Mars Reconnaissance Orbiter
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Software Interface Specification
for
HiRISE
Reduced Data Record
Products

Version 1.5

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Document Change Control

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03/15/2007	Eric E.	All	Updated document per draft reviewer comments
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12/9/2024	Rodney H.	3.2.2	Added clarification about the embedded GeoTIFF box embedded in the JPEG2000 product, vs the GeoTIFF PDS4 products.

TBD Items

Section	Description

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ACRONYMS AND ABBREVIATIONS

CCD	Charge Couple Device
CK	Instrument pointing kernel (C-matrix)
CRISM	Compact Reconnaissance Imaging Spectrometer for Mars
DARWG	Data Archive Working Group
DEM	Digital Elevation Model
DN	Density Number
DTM	Digital Terrain Model (DEM and DTM are synonymous in this context)
EDR	Experimental Data Record
FELICS	Fast and Efficient Lossless Image Compression System
GSD	Ground Sample Distance
HiRISE	High Resolution Imaging Science Experiment
HiROC	HiRISE Operations Center
IEC	International Electotechnical Commission
I/F	Intensity/Flux
ISIS	Integrated Software for Imagers and Spectrometers
ISO	International Standards Organization
JPEG2000	JPEG2000 is a wavelet-based image compression standard created by the Joint Photographic Experts Group committee.
LUT	Lookup Table
MOLA	Mars Orbiter Laser Altimeter
MRO	Mars Reconnaissance Orbiter
NAIF	Navigation and Ancillary Information Facility
ODL	Object Descriptor Language
PDS	Planetary Data System
PLT	Packet Length Tags
PSP	Primary Mapping Phase
RDR	Reduced Data Record
RSDS	Raw Science Data Server
SCLK	Spacecraft clock used to coordinate spacecraft activities
SPICE	Acronym for Space, Planet, Instrument, C-matrix, Event
SPK	Spacecraft ephemeris kernel
SIS	Software Interface Specification
TDI	Time Delay Integration
TRA	Transition Orbit Phase
UTC	Coordinated Universal Time
URL	Uniform Resource Locator
UUID	Universally Unique Identifier

1 Introduction

1.1 Purpose & Scope

The High Resolution Imaging Science Experiment (HiRISE) is one of the remote sensing instruments on the Mars Reconnaissance Orbiter (MRO) spacecraft that acquires orbital observations of the Martian surface during a two earth-year primary mapping phase. MRO, successfully launched in August 2005, arrived at Mars in March 2006. Following orbit insertion the spacecraft went into an aerobraking period to achieve a 250 x 315 kilometer near-polar orbit suitable for the Primary Science Phase (PSP) mapping that started in November 2006. Since the start of PSP, HiRISE has been continuously operating acquiring 10-20 observations per day.

The HiRISE team is responsible for maintaining an updated dataset of the best version of its science data until meaningful changes in data calibration no longer occur and to release data in an appropriate manner for public access including their final deposition to NASA's Planetary Data System (PDS) [1, 2]. In carrying out these responsibilities, the HiRISE team creates two types of standard data products: 1) Experiment Data Record (EDR) products and 2) Reduced Data Record (RDR) Products. This document describes the RDR standard products.

1.2 What are RDR Products?

RDR products are radiometrically-corrected images resampled to a standard map projection. They are formatted and organized according to the standards of the PDS [6, 7, 8, 9]. A RDR image is stored in the JPEG2000 (Joint Photographic Experts Group) format recently adopted by the PDS. The PDS Standard specifies that a JPEG2000 codestream will be stored in a "JP2" file as described by the JPEG2000 Part 1 standard [5, Appendix I]. The JPEG2000 images are accompanied by a PDS detached label (described in section 4.5) providing supporting information about the observation. There will typically be two RDR standard products per HiRISE observation a single-color RDR product built from the operating red-filter CCDs, and a three-color RDR product if the blue-green and near-infrared CCDs were additionally operating. The three-color RDR products will be released at a time later then the release of the red-filter RDR products.

The radiometric-correction (described in section 4.1.1) corrects for instrument offset, dark current, and gain then converts the image pixels to I/F reflectance. Geometric processing corrects for optical distortion and projects the image from spacecraft viewing to a map coordinate system. The Equirectangular map projection is employed for images observed in the latitude range -65 to 65 degrees. Images above 65 degrees to the poles use the Polar Stereographic

projection.

This Software Interface Specification (SIS) document provides a description of the RDR products. It is intended to provide enough information to enable users to read and understand the RDR products. The users for whom this SIS is intended are software developers, engineers, and scientists interested in accessing and using these products. The SIS also provides a specification of the products to be delivered to the Planetary Data System (PDS).

The SIS describes how the HiRISE team processes, formats, labels, and uniquely identifies the RDR products. The document describes standards used in generating the products. The data product structure and organization are described in sufficient detail to enable a user to develop software for reading the RDR products. Finally, examples of the product labels are provided.

The RDR SIS acts as a companion to the HiRISE EDR Data Product SIS [3] and the HiRISE EDR & RDR Volume SIS [4] documents. The Volume SIS describes the ancillary data that accompany the HiRISE imaging products as well as the contents and organization of the data volumes.

