  and  $t_{e1}$  the dark images,  $t_{b1}$  the bias images, and  $t_{c1}$  the calibration images.

The equation for background subtraction is

$$RT14_{x,\lambda,Ta1,Ta2,HZ}^h = RT14_{x,\lambda,Ta1,Ta2,HZ,t_{a1}}^g - Bkgd_{x,\lambda,Td1,Te1,Td2,Te2,HZ,t_{a1},t_{d1},t_{e1}}$$

with

$$Bkgd_{x,\lambda,Td1,Te1,Td2,Te2,HZ,t_{a1},t_{d1},t_{e1}} = [ 1 / ( t_{e1} - t_{d1} ) ] \cdot [ RTD14_{x,\lambda,Td1,Td2,HZ,t_{d1}}^g \cdot ( t_{e1} - t_{a1} ) + RTD14_{x,\lambda,Te1,Te2,HZ,t_{e1}}^g \cdot ( t_{a1} - t_{d1} ) ]$$

$$\text{and } RTD14_{x,\lambda,Td1,Td2,HZ,t_{d1}}^g = DND14_{x,\lambda,Td1,Td2,HZ,t_{d1}}^g / t$$

for IR. The term  $Bkgd_{x,\lambda,Td1,Te1,Td2,Te2,HZ,t_{a1},t_{d1},t_{e1}}$  is simply an average of the dark measurements taken before and after the given scene measurement, weighted by the inverse of the time difference between each dark measurement and the given scene measurement.

The term  $RTD14_{x,\lambda,Td1,Td2,HZ,t_{d1}}^g$  is simply the 14-bit DN/second for the dark measurement taken

before the measurement being background-subtracted, the superscript g indicating that it has gone through the same set of corrections as the measurement being background-subtracted. The variable td is the integration time for that particular dark measurement.

The images  $DND14^g_{x,\lambda,Td1,Td2,HZ,td}$  are stored as level 4 calibration data records (CDRs) named  $CDR4\#tttttttt\_BKrbeeewsl\_v.IMG$ , where #=spacecraft time SCLK partition at the beginning of validity of the CDR, tttttttt=spacecraft time SCLK at the beginning of validity of the CDR, r=frame rate, b=binning, eee=exposure time parameter, w=wavelength filter, s=0, L=detector (IR), and v=version number. The integration time td, used to calculate  $RTD14^g_{x,\lambda,Td1,Td2,HZ,td}$  from  $DND14^g_{x,\lambda,Td1,Td2,HZ,td}$ , may be calculated from the integration time parameter in the label file  $CDR4\#tttttttt\_BKrbeeewsl\_v.LBL$  that goes with the .IMG file containing the  $DND14^g_{x,\lambda,Td1,Td2,HZ,td}$  images.

For VNIR, there's no background correction, so it's just

$$RT14^h_{x,\lambda,TaV,HZ} = RT14^g_{x,\lambda,TaV,HZ}$$

## 2.11 Broadband scattered light correction

CRISM has two known significant sources of optical scattered light that must be removed during the correction of spectrally dispersed light, that is, an integrating sphere measurement to a responsivity correction or a Mars scene to radiance:

- Scatter from optical elements in the spectrometer scatters light and the spatial direction x and the wavelength direction  $\lambda$ . This is measured directly by the unmasked pixels to the side of the slit image. The contribution to scattered light resembles glare and is not in focus.
- 
- Second order light (source wavelength  $\lambda/2$ ) leaks through zone 3 of the order sorting filter at  $\lambda=2760-3960$  nm, and an apparent optical ghost with source wavelength near  $\lambda/1.8$  occurs in a narrow range of  $\lambda$  near 2400 nm..

The scattered light pixels are columns close enough to the edge of the detector to be outside the image of the spectrometer entrance slit but far enough away from the edges of the detector to be unmasked. They sample any stray light that is uniform in character. The stray light pixels are defined as columns  $x_1 \dots x_n$  and the values are as follows: 8-27, 4-13, 2-4, and 1 for the IR detector with 1x, 2x, 5x, and 10x binning respectively. For VNIR, there are stray light columns on both sides of the detector: 12-23 and 627-639 for 1x binning, 6-11 and 314-319 for 2x binning, 3 and 126-127 for 5x binning, and 1 and 63 for 10x binning. These values are given in a level 4 calibration data record (CDR) named  $CDR4\#0000000000\_DMrbeeewsn\_v.IMG$ , where #=spacecraft time SCLK partition at the beginning of validity of the CDR, tttttttt=spacecraft time, r=frame rate, b=binning, eee=exposure time parameter, w=wavelength filter s=0, n=detector, and v=version number.

The equation for glare correction is

$$RT14^i_{x,\lambda,TaV,TaI,Ta2,,Hz} = RT14^h_{x,\lambda,TaV,TaI,Ta2,,Hz} - \langle RT14^h_{x1\dots xn,\lambda,TaV,TaI,Ta2,,Hz} \rangle$$

We simply subtract the mean of the pixels in the scattered light columns. If a pixel in one of the scattered light columns has the value 65535, is in the bad pixel mask, or is identified as one of the cosmic ray pixels, that pixel is not used. If all the scattered light columns in a given row are bad, the scattered light column value is filled in by linear interpolation of the nearest good rows.

## 2.12 Subtraction of second-order stray light

This includes second order light (source wavelength  $\lambda/2$ ) from the grating at  $\lambda=2760-3960$  nm, and an apparent optical ghost with source wavelength near  $\lambda/1.8$  in a narrow range of  $\lambda$  near 2400 nm. This stray light is sampled by pixels inside the focal plane at the source wavelengths, so it is subtracted just by defining a matrix containing the row number of the source of scattered light for each row that contains scattered light, and another matrix defining the ratio of scattered signal to source signal. That ratio is measured in the scattered light test in ground calibration. Interpolated values are used for columns not illuminated in that test. The second order light in a single pixel should come from at most two pixels at  $\lambda/2$ , but to be safe we define 4 row numbers for each pixel. We assume the stray light is scattered directly along the columns of the detector, which is not exactly correct (there is some spectral smile) but should be good enough for stray light subtraction. The row number images  $y_{x,\lambda,n,HZ}$  with  $n=1-4$  give the row numbers of the 4 rows that are stray light sources for each pixel. The source rows are given separately for each column, but they are expected to be the same for most columns. The second order stray light does not overlap with the  $\lambda/1.8$  ghost, so the same matrix applies to both effects. If the source row is given as zero, it means there is no second order or  $\lambda/1.8$  stray light subtraction for that pixel. The coefficient images  $\kappa_{x,\lambda,n,HZ}$  with  $n=1-4$  give the fraction of the direct signal in  $(x,y_{x,\lambda,n,HZ})$  contributed to pixel  $(x,\lambda)$ . Then, the stray light is subtracted by the formula

$$RT14^i_{x,\lambda,TaI,Ta2,HZ} = RT14^i_{x,\lambda,TaI,Ta2,HZ} - \sum_{n=1}^{n=4} \kappa_{x,\lambda,n,HZ} \cdot RT14^i_{x,\lambda'=y_{x,\lambda,n,HZ},TaI,Ta2,HZ}$$

for the IR. For the VNIR, this correction is not necessary, and the formula is just

$$RT14^i_{x,\lambda,TaV,HZ} = RT14^i_{x,\lambda,TaV,HZ}$$

The  $y$  and  $\kappa$  images are calculated first using unbinned ground calibration images with all 480 wavelength pixels, and then it is straightforward to calculate versions for all wavelength tables and binning modes. These images are stored as level 4 calibration data records (CDRs) named CDR4#0000000000\_LLrbeeewsn\_v.IMG, where  $r$ =frame rate,  $b$ =binning,  $eee$ =exposure time parameter,  $w$ =wavelength filter,  $s=1$  or  $2$  depending on whether side 1 or 2 lamps are used,  $n$ =detector, and  $v$ =version number.

If any pixels in the sum  $\sum_{n=1}^{n=4} \kappa_{x,\lambda,n,HZ} \cdot RT14^i_{x,\lambda'=y_{x,\lambda,n,HZ},TaI,Ta2,HZ}$  have the value 65535.0, they are treated as being zero for the purposes of this calculation. If any such pixels are identified as cosmic ray pixels, they are replaced by linear interpolation in the spatial direction.

## 2.13 Correction of instrument responsivity for detector temperature

Responsivity as a function of wavelength results from three effects:

- The instrument design including telescope design, efficiency of optical elements, and quantum efficiency of the detectors.
- Variations in detector responsivity as a function of detector temperature. The main effects are a shift in the long wavelength edge for the VNIR detector, and a movement in the interference fringes that appear on the long wavelength end of the IR detector.
- Accumulation of absorbing contaminants on optical surface. The major expected contaminant is water ice on the detector.

CRISM's responsivity is tracked in flight using the internal integrating sphere, run under closed loop control, using either bulb. This provides a field- and aperture-filling source with stable radiance. The current plan is to take sphere calibration measurements with one lamp within a few minutes of every scene measurement, and take calibration measurements with the other lamp once a month to check the first lamp. The sphere calibration may also be checked with images from Diemos when available. The calibration is not expected to be a function of integration time or frame rate, and all of the sphere calibration images are taken at 1 Hz.

The instrument responsivity is the ratio of the DN from the in-flight sphere data, corrected for bias, background, nonlinearity, stray light etc. in the same way the as scene data, to the sphere radiance, measured on the ground and corrected to a value appropriate to the in-flight sphere data. The calculation of instrument responsivity at the time and temperatures of the in-flight sphere radiometric calibration is described in Section 3.5. The responsivity in DN/ms/(W/(m<sup>2</sup> micrometer sr) ) is  $RSP_{x,\lambda,TcV,TcI,Tc2}^j$ .

To apply that responsivity to a scene image to calculate radiance at the instrument aperture, we must first correct it for the instrument temperatures in effect during the scene measurement. Currently, the only temperatures we correct for are the detector temperatures  $T_{aV}$  and  $T_{aI}$ . It is possible the spectrometer temperature  $T_{a2}$  could also affect the responsivity by shifting the beamsplitter reflectivity and transmission in wavelength. In Section 3.4, this is discussed regarding the radiometric calibration itself, and we believe we will be taking radiometric calibration data close enough in time to the scene data that this effect will be the same in both. In other words,  $T_{a2}=T_{c2}$  to the accuracy required by the beamsplitter effect.

The equation to correct the responsivity for detector temperature is

$$RSP_{x,\lambda,TaV,Ta2}^k = RSP_{x,\lambda,TcV,Tc2}^j \cdot (\mu_{x,\lambda} + \nu_{x,\lambda} \cdot T_{aV} + \pi_{x,\lambda} \cdot T_{aV}^2) / (\mu_{x,\lambda} + \nu_{x,\lambda} \cdot T_{cV} + \pi_{x,\lambda} \cdot T_{cV}^2)$$

for VNIR, where  $(\mu_{x,\lambda} + \nu_{x,\lambda} \cdot T_{aV} + \pi_{x,\lambda} \cdot T_{aV}^2)$  is a model of relative responsivity at each element  $x,\lambda$  as a function of detector temperature  $T_{aV}$ . The quadratic functions are sufficiently accurate over the range of temperatures expected, about 2° C for the VNIR detector. If the temperature ranges are larger, they could be replaced with more descriptive functions, which

would probably be  $(1+\tanh())$  for the VNIR.

The coefficient matrices  $\mu_{x,\lambda}$ ,  $\nu_{x,\lambda}$ , and  $\pi_{x,\lambda}$  are stored as a level 4 calibration data record (CDR) named CDR4#0000000000\_TDrbeeewsS\_v.IMG, where r=frame rate=0, b=binning=0, eee=exposure time parameter, w=wavelength filter, s=0, S=VNIR detector, and v=version number.