1.3 What are EDR Products?

EDR products [3], briefly mentioned here, are companion products to the RDRs and are the permanent record of the raw images obtained by HiRISE. The EDRs have the properties of unprocessed and unrectified imaging maintaining the original spacecraft viewing orientation and optical distortion properties. As part of the EDR generation process, FELICS-compressed [11] (FELICS stands for Fast and Efficient Lossless image compression System) images are decompressed and organized as raster images. EDRs are organized at the channel level with two EDRs needed for each operating CCD (Charge Couple Device). Up to 28 EDR products are needed to capture a single HiRISE observation. Maintaining an archive of EDR products enables reprocessing of the raw science observations as calibration and geometry processing routines improve. Investigators interested in applying advanced calibration methods or needing to understand the properties of the raw imaging will find the EDRs a useful product. However, most science investigators will be interested in using the RDR products as geometry and radiometric processing has been applied to these products.

1.4 Applicable Documents and References

The RDR Product SIS is responsive to the following MRO project documents:

1. Mars Exploration Program Data Management Plan, R. E. Arvidson and S. Slavney, Rev. 2, Nov. 2, 2000.

2. Mars Reconnaissance Orbiter Project Data Archive Generation, Validation

and Transfer Plan, R. E. Arvidson, S. Noland and S. Slavney, March, 2005

3. Software Interface Specification for HiRISE Experimental Data Record Products, JPL D-32004, March 17, 2006

4. HiRISE EDR & RDR Archive Volumes Software Interface Specification, JPL D-32005, June 1, 2006

5. JPEG 2000 image coding system: Core coding system, ISO/IEC 15444-1 September 15, 2004

The SIS is also consistent with the following Planetary Data System (PDS) documents:

6. Planetary Data System Data Preparation Workbook, Version 3.1, JPL D-7669, Part 1, February 1, 1995.

7. Planetary Data System Data Standards Reference, Version 3.7, JPL D-7669, Part 2, March 20, 2006,

8. Planetary Science Data Dictionary Document, JPL D-7116, Rev. E, August 28, 2002.

9. Planetary Data System Archive Preparation Guide, Version 1.1, JPL D-31224, August 29, 2006.

Additional References:

10. McEwen, A. S., E. M. Eliason, J. W. Bergstrom, N. T. Bridges, W. A. Delamere, J. A. Grant, V. C. Gulick, K. E. Herkenhoff, L. Keszthelyi, R. L. Kirk, M. T. Mellon, S. W. Squyres, N. Thomas, C. M. Weitz, (2007), MRO's High Resolution Imaging Science Experiment (HiRISE). *J. Geophys. Res. (in press).*

11. Howard, P.G. and J.S. Vitter, (1994), "Fast progressive lossless image compression," *Proc. IST/SPIE Int'l Symp. On Electronic Imaging Science and Technology*

12. Snyder, J.P. (1987) Map Projections U.S. Geological Survey Professional Paper 1395.

13. Becker, K. J., J.A. Anderson, S.C. Sides, E.A. Miller, E.M. Eliason, and L.P. Keszthelyi, (2007)**,** Processing HiRISE Images Using ISIS3, *LPSC XXXVIII*, Abstract #1779.

14. E. G. Keys, (1981), Cubic Convolution Interpolation For Digital Image Processing, *IEEE Trans. Acoustics, Speech, and Signal Processing*, **29(6): 1153–1160.**

15. Neumann, G. A., F. G. Lemoine, D. E. Smith, M. T. Zuber, (2003), The Mars Orbiter Laser Altimeter Archive: Final Precision Final Precision Experiment Data Record Release and Status of Radiometry, *LPSC XXXIV*, *Abstract #1978.*

16. Castalia, B., (2006), Conductor: Managing Processing Pipelines, *LPSC XXXVII*, Abstract # 2159.

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17. Schaller, C. J., (2006), Automated HiRISE Data Processing: Conductor in Action, (2006), LPSC XXXVII, Abstract # 2134

18. Acton, Jr., C.H., (1996), Ancillary data services of NASA's Navigation and Ancillary Information Facility, *Planet. Space Sci., Vol. 44, No. 1, .pp 65-70*.

19. Smith et al., (2001), Mars Orbiter Laser Altimeter: Experiment summary after the first year of global mapping of Mars, *JGR-Planets*, **106**(E10): 23,689-23,722.

20. Kirk, R.L., E. Howington-Kraus, M.R. Rosiek, J.A. Anderson, B.A. Archinal, K.J. Becker, D.A. Cook, D.M. Galuszka, P.E. Geissler, T.M. Hare, I.M. Holmberg, L.P. Keszthelyi, B.L. Redding, W.A. Delamere, D. Gallagher, J.D. Chapel, E.M. Eliason, R. King, A.S. McEwen, (2008) "Ultrahigh resolution topographic mapping of Mars with MRO HiRISE stereo images: Meter-scale slopes of candidate Phoenix landing sites, *J. Geophys. Res. - Planets*, **113**(E00A24), doi:10.1029/2007JE0030000.

1.5 Configuration Management and SIS Review

The HiRISE Software Development Team controls this document. Requests for changes to the scope and contents of this document are made to the HiRISE Ground Data System Manager. An engineering change request will be evaluated against its impact on the HiRISE ground data processing system before acceptance.

The RDR SIS has been through a peer review process required by the PDS. The products described in the document have been determined to meet PDS data product standards.   Members from the PDS Geosciences, Imaging, and Engineering Nodes were on the review panel with additional members from the Planetary Science community.

1.6 Relationship with Other Interfaces

 HiRISE RDR products have been radiometrically and geometrically processed and will be used by the HiRISE Science Team and remote sensing scientists in data analysis activities. Changes to this SIS may impact the tools and methods employed by end users. The RDR products are derived from EDR products. Changes to the EDR SIS [3] may impact the ground processing systems leading up to the generation of RDR products.

The Mars Exploration Program Data Management Plan [1] defines the overarching processes and goals for generation, validation, and delivery of data products from Mars flight projects to the PDS in complete, well-documented, permanent archives in a timely fashion. The "MRO Data Archive Generation, Validation, and Transfer Plan" [2] provides project-wide details for MRO's interface activities with the PDS.

2 Instrument Overview

HiRISE is a "pushbroom" imaging system featuring a 0.5 m aperture telescope with a 12 m effective focal length and 14 CCD detectors capable of generating images of up to 20,048 crosstrack pixels (exclusive of overlap pixels) and 63,000 unbinned downtrack lines for 14-bit pixel imaging or 126,000 scan lines for 8-bit data. HiRISE samples the Martian surface at 25-32 cm/pixel depending on spacecraft altitude and off nadir roll angle. Observations can be acquired in three spectral wavelengths: blue-green (~536 nm), red (~692), and near-infrared (~874 nm). Ten detectors are employed for red-filter imaging and two detectors each for the blue-green and near-infrared filters. See Figure 2.0 for a layout of the CCD arrays located on the focal plane. At 300km orbital altitude the crosstrack aerial coverage is ~6.0 km for red-filter imaging and ~1.2 km for three-color imaging. Downtrack coverage depends on the number of scan lines commanded, varying from a few kilometers to a maximum of ~39.0 km (126,000 lines) for unbinned images. A key instrument design feature employs detectors with up to 128 lines of Time Delay and Integration (TDI) to create high signal-to-noise ratio (up to 300:1).

Several data compression methods can be employed to optimize data return. Pixel binning (permitted values: 1,2,3,4,8,16) is used to reduce data volume but increases the pixel scale (m/pixel). A second data compression method employs a lookup table (LUT) to convert the 14-bit data dynamic range (16-bit/pixel storage) to 8-bit pixels thereby reducing the data volume by half. A third data compression method employs FELICS [11] lossless data compression providing compression ratios of about 2.4:1 for most HiRISE observations. To maximize aerial coverage for the available downlink most HiRISE images are acquired using 8-bit LUT imaging with FELICS compression.

The 14 CCD detector arrays can be independently commanded offering flexibility on how an observation is acquired. Any combination of CCDs can be commanded to acquire imaging. Often, center red-filter CCDs are commanded for bin 1 while the blue-green, near-infrared and peripheral red-filter CCDs are commanded for higher binning.

A detailed instrument overview and operating capabilities of the HiRISE instrument can be found in the EDR SIS companion document [3] and the HiRISE Instrument paper [10].

14 CCDs (2048 x 128 pixels):
10 CCDs Form Red Channel (20,264 pixels)
2 CCDs Form Blue-Green Channel (4048 pixels)
2 CCDs Form NIR Channel (4048 pixels)
HiRISE power supply enables simultaneous operation of at least 10 CCDs.

Figure 2.0 - Focal Plane Array
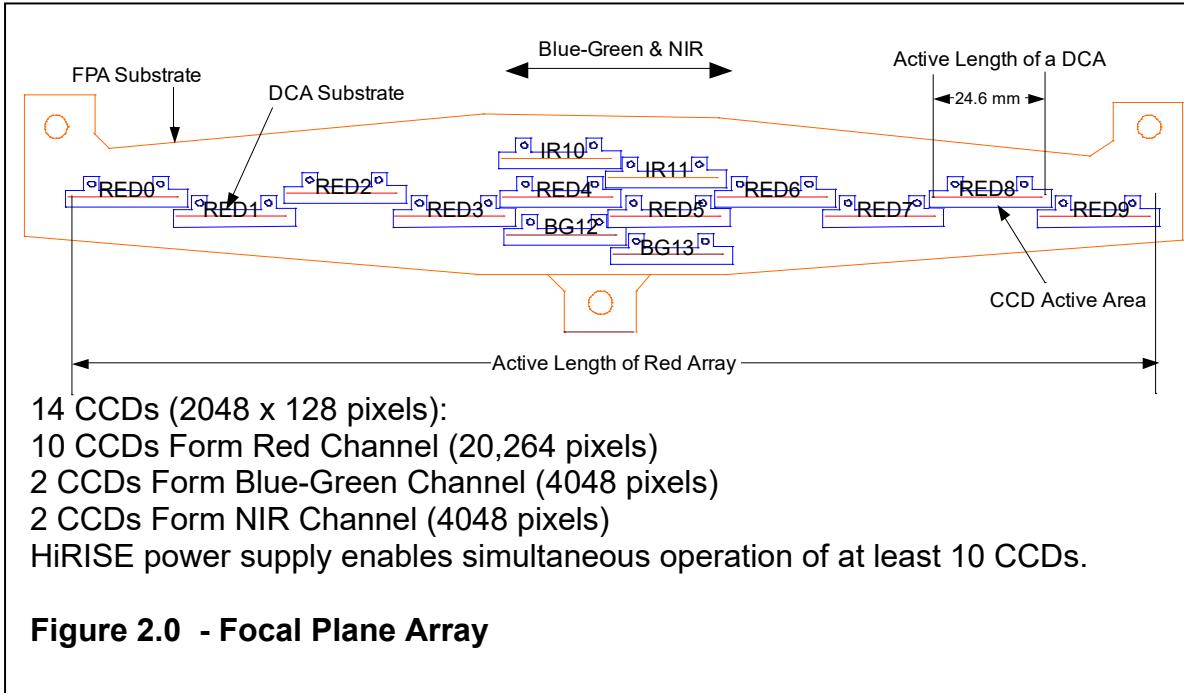
3   Standards Used in Generating Products