For IR, instead of explicitly temperature correcting a single responsivity measurement, we calculate the responsivity twice using two flight sphere calibration measurements, one dayside and one nightside. We then linearly interpolate in IR detector temperature between those two responsivity images to get the temperature-corrected IR responsivity. For IR

$$RSP_{x,\lambda,Ta1,Ta2}^k = ( RSP_{x,\lambda,Tc1,Tc2}^j \cdot ( T_{a1} - T_{fl} ) + RSP_{x,\lambda,Tfl,Tf2}^j \cdot ( T_{c1} - T_{a1} ) ) / ( T_{c1} - T_{fl} )$$

where  $T_{c1}$  and  $T_{fl}$  are the IR detector temperatures for the dayside and nightside sphere calibrations respectively. As of this writing (3/23/2006), IR detector temperature 2 is the sensor used.

## 2.14 Apply binning and detector masks to responsivity

This step is trivial, because we do not expect binning to affect the responsivity. For pixels defined as “scene” pixels in the detector mask CDR, the responsivity of a binned pixel is just the mean of the responsivity of the detector elements in that bin.

Pixels not defined as “scene” pixels in the detector mask CDR have their values replaced by 65535 at this point. This includes dark and scattered light pixels. The number of columns in the responsivity image after this step is 640/binning, where binning is 1, 2, 5, or 10. At this point, we also apply the wavelength table to the responsivity, by simply selecting out the responsivity values at each wavelength present in the table and throwing away the rest. The number of rows in the responsivity image after this step is just the number of active rows in the wavelength table.

The binned responsivity is called  $RSP_{x,\lambda,TaV,Ta1,Ta2,HZ}^l$ .

The detector masks are given in level 4 calibration data records (CDRs) named CDR4#0000000000\_DMrbeeewsn\_v.IMG, where r=frame rate, b=binning, eee=0, w=wavelength filter, s=0, n=detector, and v=version number. Each detector mask consists of an image of 8-bit integers, with the individual bits set equal to 1 for different masks. Bits 0,1,2,3,4,5,6,7 represent no data, scene, dark, dark/scatter transition, scattered light, scatter/scene transition, scene/dark transition, and row 0 respectively. For example, when bit 1 is 1, the pixel is a scene pixel, and when bit 1 is 0, the pixel is not a scene pixel.

The wavelength tables are implicit in the detector masks, because scene pixels in rows that are used have bit 1 set equal to 1 while all pixels in rows that are not used have bit 0 set equal to 1. However, the wavelength tables are also given in the level 6 CDR named CDR6\_0000000000\_WV\_n\_v.TAB, where n=sensor ID and v=version number. In these tables, a 1 indicates the row is used, and a 0 indicates the row is not used.

## 2.15 Calculate scene radiance at instrument aperture and apply detector masks and VNIR flat-fielding

Again this is trivial now that we have gone through all the correction steps. The spectral radiance  $RD_{x,\lambda}^m$  is just the count rate divided by the instrument responsivity. For IR,

$$RD_{x,\lambda}^m = RT_{x,\lambda, \text{TaV, Tal, Ta2, Hz}}^j / RSP_{x,\lambda, \text{TaV, Tal, Ta2, Hz}}^l$$

The units of  $RD_{x,\lambda}^m$  are  $W/(m^2 \text{ micrometer sr})$ .

For VNIR, we also divide the responsivity by a flat field  $FF_{x,\lambda}$ . The flat field is just the image of an external flat field with the scene pixels in each row normalized to average to 1. For VNIR,

$$RD_{x,\lambda}^m = RT_{x,\lambda, \text{TaV, Tal, Ta2, Hz}}^j / ( FF_{x,\lambda} \cdot RSP_{x,\lambda, \text{TaV, Tal, Ta2, Hz}}^l )$$

The flat field  $FF_{x,\lambda}$  for VNIR is given in the flight level 4 calibration data records (CDRs) named CDR4#ttttttttt\_NUrbeeewsS\_v.IMG, where #=spacecraft time SCLK partition at the beginning of validity of the CDR, tttttttt=spacecraft time SCLK at the beginning of validity of the CDR, r=frame rate, b=binning, eee=exposure time parameter, w=wavelength filter, s=0, S=detector (VNIR), and v=version number. Unlike the rest of the flight CDR4s, which are generated automatically by the pipeline software, the NU CDR is generated periodically by the science team, based on averages of images of a featureless area of Mars. The generation of the NU CDRs is described in section 3.3.

The bad pixels given in the bad pixel mask were replaced by interpolated values in section 2.5. However, pixels from the edge of the detector do not correctly represent the scene and are replaced with the value 65535 in this last step. The function  $M_{x,\lambda, \text{Hz}}()$  makes this replacement.

$$RD_{x,\lambda}^n = M_{x,\lambda, \text{Hz}}( RD_{x,\lambda}^m )$$

The detector masks are given in level 4 calibration data records (CDRs) named CDR4#0000000000\_DMrbeeewsn\_v.IMG, where r=frame rate, b=binning, eee=0, w=wavelength filter, s=0, n=detector, and v=version number. Each detector mask consists of an image of 8-bit integers, with the individual bits set equal to 1 for different masks. Bits 0,1,2,3,4,5,6,7 represent no data, scene, dark, dark/scatter transition, scattered light, scatter/scene transition, scene/dark transition, and row 0 respectively. For example, when bit 1 is 1, the pixel is a scene pixel, and when bit 1 is 0, the pixel is not a scene pixel..

In addition, the software will look for saturated pixels in any of the images used to generate the radiance. This includes the scene, dark, bias, and calibration images. Saturated pixels are expected to be extremely rare at this point, because the bad pixel removal algorithm is designed to remove them. Each pixel in the radiance image will be replaced with the value 65535 if the corresponding pixel in at least one of the images used to generate it is found to be saturated.

To find saturated pixels, the calibration software goes back to the unprocessed scene image in the

EDR and looks for the value 4095 for 12-bit images, or 255 for 8-bit images. The search excludes the pixels included in the bad pixel mask for that image. In this part of the search for saturated pixels, only the single frame corresponding to the radiance image is searched, and the other frames in the scene EDR are ignored.

The calibration software also searches the EDRs for every flight image used in the calibration process. Some of these images are explicitly used in the pipeline. Others are inputs to flight level 4 CDR image files. The .LBL label file that describes each .IMG level 4 CDR file includes a keyword SOURCE\_PRODUCT\_ID. The value of this keyword is a list of files that went into the creation of the CDR4 file. If any of the files on the list are EDRs, the software checks them for saturated pixels. If any of the files on the list are flight CDR4s, the software checks **their** SOURCE\_PRODUCT\_ID keyword values recursively for any flight EDRs, and finds all saturated pixels in those flight EDRs. The search excludes the pixels included in the bad pixel mask for the scene image. In this part of the search, typically all the frames in the given EDR are used in the generation of the radiance image, so all the frames in the cube are searched for saturated pixels. That's a lot of frames, but still we typically expect to see no saturated pixels, because they have already been identified in the bad pixel mask.

The radiance  $RD_{x,\lambda}^n$  for each scene image is saved in a targeted radiance data record (TRDR) named CCC#####\_XX\_SCmmmn\_TRRv.TAB, where CCC describes the observation (target mode, multispectral survey or multispectral windows mode, etc.), ##### is the observation ID in hex, XX is the counter within the observation, mmm is the macro ID, n is the detector number 1 or 2, and v is the software version number.

TRDRs are saved in both target mode and mapping mode. The use of the word “targeted” in TRDR has nothing to do with target mode versus mapping mode. Rather, “targeted” in this application is synonymous with “scene”.

In addition to the scene radiance for every image, the TRDR also contains a smaller cube with summary products. The summary products are designed to isolate surface and atmospheric spectral features of scientific interest. Typically, they are formulae based on ratios of radiances in defined wavelength channels, but sometimes they are just the radiance of a given channel. Generally, the atmospheric summary products are calculated directly from the radiance  $RD_{x,\lambda}^m$ , while the surface summary products are calculated from radiances with further atmospheric corrections applied. The summary parameters are beyond the scope of this report, which deals only with generating calibrated radiance images.

The science team will monitor the TRDR files for saturated pixels and adjust the choice of integration time or bad pixel algorithm as necessary.

## **2.16 Measurement uncertainties due to nonrepeatability**

Four sources of nonrepeatability contribute to uncertainty in  $RD_{x,\lambda}^n$ .

(1) Shot noise, from photon-counting statistics in the signal, is given as

$$\sqrt{DN14_{x,\lambda,Ta1,Ta2,TaV,HZ,t}^g \cdot gain} / gain$$

where gain is approximately  $80e^-/DN$  for each detector.

(2) Effective read noise, which contains both read noise, noise due to dark current and thermal background, and effects of any systematic detector noise. This is calculated with each set of dark data

$$Noise_{x,\lambda,HZ} = \sigma( DND14_{m=0\dots mtot,x,\lambda,Td1,Td2,HZ,t} )$$

The  $Noise_{x,\lambda,HZ}$  read noise images are stored as a level 4 calibration data record (CDR) named CDR4#0000000000\_UBrbeeewsn\_v.IMG, where r=frame rate=0, b=binning=0, eee=exposure time parameter, w=wavelength filter, n=detector, and v=version number. A time ordered list of these files is also maintained as a level 6 CDR, named CDR6\_#\_0000000000\_UD\_n\_v.TAB, where n=sensor ID and v=version number.

(3) Variations in throughput of the optics due to differences in the exact position of the shutter and what fraction of the beam of light it occludes. This would be the variations in sphere radiance after the shutter mirror correction has been made as described in section 3.4

(4) Variations in the sphere radiance each time the sphere is measured, as a function of any inaccuracy in the closed loop control system. Again, this is after the corrections for sphere temperature and shutter mirror position described in section 3.4 are made.

Note that all of the errors in the list above are either random errors or some other form of nonrepeatability. Currently, the uncertainty tables do not include any allowance for systematic error such as errors in the calibration of the reference source used on the ground or aging of the sphere lamps over the course of the mission.

Another error term that would be important for zone 3 of the IR spectrometer is error due to subtraction of the 2<sup>nd</sup> order stray light. This would include a random term due to noise in the scene data at the source wavelength, and a systematic term accounting for errors in the ground measurement of the stray light matrix.

## 2.17 Processing from radiance to I/F

The I/F is the ratio of the radiance observed from a surface to that of a perfect white Lambertian surface illuminated by the same light but at normal incidence. The formula is

$$IF_{x,\lambda} = \pi \cdot RD_{x,\lambda}^n / ( SF_{x,\lambda} / r^2 )$$

The solar flux  $SF_{x,\lambda}$  is solar spectral irradiance as seen by a normally illuminated surface 1 AU from the Sun.  $SF_{x,\lambda}$  is evaluated at the wavelengths corresponding to the CRISM spectral calibration and convolved to the CRISM spectral profile functions. The variable r is the distance of Mars from the Sun in AU for that particular observation.

The array  $SF_{x,\lambda}$  is stored as a level 4 calibration data record (CDR) named CDR4#ttttttttt\_SFrbeeewsn\_v.IMG, where #=spacecraft time SCLK partition at the beginning of validity of the CDR, tttttttttt=spacecraft time for start of applicability of the file, r=frame rate, b=binning, eee=exposure time parameter, w=wavelength filter, s=lamp=0, n=detector, and v=version number.

The I/F is not calculated as part of the data pipeline, but it's easy for the user to calculate using the radiance TRDR, the solar spectral irradiance CDR, and r. Users who are performing such analyses will also be interested in incidence and emission angles.

Incidence and emission angles relative to different models of the Martian surface are given in a derived data record (DDR) file that is associated with each TRDR file. The name of the DDR file is CCC#####\_XX\_SCmmmn\_DDRv.TAB, where CCC describes the observation (target mode, mulitspectral survey or multispectral windows mode, etc.), ##### is the observation ID in hex, XX is the counter within the observation, mmm is the macro ID, n is the detector number 1 or 2, and v is the software version number. The variable r is the value of the keyword SOLAR\_DISTANCE in the label file CCC#####\_XX\_SCmmmn\_DDRv.LBL that accompanies each DDR file and describes its contents.