3.1 PDS Standards

The HiRISE RDR products comply with the PDS standards for file formats and labels, specifically using the PDS image object definition [6, 7, 8, 9]. The RDR image files, formatted according to the JPEG2000 standard, use "JP2" as their filename extension. They are accompanied by PDS labels; files that have the same name as the image data file but use "LBL" for their filename extension. The label file provides image data characterization and science metadata information about the observation (see Section 4.5). Additionally, the ancillary data files that accompany the RDR products and the archive volume structure are in conformance with PDS standards [7, 9].

3.2 JPEG2000 Standard

RDR image data are stored in the JPEG2000 ISO/IEC Part 1 standard [5] format (http://www.jpeg.org/jpeg2000/), which was accepted as a PDS Standard in October 2005 [7, Appendix I]. The JPEG2000 standard offers benefits with distinct advantages for storage of and access to very large images. With HiRISE RDR products exceeding 30,000 x 100,000 pixels, the use of JPEG2000 was recognized as a suitable solution for the storage and distribution of these data products. Advantages include excellent compression performance, multiple resolution levels from a single image data set, progressive decompression quality

layers, lossless and lossy compression (HiRISE RDR products use lossless compression), pixel datum precision up to 38 bits, multiple image components (or bands), and selective image area access. These features are achieved by the use of a sophisticated image coding system based on discrete wavelet transforms (DWT) combined with other coding techniques to generate a JPEG2000 codestream that can be rendered to image raster format using inverse transform algorithms.

The PDS Standard specifies that a JPEG2000 codestream will be stored in a "JP2" file as described by the JPEG2000 Part 1 standard [5, Appendix I]. This file format encapsulates one or more codestreams plus characterizing metadata in a contiguous sequence of binary data "boxes". The first two boxes of a JP2 file must be Signature and File Type specification boxes that uniquely identify the file as a JP2 file. This must be followed by a JP2 Header box that contains sub-boxes that characterize the Codestream box that follows with information such as the image dimensions, pixel datum precision, compression technique and color space mapping for image display purposes. The JP2 file may also contain additional boxes that contain UUID (universally unique identifier) signatures, URL (uniform resource locator) references, and XML (extended markup language) sequences that can be used as desired by the data provider.

3.2.1 UUID List

HiRISE RDR JP2 data product files contain a UUID Information box that includes a UUID List box and a Data Entry URL box. The UUID List box has a single entry with the values (16 binary bytes shown here in hexadecimal notation) 2B, 0D, 7E, 97, AA, 2E, 31, 7D, 9A, 33, E5, 31, 61, A2, F7, D0 which is a version 3 UUID signature based on the URL namespace string "http://hirise.lpl.arizona.edu/". This signature is intended to uniquely identify the JP2 file as containing a HiRISE data product. Other HiRISE JP2 data products, in addition to RDRs, are expected to use the same UUID. The Data Entry URL box contains a relative file URL string that identifies the external PDS label file for the data product. The basename of the PDS label file is expected to be the same as the basename of the JP2 image data file; thus for the image data file "PSP_002345_1770_RED.JP2" the URL would be "PSP_002345_1770_RED.LBL". This provides a reference from the image data file to the PDS label file containing the science metadata for the image data product. Data users may change filenames, of course, so the URL also ensures that the HiRISE observation ID – the initial three segments of the filename - will be provided in the JP2 file.

3.2.2 GeoTIFF

As of HiRISE data set version 1.1 (as indicated in the DATA_SET_ID and DATA_SET_NAME PDS label parameters) RDR JP2 files will contain GeoTIFF geospatial reference information encapsulated in a UUID box. GeoTIFF is an industry standard recognized by many Geographic Information Systems (GIS)

software packages. The GeoTIFF UUID box is identified by its first sixteen UUID byte values (shown here in hexadecimal notation): B1, 4B, F8, BD, 08, 3D, 4B, 43, A5, AE, 8C, D7, D5, A6, CE, 03. The remainder of the box contains a standard TIFF (Tagged Image File Format) data set composed of TIFF tags with geospatial reference information derived from the IMAGE_MAP_PROJECTION parameters of the PDS label. The details of the GeoTIFF specification, and other related information, can be found at the RemoteSensing organization GeoTIFF web site (http://www.remotesensing.org/geotiff/). **NOTE:** This section describes the geometric information stored in the JPEG2000 product. This data is encoded using the GeoTIFF standard referenced here. For compliance with PDS4 standards, HiRISE is producing TIFF files compliant with the GeoTIFF standard. For more information on the PDS4 files, see section "4.6 – Conversion to PDS4."

3.2.3 JPEG2000 Codestream

All of the information necessary to successfully decompress JPEG2000 image data is contained in the JPEG2000 Codestream box of the JP2 file. The flexibility of the format, however, allows for significant variability in how the codestream is structured which can have a significant impact on the performance of client software accessing the codestream during rendering operations.