Interpretation of I/F. In optics, we often use BRDF, the ratio of the observed radiance from a surface area to the irradiance incident on that surface area. The quantity  $I/F=BRDF \cdot \pi \cdot \cos\theta$ , where  $\theta$  is the angle of incidence of the light from the Sun on the surface of Mars. The BRDF of a perfect Lambertian surface is a constant  $1/\pi$ , which gives the factor of  $\pi$  at  $\theta=0$ . The factor of  $\cos\theta$  comes from the fact that the solar flux is the energy per unit area per unit time incident on a normally illuminated surface, while the irradiance is the energy per unit area per unit time incident on the actual surface given the incidence angle of the light coming from the Sun. We prefer to leave in the dependence on  $\cos\theta$  rather than dividing it out because  $\theta$  depends on the local topography of the surface, so the user may decide to use different values depending on the preferred model of the local topography. The factor of  $\pi$  makes I/F more intuitive in terms of energy absorbed and reflected. If the surface has some absorption but its reflections are diffuse with a Lambertian distribution, then the value of I/F for normal incidence light at a given wavelength is just the total reflectivity, the total light energy reflected at that wavelength divided by the total light energy incident at that wavelength.

### **3. ADDITIONAL MINI-PIPELINES FOR GENERATING CALIBRATION TABLES FROM FLIGHT CALIBRATION DATA**

#### **3.1 Calculation of IR bias images**

Bias is the DN level extrapolated to zero exposure time, in image form, taken at a particular frame rate. This represents an electronics bias added to the measured signal, to prevent near-zero DNs from going negative (and being clipped) due to superimposed noise. In detector-level testing it was found that bias has a nearly fixed pattern pixel to pixel, but that its magnitude varies weakly with temperature and strongly with frame rate.

In flight, bias for the IR detector is derived from a dedicated calibration, performed periodically, in which, at each frame rate, a burst of 10 images is taken with the shutter closed at each of several short exposure times. These data are taken at IR detector temperature  $T_{bi}$ . After making a correction for a step in the bias that is a function of integration time parameter, the DN values are fit linearly on a pixel-by-pixel basis and the exposure time=0 y-intercept image is used as the bias estimate. Note the cosmic ray correction  $C()$ , described in Section 2.7, is applied to the bias images before  $Bias_{x,\lambda,TbI,TbJ,HZ}$  is calculated from them.

Processing of the bias images  $DNB_{n,x,\lambda,TbI,TbJ,Tb2,HZ,t}$  before bias  $Bias_{x,\lambda,TbI,TbJ,HZ}$  is calculated. See sections 2.2 and 2.7 for details.

$DNB_{m,x,\lambda,TbI,TbJ,Tb2,HZ,t}$  is raw DN after fast lossless compression is undone. The subscript m runs from 0 to 9 and represents image number within a burst of identical images.

Lossy compression will never be used on bias measurements, so there is no 8-bit to 12-bit conversion.

$$\begin{aligned} DNB12_{m,x,\lambda,TbI,TbJ,Tb2,HZ,t} &= DNB_{m,x,\lambda,TbI,TbJ,Tb2,HZ,t} \\ DNB14_{m,x,\lambda,TbI,TbJ,Tb2,HZ,t} &= Offset_{\lambda} + Gain_{\lambda} \cdot DNB12_{m,x,\lambda,TbI,TbJ,Tb2,HZ,t} \\ DNB14^a_{x,\lambda,TbI,TbJ,Tb2,HZ,t} &= C_{all} ( DNB14_{m,x,\lambda,TbI,TbJ,Tb2,HZ,t} ) \end{aligned}$$

The function  $C()$  is the cosmic ray removal algorithm (see section 2.5). The bias images in a single burst are averaged as part of that algorithm.

At a single frame rate, each pixel of the set of bias images at different integration rates are fit to the following equation.

$$DNB14^a_{x,\lambda,TbI,TbJ,Tb2,HZ,t} = c0_{x,\lambda,TbI,TbJ,HZ} + c1_{x,\lambda,TbI,Tb2,HZ} \cdot t - a0_1 \cdot Hv(row_{\lambda}+1-(502/480)) \cdot (480-integ(t))$$

Note that  $c0$  corresponds to the bias for that frame rate, and  $c1 \cdot t$  corresponds to the background signal for that frame rate. The third term is a step function resulting from details of the readout of the image in the electronics. It is entirely predetermined. The constant  $a0$  is determined from ground calibration data,  $Hv()$  is the Heaviside function, and  $integ_t$  is the integration parameter. The value of  $t$  in ms is calculated from the integration time parameter  $integ$  using the formula  $t = 1000 \cdot ( 502 - floor((502/480) \cdot (480-integ)) / (502 \cdot rate) )$ , where  $floor()$  is a function that creates an integer from a real number by rounding down.

To calculate  $c0$  and  $c1$ , DNB is corrected for the third term and a linear fit is performed for each pixel. The fit is  $y=mx+b$ , where  $y = DNB14^a_{x,\lambda,TbI,TbJ,Tb2,HZ,t} + a0_1 \cdot Hv(row_{\lambda}+1-(502/480)) \cdot (480-integ(t))$ ,  $m = c1$ ,  $x = t$ , and  $b = c0$ . Then,

$$Bias_{x,\lambda,TbI,TbJ,HZ} = c0_{x,\lambda,TbI,TbJ,HZ}$$

Bias images  $Bias_{x,\lambda,TbI,TbJ,HZ}$  are stored as level 4 calibration data records (CDRs) named

CDR4#ttttttttt\_BIrbeeewsL\_v.IMG, where #=spacecraft time SCLK partition at the beginning of validity of the CDR, tttttttt=spacecraft time SCLK at the beginning of validity of the CDR, r=frame rate, b=binning, eee=exposure time parameter, w=wavelength filter, s=0, L=detector (IR), and v=version number. The tttttttt=spacecraft time SCLK at the beginning of validity of the CDR tells the software which bias measurement to use for a given scene measurement. The calibration software uses the CDR4 file with the largest value of tttttttt that is smaller than the value of SCLK for the scene measurement.

The constants  $a_{0I}$  for IR and  $a_{0V}$  for VNIR are calculated from ground calibration data and given in the level 6 CDR named CDR6\_#\_0000000000\_BS\_n\_v.TAB, where #=spacecraft time SCLK partition at the beginning time of validity of the CDR, 0000000000=spacecraft time SCLK at the beginning time of validity of the CDR, n=detector, and v=version number.

### 3.2 Mini-pipeline for IR background and VNIR bias images (darks)

Shutter-closed images (darks) are taken with every scene and calibration measurement to subtract instrumental background. They are taken at the same set of frame rates, integration times, wavelength tables, and binning as the associated scene or calibration measurement. For the VNIR, there is no dark current or IR thermal background and this represents just detector bias, the DN level at zero integration time. For the IR, the bias is subtracted separately so that the nonlinearity correction may be applied before the dark current and IR thermal background subtraction. The shutter-closed images are then used in the IR background subtraction step.

Pipeline for VNIR darks:

$DND_{m,x,\lambda,TdV,Hz,t}$  is raw DN after fast lossless compression is undone. The subscript m represents image number within a burst of identical images. The subscript d on the temperatures indicates temperatures for the dark image taken before the scene image. The pipeline is exactly the same for the dark image taken after the scene image, which is given the subscript e in the main pipeline.

Lossy compression will never be used on dark measurements, so there is no 8-bit to 12-bit conversion.

$$DND12_{m,x,\lambda,TdV,TdW,Hz,t} = DND_{m,x,\lambda,TdV,TdW,Hz,t}$$

$$DND14_{m,x,\lambda,TdV,TdW,Hz,t} = \text{Offset}_{\lambda} + \text{Gain}_{\lambda} \cdot DND12_{m,x,\lambda,TdV,TdW,Hz,t}$$

$$\text{Bias}_{x,\lambda,TdV,TdW,Hz,t} = C_{\text{all}} ( B_{x,\lambda,Hz} ( DND14_{m,x,\lambda,TdV,TdW,Hz,t} ) )$$

VNIR bias images will have to be binned in ground processing for use with scene images that are EPFs and have 10x binning at 3.75 Hz.

The function C() is the cosmic ray removal algorithm (see section 2.5), the function B() is the bad pixel removal algorithm (see section 2.7), and DND14 is the 14-bit DN for the dark images. The images within the burst are averaged as part of the cosmic ray removal algorithm, so the subscript m disappears at that point. The dark image taken before has VNIR detector temperature  $T_{dV}$ , and the dark image taken after has VNIR detector temperature  $T_{eV}$ .

The VNIR bias images  $\text{Bias}_{x,\lambda,TdV,TdW,HZ,t}$  are stored as level 4 calibration data records (CDRs) named  $\text{CDR4\#tttttttt\_BkrbeeewsS\_v.IMG}$ , where  $\#$ =spacecraft time SCLK partition at the beginning of validity of the CDR,  $\text{tttttttt}$ =spacecraft time SCLK at the beginning of validity of the CDR,  $r$ =frame rate,  $b$ =binning,  $eee$ =exposure time parameter,  $w$ =wavelength filter,  $s=0$ ,  $S$ =detector (VNIR), and  $v$ =version number. The calibration software uses the CDR4 file with the largest value of  $\text{tttttttt}$  that is smaller than the value of SCLK for the scene measurement.

Pipeline for IR darks:

$\text{DND}_{m,x,\lambda,TdI,TdJ,Td2,HZ,t}$  is raw DN after fast lossless compression is undone. The subscript  $m$  represents image number within a burst of identical images. The subscript  $d$  on the temperatures indicates temperatures for the dark image taken before the scene image. The pipeline is exactly the same for the dark image taken after the scene image, which is given the subscript  $e$  in the main pipeline.

Lossy compression will never be used on dark measurements, so there is no 8-bit to 12-bit conversion.

$$\begin{aligned} \text{DND12}_{m,x,\lambda,TdI,TdJ,Td2,HZ,t} &= \text{DND}_{m,x,\lambda,TdI,TdJ,Td2,HZ,t} \\ \text{DND14}_{m,x,\lambda,TdI,TdJ,Td2,HZ,t} &= \text{Offset}_{\lambda} + \text{Gain}_{\lambda} \cdot \text{DND12}_{m,x,\lambda,TdI,TdJ,Td2,HZ,t} \\ \text{DND14}^a_{m,x,\lambda,TdI,Td2,HZ,t} &= \text{DND14}_{m,x,\lambda,TdI,TdJ,Td2,HZ,t} - \text{Bias}_{x,\lambda,TbI,TbJ,HZ} \\ &\quad + a_{0I} \cdot \text{Hv}(\text{row}_{\lambda} + 1 - (502/480) \cdot (480 - \text{integ}(t))) - \beta_{I,HZ} \cdot (T_{dI} - T_{bI}) - \beta_{J,HZ} \cdot (T_{dJ} - T_{bJ}) \\ \text{DND14}^b_{m,x,\lambda,TdI,Td2,HZ,t} &= \text{DND14}^a_{m,x,\lambda,TdI,Td2,HZ,t} - \sum_{n=0}^{n=3} G_I(\text{DND14}^a_{m,x_0+n \cdot \delta_{\lambda},TdI,Td2,HZ,t}) \\ \text{DND14}^c_{m,x,\lambda,TdI,Td2,HZ,t} &= \\ &\quad S(\text{DND14}^b_{m,x,\lambda,TdI,Td2,HZ,t}, \text{DND14}^a_{m,x,\lambda,TdI,Td2,HZ,t}, \text{DND}_{m,x,\lambda,TdI,TdJ,Td2,HZ,t}) \\ \text{DND14}^d_{m,x,\lambda,TdI,Td2,HZ,t} &= B_{x,\lambda,HZ}(\text{DND14}^c_{m,x,\lambda,TdI,Td2,HZ,t}) \\ \text{DND14}_{x,\lambda,TdI,Td2,HZ,t} &= C_{\text{all}}(\text{DND14}^d_{m,x,\lambda,TdI,Td2,HZ,t}) \\ \text{DND14}^g_{x,\lambda,TdI,Td2,HZ,t} &= \text{DND14}^e_{x,\lambda,TdI,Td2,HZ,t} / (\epsilon_{HZ} \cdot \log(\text{DND14}^e_{x,\lambda,TdI,Td2,HZ,t}) + \phi_{HZ}) \\ \text{RTD14}^g_{x,\lambda,TdI,Td2,HZ,t} &= \text{DND14}^g_{x,\lambda,TdI,Td2,HZ,t} / t \end{aligned}$$

IR darks will have to be binned in ground processing for use with scene images that are EPFs and have 10x binning at a given frame rate 3.75 Hz.

The steps above follow the steps of correcting the scene images up to the point of the IR background subtraction. Those steps are described in sections 2.2-2.9.

Background images  $\text{DND14}^g_{x,\lambda,TdI,Td2,HZ,t}$  are stored as level 4 calibration data records (CDRs) named  $\text{CDR4\#tttttttt\_BkrbeeewsL\_v.IMG}$ , where  $\#$ =spacecraft time SCLK partition at the beginning of validity of the CDR,  $\text{tttttttt}$ =spacecraft time SCLK at the beginning of validity of the CDR,  $r$ =frame rate,  $b$ =binning,  $eee$ =exposure time parameter,  $w$ =wavelength filter,  $s=0$ ,  $L$ =detector (IR), and  $v$ =version number. The integration time  $t$ , used to calculate  $\text{RTD14}^g_{x,\lambda,TdI,Td2,HZ,t}$  from  $\text{DND14}^g_{x,\lambda,TdI,Td2,HZ,t}$ , may be calculated from the integration time parameter in the label file  $\text{CDR4\#tttttttt\_BkrbeeewsL\_v.LBL}$  that goes with the .IMG file

containing the  $DND14_{x,\lambda,Td1,Td2,HZ,t}^g$  images.

The IR background rate  $RTD14_{x,\lambda,Td1,Td2,HZ,t}^g$  is an input to section 2.10 of the main pipeline, where the dark images are interpolated to the time of the scene or calibration measurement.

### 3.3 Generation of the flat fields for VNIR

The VNIR flat field  $FF_{x,\lambda}$  is just an average of many images of a featureless region of Mars, with the scene pixels in each row normalized so they average to 1. The EDRs are sent through the entire calibration pipeline to make radiance images, and then averaged. A slight correction has to be made to the averaged images to account for the fact that the featureless scene spectral radiance varies with wavelength and the spectrometer has smile. Then, each row is normalized so that the scene pixels in that row average to 1.

The flat field  $FF_{x,\lambda}$  for VNIR is given in the flight level 4 calibration data records (CDRs) named  $CDR4\#\text{tttttttt\_NurbeewsS\_v.IMG}$ , where  $\#$ =spacecraft time SCLK partition at the beginning of validity of the CDR,  $\text{tttttttt}$ =spacecraft time SCLK at the beginning of validity of the CDR,  $r$ =frame rate,  $b$ =binning,  $eee$ =exposure time parameter,  $w$ =wavelength filter,  $s=0$ ,  $S$ =detector (VNIR), and  $v$ =version number. Unlike the rest of the flight CDR4s, which are generated automatically by the pipeline software, the NU CDR is generated periodically by the science team, based on averages of images of a featureless area of Mars.

### 3.4 Calculating sphere radiance including sphere temperature and shutter mirror position

The sphere radiance was measured in ground calibration with respect to known external sources. The most useful ones were a Spectralon plate illuminated by a NIST standard lamp and a cavity radiation source imaged through a collimator. The sphere radiance measured on the ground is then corrected to a value appropriate for a given calibration source measurement in flight. There are two corrections currently planned:

1. A correction for the temperature of the integrating sphere in flight. The current in the sphere is controlled by a silicon photodiode through a closed loop. The long-wavelength edge of the sensitivity of that photodiode is temperature-dependent, which causes the lamp current and sphere output to be temperature-dependent. From the ground calibration data, we have images taken at different sphere temperatures and we can estimate this effect. This also corrects for variations in the thermal emission of the sphere, which may have a small effect at long wavelengths. In addition, the temperature of the beamsplitter tracks the temperature of the optical bench to some extent, and the temperature of the optical bench tracks the temperature of the integrating sphere. As an unintended side effect, the correction of the sphere radiance for the integrating sphere temperature will also give a partial correction for any dependence of the instrument response on the beamsplitter temperature.
2. A correction for the exact angle of the shutter mirror for the sphere measurement in flight. The shadow of the mask at the boundary of the VNIR order-sorting filter is

compared between the flight measurement and the ground measurement, and a correction is made to the ground radiance to give the radiance expected for that flight measurement. This correction changes every time the shutter mirror is moved.

It is possible that other effects such as the temperature of the focal plane board controlling the sphere lamp have an effect on sphere radiance, but as of this writing (10/19/2005) we have not yet investigated the repeatability of the sphere images with changes in the temperature of the focal plane boards.

First, the calculation of sphere radiance at the temperature of the flight sphere images.

The ground measured sphere radiance as a function of temperature is found in level 4 calibration data record CDR4#ttttttttt\_SSrbeeewsn\_v.IMG, where #=spacecraft time SCLK partition at the beginning of validity of the CDR, tttttttt=spacecraft time, r=frame rate=0, b=binning, eee=exposure time parameter, w=wavelength filter, s=1 or 2 depending on whether side 1 (IRFPE-controlled, cross-slit) or 2 (VNIRFPE-controlled, along-slit) lamp is used, n=detector, and v=version number. It consists of 3 images that are polynomial coefficients for the sphere radiance at each pixel as a function of temperature in degrees C. The sphere radiance is

$$\theta_{s,x,\lambda} + \sigma_{s,x,\lambda} \cdot T_{c3} + \tau_{s,x,\lambda} \cdot T_{c3}^2$$

The units of sphere radiance are W/(m<sup>2</sup> micrometer sr).

Second, the correction of the sphere radiance for shutter mirror position nonrepeatability.

Rows 223-247 of the VNIR sphere images have DN levels sensitive to the shutter mirror position because they are on the edges of the VNIR filter zone boundary mask, and the shadow of the mask moves with the shutter mirror. The mirror parameter MP<sub>s</sub>, a single value for each set of calibration images taken without moving the shutter mirror, measures the microscopic difference between the shutter mirror angle for the flight radiance calibration and the ground radiance calibration. A different definition of MP<sub>s</sub> is used for s=1 (IRFPE controlled, cross-slit lamp) and s=2 (VNIRFPE-controlled, along-slit lamp).

$$MP_1 = \sum_{s=1, x=0 \dots 639, \lambda=232 \dots 234, T_{c3}} RTS14^j / RGSB^j_{s=1, T_{c3}} - \sum_{s=1, x=0 \dots 639, \lambda=223 \dots 225, T_{c3}} RTS14^j / RGSB^j_{s=1, T_{c3}}$$

$$MP_2 = \sum_{s=2, x=0 \dots 639, \lambda=235 \dots 237, T_{c3}} RTS14^j / RGSB^j_{s=2, T_{c3}} - \sum_{s=2, x=0 \dots 639, \lambda=245 \dots 247, T_{c3}} RTS14^j / RGSB^j_{s=2, T_{c3}}$$

with

$$RGSB^j_{s=1, T_{c3}} = \sum_{x=0 \dots 639, \lambda=232 \dots 234} RGS14^j_{s=1, x, \lambda, T_g V, T_g 3} \cdot (\theta_{s=1, x, \lambda} + \sigma_{s=1, x, \lambda} \cdot T_{c3} + \tau_{s=1, x, \lambda} \cdot T_{c3}^2) / (\theta_{s=1, x, \lambda} + \sigma_{s=1, x, \lambda} \cdot T_{g3} + \tau_{s=1, x, \lambda} \cdot T_{g3}^2)$$

$$RGSB^j_{s=2, T_{c3}} = \sum_{x=0 \dots 639, \lambda=235 \dots 237} RGS14^j_{s=2, x, \lambda, T_g V, T_g 3} \cdot (\theta_{s=2, x, \lambda} + \sigma_{s=2, x, \lambda} \cdot T_{c3} + \tau_{s=2, x, \lambda} \cdot T_{c3}^2) / (\theta_{s=2, x, \lambda} + \sigma_{s=2, x, \lambda} \cdot T_{g3} + \tau_{s=2, x, \lambda} \cdot T_{g3}^2)$$

$$\begin{aligned}
\text{RGSB}_{s=2, \text{Tc}3}^j &= \sum_{x=0 \dots 639, \lambda=235 \dots 237} \text{RGS14}_{s=2, x, \lambda, \text{TgV}, \text{Tg}3}^j \cdot (\theta_{s=2, x, \lambda} + \sigma_{s=2, x, \lambda} \cdot \text{T}_{c3} + \tau_{s=2, x, \lambda} \cdot \text{T}_{c3}^2) / \\
&(\theta_{s=2, x, \lambda} + \sigma_{s=2, x, \lambda} \cdot \text{T}_{g3} + \tau_{s=2, x, \lambda} \cdot \text{T}_{g3}^2) \\
\text{RGSA}_{s=2, \text{Tc}3}^j &= \sum_{x=0 \dots 639, \lambda=245 \dots 247} \text{RGS14}_{s=2, x, \lambda, \text{TgV}, \text{Tg}3}^j \cdot (\theta_{s=2, x, \lambda} + \sigma_{s=2, x, \lambda} \cdot \text{T}_{c3} + \tau_{s=2, x, \lambda} \cdot \text{T}_{c3}^2) / \\
&(\theta_{s=2, x, \lambda} + \sigma_{s=2, x, \lambda} \cdot \text{T}_{g3} + \tau_{s=2, x, \lambda} \cdot \text{T}_{g3}^2)
\end{aligned}$$

RTS14 is count rate observed with the onboard sphere as a source, and RGSA, RGSB are the total count rates from sample rows in a given column of the ground data from which the sphere radiance CDR is derived, corrected from  $\text{T}_{g3}$ , the integrating sphere temperature for the ground calibration, to  $\text{T}_{c3}$ , the integrating sphere temperature for the flight calibration. Rows 223-247 of the VNIR have responsivity insensitive to detector temperature, so RTS14, RGSA, and RGSB are not functions of  $\text{T}_{cV}$  or  $\text{T}_{gV}$ .  $\text{RTS14}^j$  and  $\text{RGS14}^j$  have the full set of corrections for bias, detector ghosts, bad pixel and cosmic ray removal, detector nonlinearity, background subtraction, and stray light subtraction. A detailed description of these corrections is given in section 3.5, and also in the main data pipeline in sections 2.2 to 2.12.

$\text{RGS14}_{s, x, \lambda, \text{TgV}, \text{Tg}3}^j$  is the count rate for the ground sphere radiance measurement. It is calculated from  $\text{DGS14}_{s, x, \lambda, \text{TgV}, \text{Tg}3, t}^j$ , the counts in the ground sphere radiance measurement, using the equation  $\text{RGS14}_{s, x, \lambda, \text{TgV}, \text{Tg}3}^j = \text{DGS14}_{s, x, \lambda, \text{TgV}, \text{Tg}3, t}^j / t$ . The counts  $\text{DGS14}_{s, x, \lambda, \text{TgV}, \text{Tg}3, t}^j$  are given in the level 4 calibration data record `CDR4#ttttttttt_SHrbeeewsn_v.IMG` described at the end of this chapter. The integration time  $t$  for the ground measurement may be calculated from the integration time parameter for the ground measurement, which is given in the label file `CDR4#ttttttttt_SHrbeeewsn_v.LBL`. The integrating sphere temperature  $\text{T}_{g3}$  for the ground measurement is also given in the label file `CDR4#ttttttttt_SHrbeeewsn_v.LBL`.