While the JPEG2000 standard supports an exceptionally efficient lossy image coding technique, to ensure the preservation of the science information of the image data the PDS requires that only lossless image compression be used. Therefore HiRISE RDR image data are compressed using the JPEG2000 5-3 reversible transform. The JPEG2000 codestream may be partitioned into quality layers to enable rendering software to provide progressing quality displays. HiRISE RDR image data are compressed with a single quality layer.

Perhaps the most significant data structure decision is whether to organize the codestream into image area tiles. Some client software may render full resolution image data for a relatively small display area of a large image more quickly if the codestream is tiled; other client software may render low resolution image data for the entire image more quickly if the codestream is not tiled. The HiRISE RDR image data are not tiled in the JPEG2000 codestream (the entire codestream is a single tile). To assist client software in locating selective sub-areas of the codestream called precincts, which contain codestream packets, HiRISE RDR image data files include Packet Length Markers (PLT) in the JPEG2000 codestream.

Another obvious data structure decision is the number of resolution levels to provide in the codestream. The DWT image coding technique naturally partitions the image information into powers of two resolution levels; i.e. starting with the full (1:1) resolution level the next resolution level will result in an image having dimensions half that of the full resolution image, and so forth for subsequent additional resolution levels. Image rendering proceeds from the lowest resolution

level and incrementally adds image information from higher resolution levels; image data rendering may stop at any selected level to provide pixel rasters suitable for display. A maximum of 32 resolution levels are possible, but too many resolution levels can result in storage and rendering inefficiencies depending on the image dimensions. Therefore the number of resolution levels in HiRISE JPEG2000 codestreams is determined dynamically such that the minimum dimension of the image at the lowest resolution is not less than 64.

The order in which codestream information is stored may have some affect on software rendering performance, depending on the intended application. HiRISE RDR codestreams are organized in position (image area), component (image band), resolution, and layer (quality) order.

The JPEG2000 image coding techniques are sensitive to byte ordering (for multi-byte data) and signedness of the image data. HiRISE RDR image data are MSB ordered and unsigned.

3.2.4 JPIP

Part 9 of the JPEG2000 standard specifies a JPEG2000 Internet Protocol (JPIP) for the network communication of JP2 file contents by a JPIP server to a client in response to client requests. The client requests provide selective access to the source file's metadata and image data in the component (bands), area, resolution and quality dimensions. In addition, the client may establish a session relationship with the server in which the server maintains a record of what parts of the source JP2 file are already in the client's possession so that only those parts of the file that the client does not have are sent in response to a request from the server. For example, a client requesting that portion of the codestream to render a specified image area at some low resolution level may then request the codestream to render the same image area at full resolution in which case the server will respond to the second request by only sending that portion of the codestream for the additional resolution levels beyond that already sent in response to the first request. This takes advantage of the incremental rendering of the image data and results in significantly reduced data network bandwidth requirements. As a result users of JPIP capable client software should be able to efficiently pan and zoom throughout the entire large HiRISE RDR image without requiring that the entire large image be transmitted and rendered. HiRISE RDR image data JP2 files will be made available via JPIP. Both the JP2 image data files and the PDS label files will also be made available via HTTP and other delivery methods.

3.2.5 JPEG2000 Software

Part 5 of the JPEG2000 offers reference software implementations of the Part 1 core-coding standard. The JasPer Project provides a C language API and demonstration applications (http://www.ece.uvic.ca/~mdadams/jasper/). JJ2000

(http://jj2000.epfl.ch/) provides pure Java classes. Both of these implementations are employed in two J2K plugins for the Image I/O Tools from Sun Microsystems' Java Advanced imaging (JAI).
(http://java.sun.com/javase/6/docs/technotes/guides/imageio/)
(http://java.sun.com/javase/technologies/desktop/media/jai/)

Dr. David Taubman, one of the principle JPEG2000 standard developers, implemented the Kakadu software. Kakadu offers a full range of application utilities and highly optimized C++ classes (http://www.kakadusoftware.com/).

The JP2_Info utility, in the Image_Tools package of the PIRL Java Packages (http://pirlwww.lpl.arizona.edu/software/PIRL_Java_Packages.shtml) provides a detailed report on the contents of a JP2 file.

The HiRISE Team offers a freely available JPIP Client, HiView, that allows efficient access to the HiRISE image collection through Internet resources. For more information on how to obtain the viewer go to the team's web site at (http://hirise.lpl.arizona.edu).

3.3 Data Storage Conventions

The HiRISE RDR products contain binary data. Image pixel values are stored within the JPEG2000 framework as 10-bit values with a dynamic range of 0-1023. When rendered as an image array they are stored as unsigned 16-bit pixel values but still maintaining the range 0-1023. The PDS label sections are stored as ASCII character strings conforming to the requirements defined in the PDS Standards Reference. The storage order is most significant byte (MSB) first. MSB ordering is the order used on the MRO spacecraft and the HiRISE instrument.

3.4 Time Standards

Two time-related standards are used in HiRISE RDR labels:
- Spacecraft clock (SCLK);
- Coordinated Universal time (UTC).