The movement of the shutter mirror causes the signal to increase in one set of rows and decrease in the other. Subtracting the ratios in the two sets of rows makes the parameter  $\text{MP}_s$  insensitive to small changes in the brightness of the sphere lamps.  $\text{MP}_s$  is derived from just the VNIR image, but it is used to correct both VNIR and IR images.

The formula for sphere radiance  $\text{SR}_{s, x, \lambda, \text{Tc}3}$  including the shutter mirror nonrepeatability correction simply comes from the assumption that the correction is linearly dependent on the shutter movement parameter  $\text{MP}_s$ . This should be a good assumption if the correction is small, and in ground data it appears to be 5% or less so far.

$$\text{SR}_{s, x, \lambda, \text{Tc}3} = (\theta_{s, x, \lambda} + \sigma_{s, x, \lambda} \cdot \text{T}_{c3} + \tau_{s, x, \lambda} \cdot \text{T}_{c3}^2) / (1 + \text{MP}_s \cdot \text{SC}_{s, x, \lambda})$$

The shutter correction  $\text{SC}_{s, x, \lambda}$  image is derived by taking ratios of images, subtracting 1, and dividing by the value of  $\text{MP}_s$  for each image ratio. This may be done with ground or flight images, and the correction is proven valid by the fact that the correction image thus derived is pretty much the same for all image pairs for which the shutter mirror has moved enough that the correction is significant. In practice,  $\text{SC}_{s, x, \lambda}$  is an average of values calculated from multiple ground images. Note: the images ratioed to calculate  $\text{SC}_{s, x, \lambda}$  as part of the analysis of the ground calibration data not only have all the data pipeline corrections from sections 2.2 to 2.12, but also are corrected for the detector temperature as described in section 2.13, a later step. This is just a detail of how the relevant ground CDR4 is generated, and it does not affect the flight data pipeline.

MPs itself will depend on which sphere lamp is used, but the correction for shutter mirror position should be the same for either sphere lamp if the mirror is not moved between one sphere lamp measurement and the other.

The shutter correction image  $SC_{s,x,\lambda}$  is kept in layer 1 of the level 4 calibration data record CDR4#ttttttttt\_SHrbeeewsn\_v.IMG, where #=spacecraft time SCLK partition at the beginning of validity of the CDR, tttttttt=spacecraft time, r=frame rate=0, b=binning=0, eee=exposure time parameter, w=wavelength filter=0, s=1 or 2 depending on whether side 1 (IRFPE-controlled, cross-slit) or 2 (VNIRFPE-controlled, along-slit) lamp is used, n=detector, and v=version number. The image  $DGS14^j_{s,x,\lambda,TgV,Tg3,t}$  is kept in layer 0 of the level 4 calibration data record CDR4#ttttttttt\_SHrbeeewsn\_v.IMG, where #=spacecraft time SCLK partition at the beginning of validity of the CDR, tttttttt=spacecraft time, r=frame rate=0, b=binning=0, eee=exposure time parameter, w=wavelength filter=0, s=1 or 2 depending on whether side 1 (IRFPE-controlled, cross-slit) or 2 (VNIRFPE-controlled, along-slit) lamp is used, n=detector, and v=version number. The image  $DGS14^j_{s,x,\lambda,TgV,Tg3,t}$  is simply the counts for the VNIR ground sphere radiance measurement, converted to 14-bits and with all corrections applied that are applied to the RT<sup>j</sup> flight data except the division by integration time t is not applied. The counts from the VNIR ground sphere radiance measurement are necessary in order to calculate the shutter movement parameter  $MP_s$  from the flight VNIR calibration image. That calculation also requires the sphere temperature  $T_{g3}$  for the ground sphere radiance measurement.  $T_{g3}$  is listed in the label file CDR4#ttttttttt\_SHrbeeewsn\_v.LBL. The integration time parameter is listed in the label file CDR4#ttttttttt\_SHrbeeewsn\_v.LBL, and the integration time t may be calculated from the integration time parameter.

### 3.5 Calculation of instrument responsivity from sphere radiance

Responsivity as a function of wavelength results from three effects:

- The instrument design including telescope design, optical efficiency, and detector performance.
- Variations in detector responsivity as a function of detector temperature. The main effects are a shift in the long wavelength edge for the VNIR detector, and a movement in the interference fringes that appear on the long wavelength end of the IR detector.
- Accumulation of absorbing contaminants on optical surface. The major expected contaminant is water ice on the detector.

CRISM's responsivity is tracked in flight using the internal integrating sphere, run under closed loop control, using either bulb. This provides a field- and aperture-filling source with stable radiance. The current plan is to take sphere calibration measurements with one lamp within a few minutes of every scene measurement, and take calibration measurements with the other lamp once a month to check the first lamp. The sphere calibration may also be checked with images from Diemos when available.

The calculation of sphere radiance  $SR_{s,x,\lambda,Tc3}$  is described in Section 3.4, including the correction for shutter mirror position.

The pipeline processing for the onboard integrating sphere images before they are used to calculate the responsivity.

$DNS_{m,s,x,\lambda,TcV,TcI,Tc2,Tc3,t}$  is raw DN after fast lossless compression is undone. The subscript m represents image number within a burst of identical images. The subscript s represents choice of sphere lamp, 1 or 2. The subscript c on the temperatures indicates temperatures for the calibration images. Note the sphere radiance depends on the sphere temperature Tc3, so there's an implicit dependence of DNS on Tc3 that is shown. Also, all sphere images are taken at 1 Hz with no binning and the largest wavelength tables, so the Hz subscript is omitted. The results are binned and the wavelength tables applied in section 2.14 of the main pipeline.

Lossy compression will never be used on sphere measurements, so there is no 8-bit to 12-bit conversion.

$$\begin{aligned} DNS12_{m,s,x,\lambda,TcV,TcW,TcI,TcJ,Tc2,Tc3,t} &= DNS_{m,s,x,\lambda,TcV,TcW,TcI,TcJ,Tc2,Tc3,t} \\ DNS14_{m,s,x,\lambda,TcV,TcW,TcI,TcJ,Tc2,Tc3,t} &= Offset_{\lambda} + Gain_{\lambda} \cdot DNS12_{m,s,Lx,\lambda,TcV,TcW,TcI,TcJ,Tc2,Tc3,t} \\ DNS14^a_{m,s,x,\lambda,TcI,Tc2,Tc3,t} &= DNS14_{m,s,x,\lambda,TcI,TcJ,Tc2,Tc3,t} - Bias_{x,\lambda,TbI,TbJ,Hz=1} \\ &+ a0_I \cdot Hv(row_{\lambda}+1-(502/480) \cdot (480-integ(t))) - \beta_{I,Hz=1} \cdot (T_{cI} - T_{bI}) - \beta_{J,Hz=1} \cdot (T_{cJ} - T_{bJ}) \end{aligned}$$

for the IR and

$$\begin{aligned} DNS14^a_{m,s,x,\lambda,TcV,t} &= DNS14_{m,s,x,\lambda,TcV,TcW,t} - ( \alpha_{ec} \cdot Bias_{x,\lambda,TdV,TdW,t} + \alpha_{cd} \cdot Bias_{x,\lambda,TcV,TcW,t} ) / \\ &(\alpha_{cd} + \alpha_{ec}) \\ &- \beta_{V,Hz=1} \cdot [ \alpha_{ec} \cdot (T_{cV} - T_{dV}) + \alpha_{cd} \cdot (T_{eV} - T_{cV}) ] / (\alpha_{cd} + \alpha_{ec}) \\ &- \beta_{W,Hz=1} \cdot [ \alpha_{ec} \cdot (T_{cW} - T_{dW}) + \alpha_{cd} \cdot (T_{eW} - T_{cW}) ] / (\alpha_{cd} + \alpha_{ec}) \text{ for VNIR.} \\ DNS14^b_{m,s,x,\lambda,TcV,t} &= DNS14^a_{m,s,x,\lambda,TcV,t} - \sum_{n=0}^{n=3} G_V(DNS14^a_{m,s,x0+n \cdot \delta,\lambda,TcV,t}) \text{ for VNIR and} \\ DNS14^b_{m,s,x,\lambda,TcI,Tc2,Tc3,t} &= DNS14^a_{m,s,x,\lambda,TcI,Tc2,Tc3,t} - \sum_{n=0}^{n=3} G_I(DNS14^a_{m,s,x0+n \cdot \delta,\lambda,TcI,Tc2,Tc3,t}) \text{ for IR} \\ DNS14^c_{m,x,\lambda,TcV,TcI,Tc2,Tc3,t} &= \\ &S( DNS14^b_{m,x,\lambda,TcV,TcI,Tc2,Tc3,t}, DNS14^a_{m,x,\lambda,TcV,TcI,Tc2,Tc3,t}, DNS_{m,x,\lambda,TcV,TcW,TcI,TcJ,Tc2,Tc3,t} ) \\ DNS14^d_{m,s,x,\lambda,TcV,TcI,Tc2,Tc3,t} &= B_{x,\lambda,Hz}( DNS14^c_{m,s,x,\lambda,TcV,TcI,Tc2,Tc3,t} ) \\ DNS14^e_{s,x,\lambda,TcV,TcI,Tc2,Tc3,t} &= C_{all}( DNS14^d_{m,s,x,\lambda,TcV,TcI,Tc2,Tc3,t} ) \\ DNS14^g_{s,x,\lambda,TcI,Tc2,Tc3,Taf,t} &= DNS14^e_{s,x,\lambda,TcI,Tc2,Tc3,TcV,t} / ( \epsilon_{Hz} \cdot \log(DNS14^e_{s,x,\lambda,TcI,Tc2,Tc3,TcV,t}) + \phi_{Hz} ) \\ RTS14^g_{s,x,\lambda,TcI,Tc2,Tc3,TcV} &= DNS14^g_{s,x,\lambda,TcI,Tc2,Tc3,TcV,t} / t \\ RTS14^h_{s,x,\lambda,TcI,Tc2,Tc3} &= RTS14^g_{s,x,\lambda,TcI,Tc2,Tc3,tal} - Bkgd_{x,\lambda,TdI,TcI,Td2,Tc2,tal,td1,te1} \text{ for IR and} \\ RTS14^h_{s,x,\lambda,TcV,Tc3} &= RTS14^g_{s,x,\lambda,TcV,Tc3} \text{ for VNIR} \\ RTS14^i_{s,x,\lambda,TcV,TcI,Tc2,Tc3,Hz} &= RTS14^h_{s,x,\lambda,TcV,TcI,Tc2,Tc3} - \langle RTS14^h_{s,x1 \dots xn,\lambda,TcV,TcI,Tc2,Tc3} \rangle \\ RTS14^i_{s,x,\lambda,TcI,Tc2,Tc3} &= RTS14^i_{s,x,\lambda,TcI,Tc2,Tc3} - \sum_{n=1}^{n=4} \kappa_{x,\lambda,n,Hz} \cdot RTS14^i_{s,x,\lambda,=yx\lambda nHz,TcI,Tc2,Tc3} \text{ for IR and} \\ RTS14^i_{s,x,\lambda,TcV,Tc3} &= RTS14^i_{s,x,\lambda,TcV,Tc3} \\ &\text{for VNIR} \end{aligned}$$

The steps above follow the steps of correcting the scene images up to the point of the subtraction of second-order stray light. Those steps are described in sections 2.2 to 2.12. The images in a

single burst are averaged as part of the cosmic ray removal algorithm.

There will probably be some TBD additional processing to sphere images for VNIR short wavelengths only (<500 nm), where the sphere images are very dim. This could involve spatial averaging or temporal averaging. One might even average temporally over a very long time and assume the response in this spectral region doesn't change with time. The choice will depend on the results for VNIR detector response after the stray light correction is applied, which will tell us the true VNIR counts at short wavelength.

The sphere count rate images  $RTS14^j_{s,x,\lambda,Tc1,Tc2,Tc3}$  are written to level 4 calibration data records (CDRs) named CDR4#ttttttttt\_SPRbeeewsn\_v.IMG, where #=spacecraft time SCLK partition at the beginning of validity of the CDR, tttttttt=spacecraft time SCLK at the beginning of validity of the CDR, r=frame rate, b=binning, eee=exposure time parameter, w=wavelength filter, s=0, n=detector, and v=version number.

The calculation of responsivity  $RSP^j_{x,\lambda,Tc1,Tc2}$  is then very simple. It's just counts/radiance.

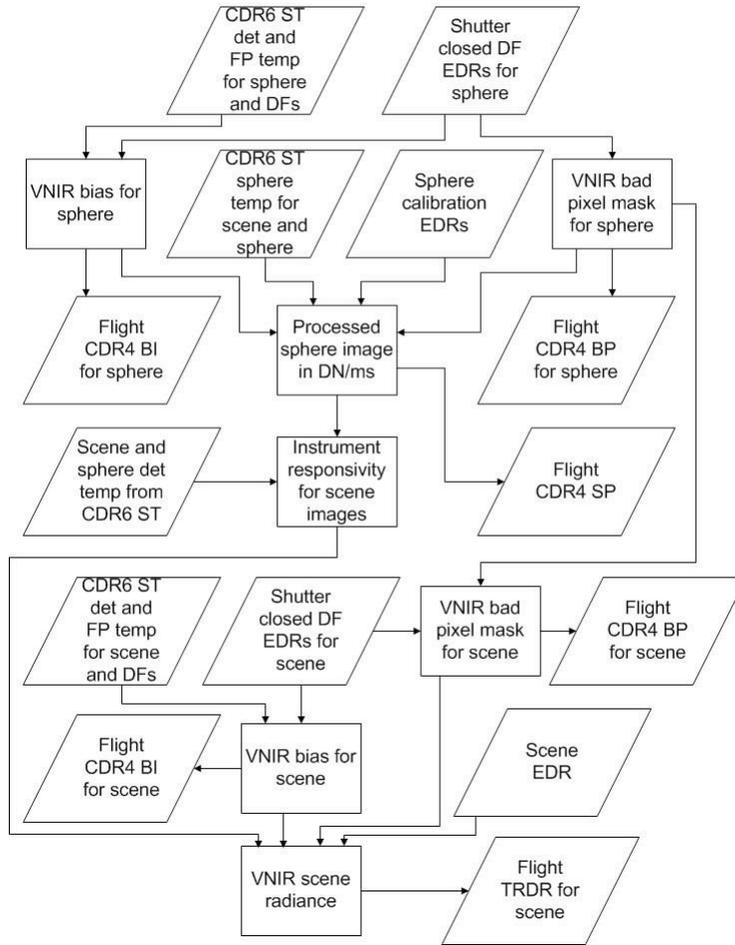
$$RSP^j_{x,\lambda,Tc1,Tc2} = RTS14^j_{s,x,\lambda,TcV,Tc1,Tc2,Tc3} / SR_{s,x,\lambda,Tc3}$$

The corrections to the responsivity for detector temperature are made in the main data pipeline in section 2.13. The responsivity is not saved as a calibration data record. It is calculated each time from the flight sphere images and the ground sphere radiance. Normally, the responsivity is calculated using data from the primary sphere lamp, which is s=2 (the VNIRFPE-controlled, cross-slit lamp) as of 10/28/2005. Measurements with the secondary lamp are taken during monthly engineering checkouts. The responsivity should be the same calculated with either lamp, and this is a useful in-flight check on the accuracy of the onboard calibration system. The units of responsivity are DN/ms/(W/(m<sup>2</sup> micrometer sr)).

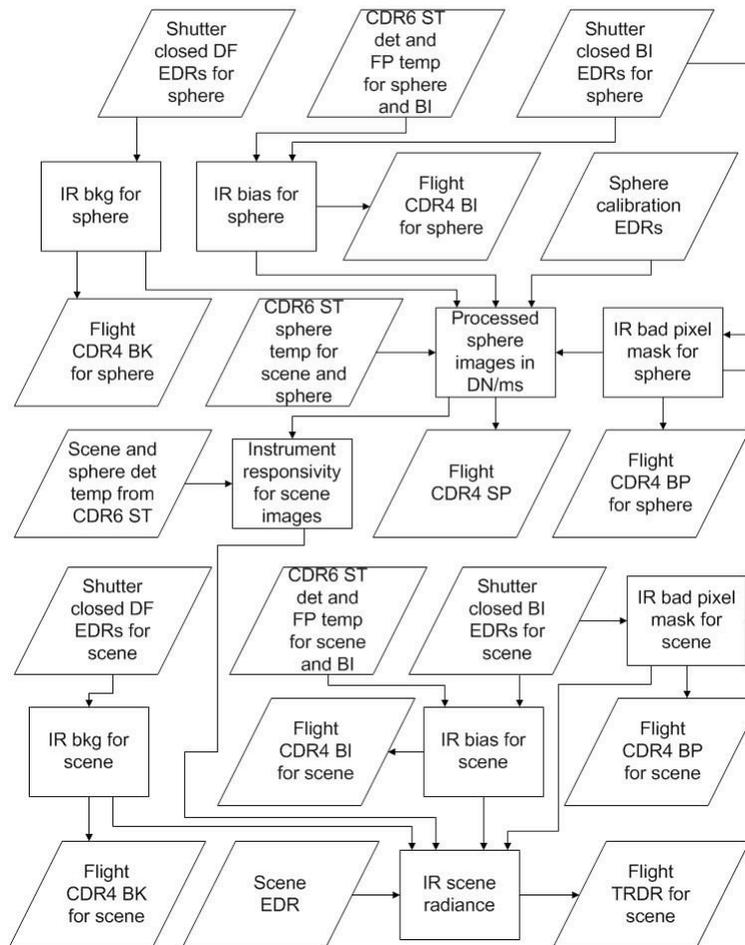
## 4. IMPLEMENTATION IN PIPE

### 4.1 Data flow of flight calibration and scene EDRs to flight CDR4s and TRDRs

# VNIR



## IR



### 4.2 Logic for choosing specific flight calibration EDRs to use with a given scene EDR

The ATF table is a special CDR used to list the calibration EDRs to be used to calibrate each scene EDR. It is located in the `crism_pds_archive/edr/CDR/yyyy_doy/ATF` directory of the PDS archive. The first column of the ATF table lists every scene EDR with `START_TIME` in that day. The remaining columns of each row list the calibration EDRs to use for the scene EDR given in the first column of that row. The ATF table consists only of EDRs that have actually been received. These are the ones used in calibration. There is a similar BTF table that gives the calibration EDRs that were planned for use with each scene EDR. The BTF table is generated for comparison with the ATF table, in case some of the calibration EDRs are not downlinked and the algorithm was forced to use a substitute.

### VNIR

There are 2 types of calibration EDRs to be searched for, the shutter-closed DFs (for VNIR these are for the bias calculation) and the sphere calibration SP EDRs. The SP EDRs have their own

DFs for calculating the bias for sphere measurements.

Note that any downlinked EDRs with a “UN” macro descriptor in the filename should be rejected as calibration EDRs. This will filter out any problem EDRs caused when the instrument occasionally reverts back to default state 2 frames before the end of a mapping mode observation.

- I. Logic for determining desired calibration EDRs from predicted EDRs in initial observation tracking table for a given measurement (BTF table)
  - a. Shutter closed DF EDRs for bias for scene or sphere EDR
    - i. Select latest (in encoded SCLK) DF EDR that is earlier than the scene or sphere EDR and has the same frame rate, exposure, and binning as the scene or sphere EDR, and acceptable wavelength filter for the scene or sphere EDR
    - ii. Select earliest (in encoded SCLK) DF EDR that is later than the scene or sphere EDR and has the same frame rate, exposure, and binning as the scene or sphere EDR, and acceptable wavelength filter for the scene or sphere EDR
    - iii. Definition of “acceptable wavelength filter for the scene or sphere EDR”
      1. Filter 0 DF is acceptable for filters 0, 1, 2, and 3 SP or SC
      2. Filter 1 DF is acceptable for filter 1 SP or SC
      3. Filter 2 DF is acceptable for filters 1, 2, and 3 SP or SC
      4. Filter 3 DF is acceptable for filters 1 and 3 SP or SC
  - b. Sphere calibration SP SC EDR for radiometric calibration
    - i. Select closest (in encoded SCLK) SP EDR that is has acceptable binning and wavelength filter to go with the scene EDR
    - ii. Select shutter closed DF EDRs to go with the SP EDR by following (a) above
    - iii. Definition of “acceptable binning to go with the scene EDR”
      1. For 10x binning scene EDR, any binning is OK for the SP EDR
      2. For 5x binning scene EDR, 1x or 5x are OK for the SP EDR
      3. For 2x binning scene EDR, 1x or 2x are OK for the SP EDR
      4. For 1x binning scene EDR, 1x is OK for the SP EDR
  - c. Shutter closed DF EDR for bad pixel mask
    - i. Select closest (in encoded SCLK) DF EDR with 1x binning, 1Hz frame rate, integ time parameter 425, and hyperspectral wavelength filter
- II. Logic for determining calibration EDRs to use from the list of valid downlinked calibration EDRs (ATF table), and what to do if some of them are invalid
  - a. Shutter closed DF EDRs for bias for scene or sphere EDR
    - i. Select latest (in encoded SCLK) existing valid DF EDR that is earlier than the scene or sphere EDR and has the same frame rate, exposure, and binning as the scene or sphere EDR, and acceptable wavelength filter for the scene or sphere EDR
    - ii. Select earliest (in encoded SCLK) existing valid DF EDR that is later than the scene or sphere EDR and has the same frame rate, exposure, and

- binning as the scene or sphere EDR, and acceptable wavelength filter for the scene or sphere EDR
- iii. If unexpected DF EDRs are selected
    1. If the early DF EDR is more than 6 hours earlier than the scene EDR, do not select that EDR but instead select the late DF EDR twice
    2. If the late DF EDR is more than 6 hours later than the scene EDR, do not select that EDR but instead select the early DF EDR twice
    3. If both DF EDRs differ from the scene EDR by more than 6 hours, select the one that is closest in time to the scene EDR twice
    4. If either of the DF EDRs selected is different from that predicted in the early observation tracking table (note this part of the logic is implemented by the C++ program, while the rest is implemented in PIPE)
      - a. For scene measurements, set the flag in the data quality indicator in the TRDR but otherwise continue normally
      - b. For DF EDRs to be used with SP EDRs, declare that SP EDR invalid, do not generate an SP flight CDR4 from that SP EDR, and go back to PIPE to get another SP EDR
  - b. Sphere calibration SP EDR for radiometric calibration
    - i. For VNIR, detector temperature is thermostatically controlled and effect on responsivity is forward modeled, so we use only one SP EDR
    - ii. Select closest (in encoded SCLK) SP EDR that has acceptable binning and wavelength filter to go with the scene EDR
    - iii. Select shutter closed DF EDRs to go with the SP EDR by following (a) above
    - iv. If unexpected SP EDRs are selected
      1. There is no time limit on whether SP EDRs are acceptable, just use the closest in time of the valid ones
      2. If the SP EDR selected is different from that predicted in the early observation tracking table, set the flag in the data quality indicator in the TRDR but otherwise continue normally (note this part of the logic is implemented by the C++ program, while the rest is implemented in PIPE)
  - c. Shutter closed DF EDR for bad pixel mask
    - i. Select closest (in encoded SCLK) DF EDR with 1x binning, 1 Hz frame rate, integ time parameter 425, and hyperspectral wavelength filter

## IR

There are 3 types of calibration EDRs to be searched for, the shutter-closed DFs (for IR these are used for background subtraction), the shutter-closed BIs (for IR these are used for bias subtraction), and the sphere calibration SP EDRs. The SP EDRs have their own DF EDRs for calculating the background for sphere measurements.