The spacecraft clock (SCLK) is the fundamental clock on MRO for initiating spacecraft events and coordinating spacecraft activities. The SCLK has a high precision counting unit of $1/(2^{16})$ seconds for each tick of its sub-seconds field. Thus there are 65,536 SCLK ticks per second (a time interval of 15.2588 microseconds). The RDR product labels provide the start and stop SCLK time for an observation. The labels additionally include a start and stop time in Coordinated Universal Time (UTC). The UTC has uniform seconds defined by the International Atomic Time, with leap seconds announced at irregular intervals to compensate for the Earth's slowing rotation and other discrepancies. Processing at the HiRISE Operations Center (HiROC) converts SCLK to UTC

time using the SPICE NAIF toolkit [18].

3.5 Cartographic Standards

The HiRISE RDR products are compatible with the cartographic standards and mapping conventions defined by the MRO Cartography Working Group. When spatially registering map products produced by the HIRISE and CRISM instrument teams only a translation and scale change is required. The coordinate system used is planetocentric latitude and east positive longitude direction. The planetocentric latitude is the angle from the equator to a point on the surface of an oblate planet. The longitude increases from west to east (left to right).

The planetary constants used in the camera model to produce the HiRISE RDR products are obtained from the NAIF SPICE planetary constants kernel pck0008.tpc. The Mars constants of particular importance are the right ascension (BODY499_POLE_RA) and declination (BODY499_POLE_DEC) of the pole, the prime meridian (BODY499_PM) rotation rate, and radii (BODY499_RADII). The orientation models use three Euler angles to describe the orientation of the coordinate axes of the "Body Equator and Prime Meridian" system with respect to the inertial system. The inertial system is J2000 (also called EME2000). The constants used are:

```
BODY499_POLE_RA       = (  317.68143   -0.1061      0.  )
BODY499_POLE_DEC      = (   52.88650   -0.0609      0.  )
BODY499_PM            = (  176.630    350.89198226  0.  )
BODY499_RADII         = ( 3396.19     3396.19     3376.20 )
```

Additionally, the SPICE kernel de405.bsp was used for the ephemeris data for Mars. For more information regarding the planetary constants please refer to the NAIF Node at http://naif.jpl.nasa.gov/naif/

Two map projections are used in the HiRISE RDR products: Equirectangular and Polar Stereographic. Each will be discussed separately.

3.5.1 Equirectangular Projection

The EQUIRECTANGULAR projection is based on the formula for a sphere. To eliminate confusion in the IMAGE_MAP_PROJECTION object we have set all three values, A_AXIS_RADIUS, B_AXIS_RADIUS, and C_AXIS_RADIUS to the same number. The value recorded in the three radii is the local radius at the CENTER_LATITUDE on the Mars ellipsoid. The ellipsoid is defined as, equatorial radius of 3396.190000 km and polar radius of 3376.200000 kilometers. Using the local radius of the ellipsoid implies that the MAP_SCALE and MAP_RESOLUTION are true at the CENTER_LATITUDE

The Equirectangular projection [12], used in observations whose center latitude of the observation is in the range -65 to 65 degrees latitude, is a simple

projection providing a linear relationship between the geographic coordinates of latitude and longitude and the Cartesian space of the map. In continuous form, the equations relating map coordinates (x, y) to geographic coordinates (Lat, Lon) are:

```
x = R·(Lon-LonP)·COS(LatP)

y = R·Lat
```

where $LonP$ is the center longitude of the map projection, $LatP$ is the center latitude of the projection at which scale is given, and R the radius of the body at the center latitude. The Re and Rp parameters refer to equatorial and polar radius respectively.

```
R = Re · Rp / SQRT(a² + b²)

a = Rp · COS(LatP)

b = Re · SIN(LatP)
```

The inverse formulas for Lat and Lon from x and y position in the projection are:

```
Lat = y/R

Lon = LonP + x/(R·COS(LatP))
```

The Conversion from (x, y) map coordinates to image array coordinates (sample, line) is standard for all map projections and is:

```
x       = (Sample-S0)·Scale

y       = (-L0-Line)·Scale
```

where **Scale** is the map resolution in km/pixel (located at the center planetocentric latitude of the projection). $Line$ and $Sample$ are the coordinates of the image array, and line ($L0$) and sample offsets ($S0$) are the respective image coordinate displacements from pixel (1,1) to the origin of the projection (x,y) = (0,0). Please note, pixel (1,1) is spatially located in the upper-left corner of the image array.

The equations from (x, y) to (Sample, Line) are:

```
Sample      = x/Scale+S0+1

Line        = -y/Scale-L0+1
```

The equation from ($Sample, Line$) to (Lat, Lon) is:

```
Lat = y/R
y   = (1-L0-Line)·Scale
Lat = (1-L0-Line)·Scale/R


Lon = LonP + x/(R·COS(LatP))
x   = (Sample-S0-1)·Scale
Lon = LonP + (Sample-S0-1)·Scale/(R·COS(LatP))
```

The keywords corresponding to the Equirectangular projection parameters are located in the IMAGE_MAP_PROJECTION object found in the PDS labels. The keywords for each equation parameter are shown in table 3.5.0.

Table 3.5.0 – PDS Keywords for corresponding Equirectangular projection equation parameters	
Equation	Keyword
LonP	CENTER_LONGITUDE
LatP	CENTER_LATITUDE
L0	LINE_PROJECTION_OFFSET
S0	SAMPLE_PROJECTION_OFFSET
Scale	MAP_SCALE
Re	A_AXIS_RADIUS
Rp	C_AXIS_RADIUS

The HiRISE RDR products mapped with the Equirectangular projection use different center latitudes of projection for every five-degree latitude bin from the equator to the 65 degrees latitude as shown in Table 3.5.1 This choice of center latitudes reduces the total size of the dataset and reduces scale distortions. Note that the center latitude of the map projection is generally not the same as the center latitude of the observation.