Note that any downlinked EDRs with a “UN” macro descriptor in the filename should be

rejected as calibration EDRs. This will filter out any problem EDRs caused when the instrument occasionally reverts back to default state 2 frames before the end of a mapping mode observation.

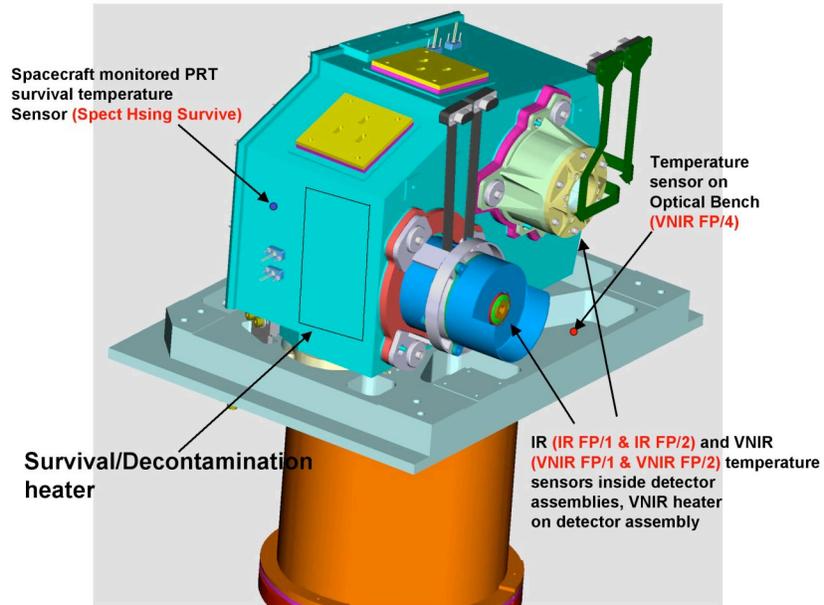
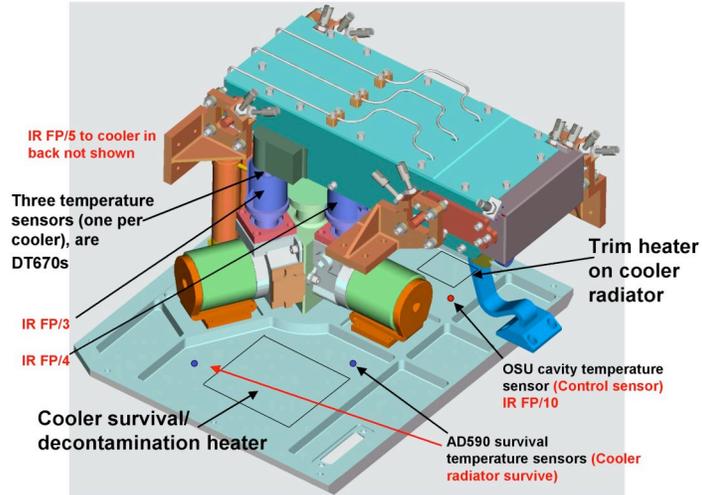
- I. Logic for determining desired calibration EDRs from predicted EDRs in initial observation tracking table for a given measurement (BTF table)
  - a. Shutter closed DF EDRs for background for scene or sphere EDR
    - ii. Select latest (in encoded SCLK) DF EDR that is earlier than the scene or sphere EDR and has the same frame rate, exposure, and binning as the scene or sphere EDR, and acceptable wavelength filter for the scene or sphere EDR
    - iii. Select earliest (in encoded SCLK) DF EDR that is later than the scene or sphere EDR and has the same frame rate, exposure, and binning as the scene or sphere EDR, and acceptable wavelength filter for the scene or sphere EDR
  - b. Shutter closed BI EDRs for bias for scene or sphere EDR
    - iv. Find closest (in encoded SCLK) set of BI EDRs and select all EDRs from that set that have the same frame rate and binning as the scene or sphere measurement regardless of exposure, and acceptable wavelength filter for the scene or sphere EDR
  - c. Sphere calibration SP EDRs for radiometric calibration
    - i. Select closest (in encoded SCLK) nightside SP EDR that has acceptable binning and wavelength filter to go with the scene EDR
    - ii. Select closest (in encoded SCLK) dayside SP EDR that has acceptable binning and wavelength filter to go with the scene EDR
    - iii. If either SP EDR differs from the scene EDR by more than 24 hours, replace the errant SP EDR by a dummy EDR name to force the C++ program to set the data quality flag in the TRDR no matter what SP EDR it actually ends up using
    - iv. Select shutter closed DF EDRs to go with each sphere EDR by following (a) above
    - v. Select shutter closed BI EDRs to go with each sphere EDR by following (b) above
  - d. Shutter closed BI EDRs for bad pixel mask
    - i. Select closest (in encoded SCLK) set of BI EDRs with 1x binning and hyperspectral wavelength filter
- II. Logic for determining calibration EDRs to use from the list of valid downlinked calibration EDRs (ATF table), and what to do if some of them are invalid
  - a. Shutter closed DF EDRs for background for scene or sphere EDR
    - ii. Find latest (in encoded SCLK) existing valid DF EDR that is earlier than the scene or sphere EDR and has the same frame rate, exposure, and binning as the scene or sphere EDR, and acceptable wavelength filter for the scene or sphere EDR
    - i. Find earliest (in encoded SCLK) existing valid DF EDR that is later than the scene or sphere EDR and has the same frame rate, exposure, and

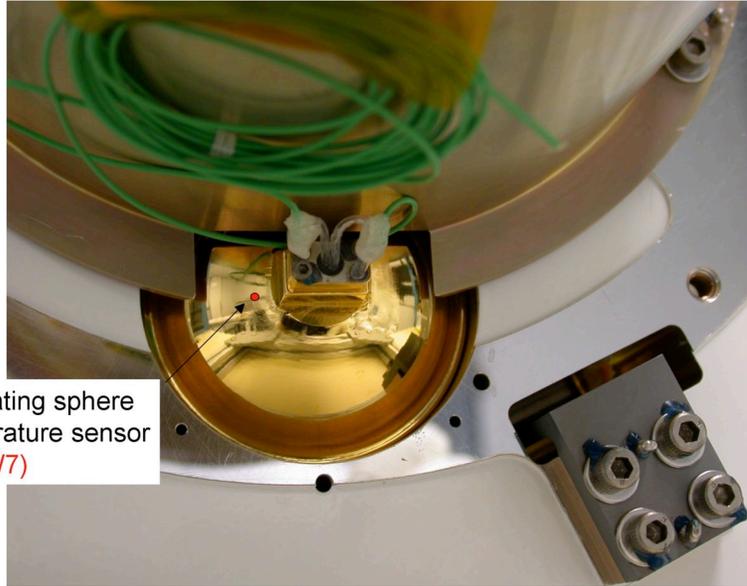
- binning as the scene or sphere EDR, and acceptable wavelength filter for the scene or sphere EDR
- ii. If unexpected DF EDRs are selected
    1. If the early DF EDR is more than 6 hours earlier than the scene EDR, do not select that EDR but instead select the late DF EDR twice
    2. If the late DF EDR is more than 6 hours earlier than the scene EDR, do not select that EDR but instead select the early DF EDR twice
    3. If both DF EDRs differ from the scene EDR by more than 6 hours, select the one that is closest in time to the scene EDR twice
    4. If either of the DF EDRs selected is different from that predicted in the early observation tracking table (note this part of the logic is implemented by the C++ program, while the rest is implemented in PIPE)
      - a. For scene measurements, set the flag in the data quality indicator in the TRDR but otherwise continue normally
      - b. For DF EDRs to be used with SP EDRs, declare that SP EDR invalid, do not generate an SP flight CDR4 from that SP EDR, and go back to PIPE to get another SP EDR
  - b. Shutter closed BI EDRs for bias for scene or sphere EDR
    - i. Find closest (in encoded SCLK) set of BI EDRs and choose all EDRs from that set that have the same frame rate and binning as the scene or sphere measurement regardless of exposure, and acceptable wavelength filter for the scene or sphere EDR
    - ii. If unexpected BI EDRs are selected (note this part of the logic is implemented by the C++ program, while the rest is implemented in PIPE)
      1. There is no time limit on whether BI EDRs are acceptable, just use the closest in time of the valid ones
      2. If the BI EDR selected is different from that predicted in the early observation tracking table, set the flag in the data quality indicator in the TRDR but otherwise continue normally
      3. For BI EDRs to be used with SP EDRs, declare that SP EDR invalid, do not generate an SP flight CDR4 from that SP EDR, and go back to PIPE to get another SP EDR
  - c. Sphere calibration SP EDRs for radiometric calibration
    - i. Select closest (in encoded SCLK) nightside SP EDR that has acceptable binning and wavelength filter to go with the scene EDR
    - ii. Select closest (in encoded SCLK) dayside SP EDR that has acceptable binning and wavelength filter to go with the scene EDR
    - iii. Ensure the IR detector temperature for the scene EDR does not fall too far outside the range of the dayside and nightside SP EDRs
      1. Let  $T$ ,  $T_d$ , and  $T_n$  be the median IR detector temperatures for the frames of each of the scene, dayside SP, and nightside SP EDRs respectively

2. If  $T_d \leq T_n$ , replace the dayside SP EDR with the one closest (in encoded SCLK) to the scene EDR with  $T_d > T_n$
  3. If  $(T - T_d) > 0.5 * (T_d - T_n)$ , replace the currently selected dayside SP EDR with the one closest (in encoded SCLK) to the scene EDR with  $(T - T_d) < 0.5 * (T_d - T_n)$
  4. If  $(T_n - T) > 0.5 * (T_d - T_n)$ , replace the nightside SP EDR with the one closest (in encoded SCLK) to the scene EDR with  $(T_n - T) < 0.5 * (T_d - T_n)$
- iv. Find shutter closed DF EDRs to go with each sphere EDR by following (a) above
  - v. Find shutter closed BI EDRs to go with each sphere EDR by following (b) above
  - vi. If unexpected SP EDRs are selected
    1. If either SP EDR differs from the scene EDR by more than 24 hours, generate an error and ask for human intervention to select the proper pair of SP EDRs to use in generating the TRDR for the given scene EDR
    2. If either of the SP EDRs selected is different from that predicted in the early observation tracking table, set the flag in the data quality indicator in the TRDR but otherwise continue normally (note this part of the logic is implemented by the C++ program, while the rest is implemented in PIPE)
  - e. Shutter closed BI EDRs for bad pixel mask
    - i. Select closest (in encoded SCLK) set of BI EDRs with 1x binning and hyperspectral wavelength filter

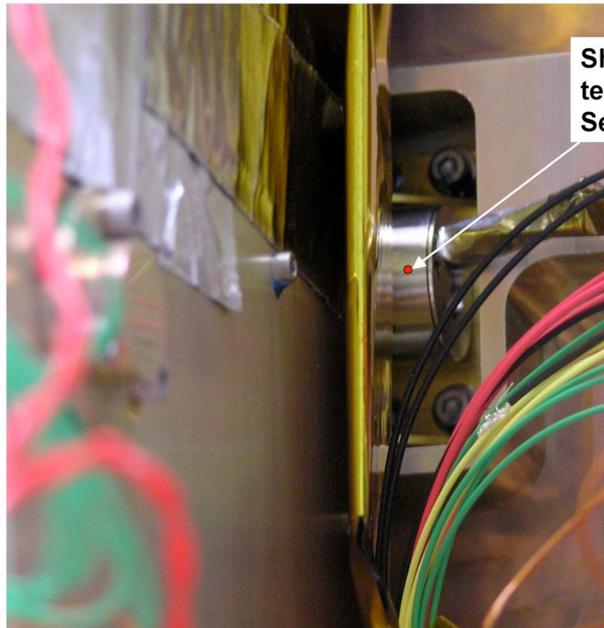
## APPENDIX N. TEMPERATURE SENSOR AND HEATER LOCATIONS

Locations of the reported temperatures, as well as locations of heaters whose current is reported in housekeeping, are shown in the following graphics

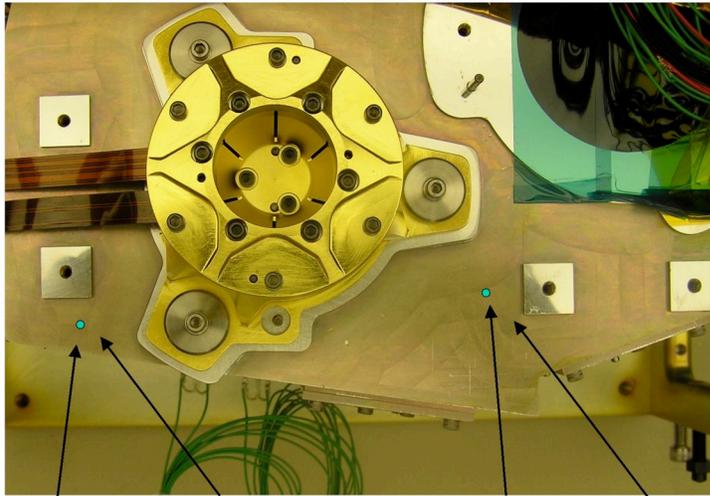




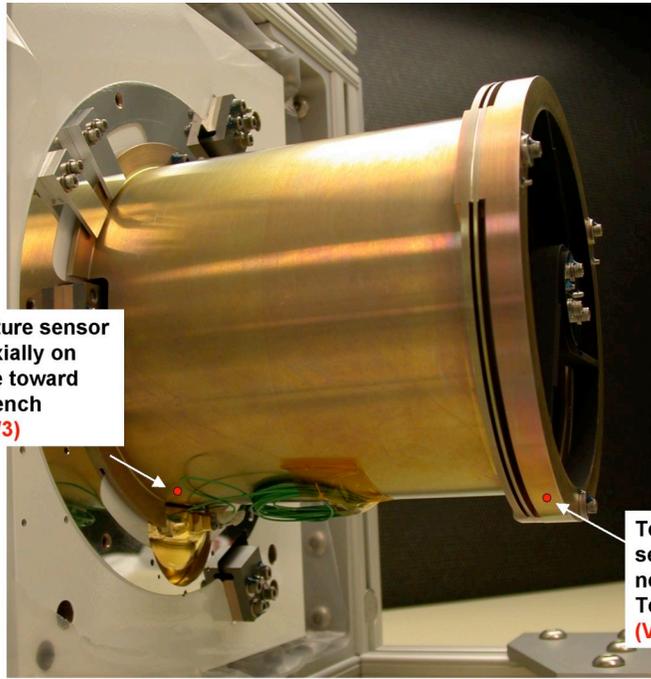
Integrating sphere  
temperature sensor  
(IR FP/7)



Shutter motor  
temperature  
Sensor (IR FP/6)

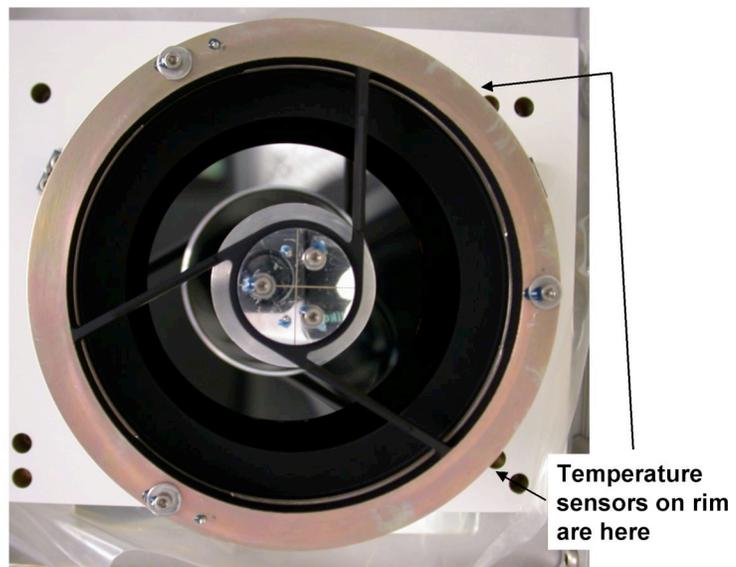
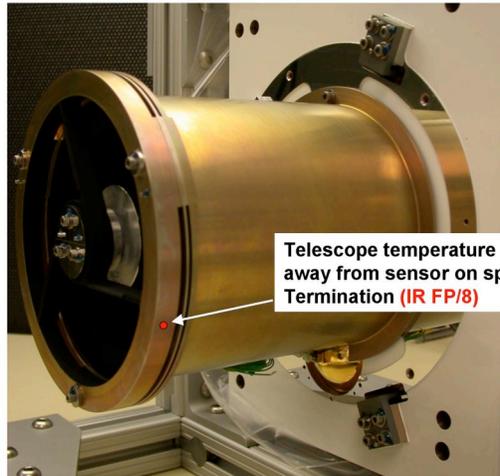


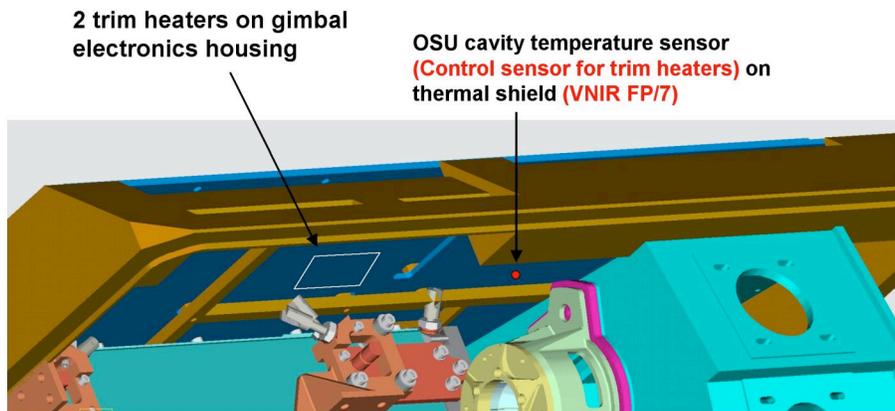
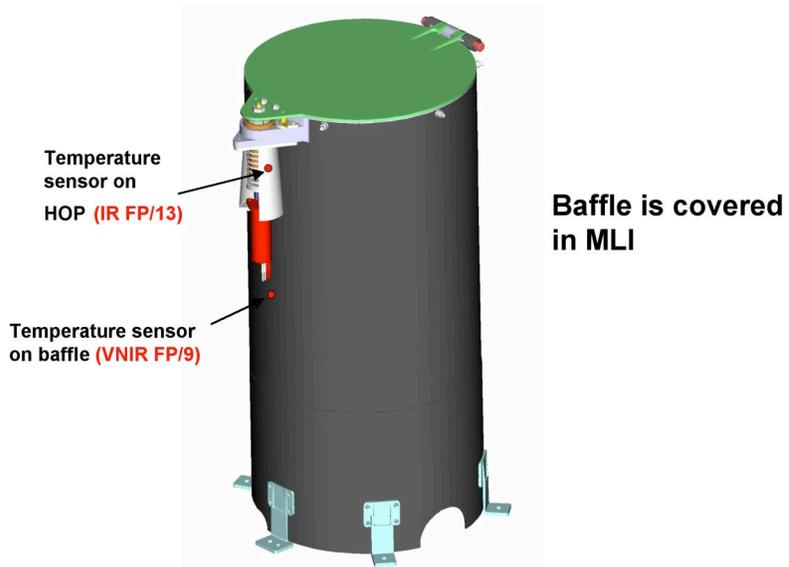
Spectral cavity temperature sensors (these will be the SD (rectangular) package, not the CU package (with hole in it))  
**IR FP/9 (control temp sensor for the trim heater)** **VNIR FP/6**



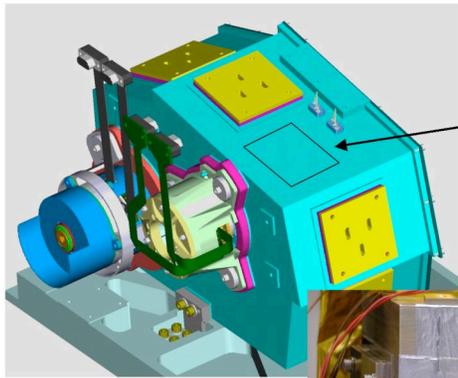
Temperature sensor moved axially on telescope toward optical bench  
**(VNIR FP/3)**

Temperature sensor on rim near spider Termination  
**(VNIR FP/5)**

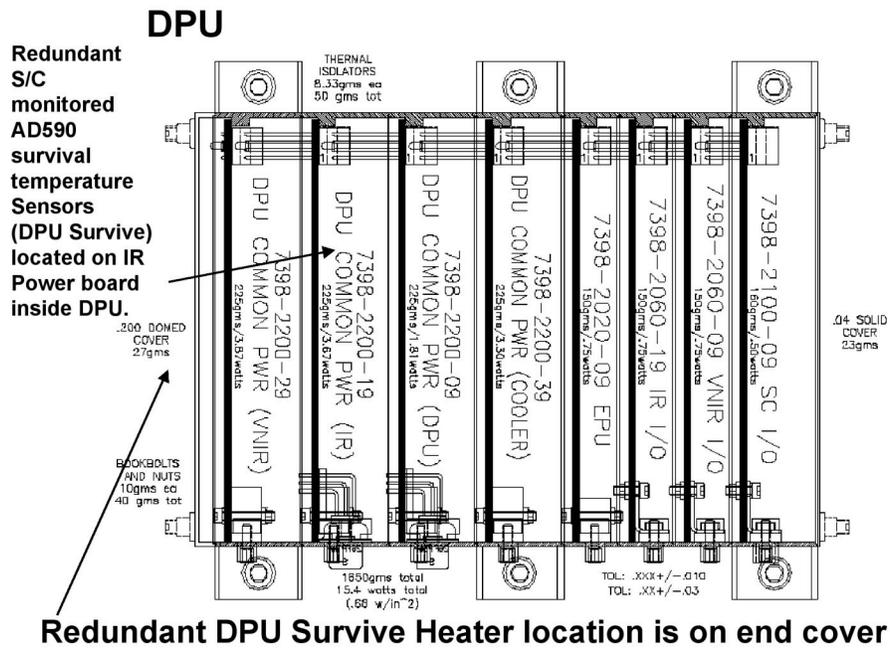
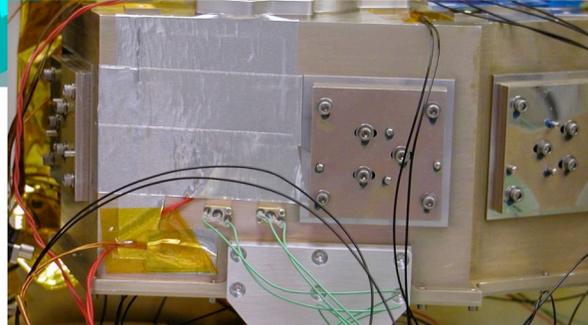




IR (IR FP/11) and VNIR (VNIR FP/8) FPU board temperature sensors on boards



Trim heater on spectrometer housing - similar to OCF calibration configuration (seen in picture below) (IR FP/9 is the control)



## **APPENDIX O. DESCRIPTION AND USAGE OF ADRS**