Table 3.5.1 – Center latitude of projection for image centers falling in five-degree latitude bins			
Latitude Range	Center Latitude of Projection	Latitude Range	Center Latitude of Projection
90 to 65	Polar Stereo.	-90 to -65	Polar Stereo.
70 to 65	65	-70 to -65	-65
65 to 60	60	-65 to -60	-60
60 to 55	55	-60 to -55	-55
55 to 50	50	-55 to -50	-50
50 to 45	45	-50 to -45	-45
45 to 40	40	-45 to -40	-40

40 to 35	35	-40 to -35	-35
35 to 30	30	-35 to -30	-30
30 to 25	25	-30 to -25	-25
25 to 20	20	-25 to -20	-20
20 to 15	15	-20 to -15	-15
15 to 10	10	-15 to -10	-10
10 to 5	5	-10 to -5	-5
5 to 0	0	-5 to 0	0

3.5.2 Polar Stereographic Projection

The Polar Stereographic projection [12], used in observations whose center latitude of the observation is greater than 65 or less than -65 degrees latitude, is ideally suited for observations near the poles as shape and scale distortion are minimized. The HiRISE RDR products with Polar Stereographic projection use the ellipsoid form of the equations. However, most cartographic processing software cannot support planetocentric coordinates for this projection with the ellipsoid equation. The fallback is to use the spherical equations. The error between the spherical and ellipsoidal equations is highest at 60 and -60 degrees latitude and is approximately 26 meters or about 100 HiRISE pixels. The error is less than the accuracy of the camera pointing, approximately 100m, and can be ignored.

In continuous form, the spherical equations relating map coordinates (x, y) to planetocentric coordinates (`Lat`, `Lon`) are:

```
North Polar Stereographic
x =  2·Rp·TAN(Pi/4-Lat/2)·SIN(Lon-LonP)
y = -2·Rp·TAN(Pi/4-Lat/2)·COS(Lon-LonP)

South Polar Stereographic
x =  2·Rp·TAN(Pi/4+Lat/2)·SIN(Lon-LonP)
y =  2·Rp·TAN(Pi/4+Lat/2)·COS(Lon-LonP)
```

Where `LonP` is the central longitude, `LatP` is the latitude of true scale and is always 90 or -90, and Rp is the polar radius of Mars or 3376.2 km.

The spherical inverse formulas for `Lat` and `Lon` from X and Y position in the image array are:

```
Lat = ARCSIN[COS(C)·SIN(LatP)+y·SIN(C)·COS(LatP)/P]

North Polar Stereographic
Lon = LonP + ARCTAN[x/(-y)]

South Polar Stereographic
Lon = LonP + ARCTAN[x/y]
```

where:

```
P = SQRT(x² + y²)

C =2·ARCTAN(P/2*Rp)
```

recall:

```
x = (Sample-S0-1)·Scale

y = (1-L0-Line)·Scale
```

The keywords corresponding to the equation parameters for the Polar Stereographic projection are located in the IMAGE_MAP_PROJECTION object found in the PDS labels. The keywords for each equation parameter are shown in table 3.5.0.

4 RDR Product Specification

4.1 Data Processing

Science data from the MRO payload experiments are packetized on the spacecraft, transmitted to Earth through the Deep Space Network, and sent to the Jet Propulsion Laboratory (JPL) through ground communications. The JPL Multi-Mission Operations Facility converts the packetized data back to the original science data format as produced by the instruments. For HiRISE observations, a raw science product is created for each CCD/Channel involved in the observation. The data are stored at JPL's Raw Science Data Server (RSDS) for access by the science teams.

At HiROC we have developed a ground data system that provides automated methods for retrieving and processing our images. Science data are automatically retrieved from the RSDS and passed to a series of pipeline procedures managed under the Conductor environment [16, 17] (http://pirlwww.lpl.arizona.edu/software). The pipelines generate intermediate products used for image evaluation and standard data products for science analysis. Additionally, the pipelines populate HiRISE catalog's EDR and RDR product tables and observation geometry tables with relevant metadata (see Figure 4.1.0). The product and geometry tables are used to generate index tables provided as part of the product distribution to the PDS [4]. The HiRISE team verifies observations were properly acquired and science objectives achieved. Missed targets or observations with poor viewing conditions are flagged for reacquisition at a later time.

HiROC uses the Integrated Software for Imagers and Spectrometers (ISIS) system [13] in the pipeline processing. ISIS contains a wide range of tools including radiometric calibration and cartographic processing procedures. The ISIS components applicable to HiRISE include radiometric calibration, map

projection transformation, image mosaicking, camera pointing correction, and general image enhancement, display, and analysis tools. For more information on this freely available image analysis package, see the ISIS web site (http://isis.astrogeology.usgs.gov/).

HiROC's pipeline processing starts when the WatchDog procedure, responsible for periodically monitoring the RSDS, determines a raw science data file is ready to be downloaded from the RSDS and passes the name of the product to the HiDog pipeline (Downlink Organizer). The HiDog pipeline retrieves the data product then submits the file name to the EDRgen pipeline (EDR generator) for creating the EDR product and populating the EDR product table with metadata about the product. The EDR_Stats pipeline creates an ISIS file and generates image statistics that are placed in the EDR products table. The HiCal pipeline performs the radiometric correction (see Section 4.1.1), and generates a browse and thumbnail image of the EDR product to be used by the HiRISE and PDS Imaging Node data-distribution web services. When the HiCal pipeline determines two channel files of a CCD have been calibrated the file names are passed on to the HiStitch pipeline for creating an intermediate CCD image file.
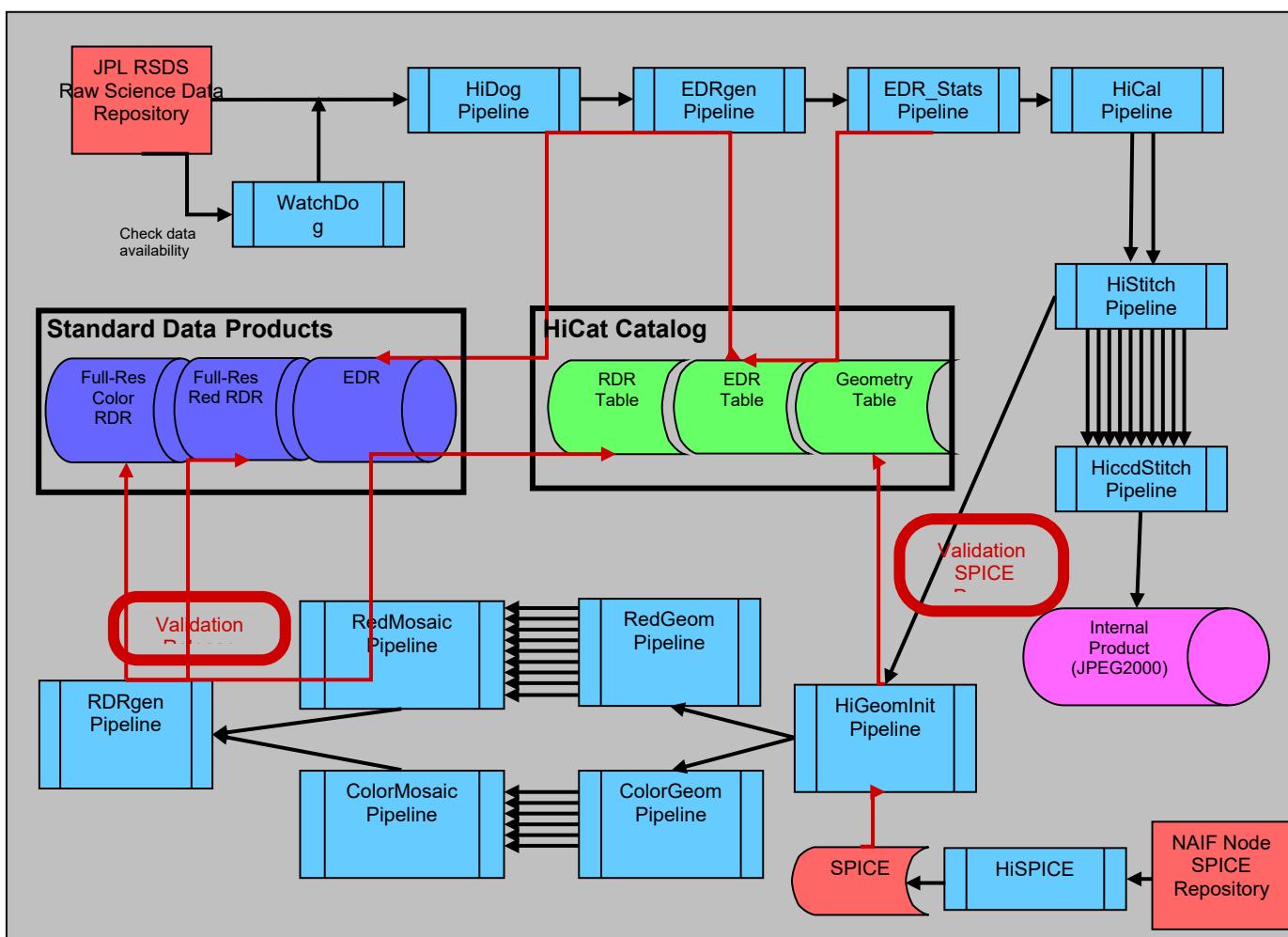
Figure 4.1.0 - HiROC pipeline system - HiRISE images pass through a series of processing pipelines starting with the retrieval of the raw science data from the RSDS. EDR products are generated early in the pipelines. Pipelines create intermediate products used to evaluate imaging. RDR processing continues when SPICE data are retrieved from the NAIF Node.

HiStitch additionally adjusts the channels to radiometrically match at the seam where the two channels come together. When the HiStitch pipeline determines all of the observation's CCDs have been stitched together for a filter set then the HiccdStitch pipeline is invoked to create an intermediate product with the CCDs stitched together to form a single image for the color filter. HiccdStitch additionally adjusts the CCD images to radiometrically match the overlapping areas of adjacent CCDs. Finally HiccdStitch creates an intermediate JPEG2000 image for evaluation by the HiRISE team.

At this point in the processing the EDR-validation step occurs (see Section 4.3). To continue the pipeline processing the reconstructed SPK and CK SPICE kernels [18], providing information about the observing viewing geometry and spacecraft ephemerides, need to be retrieved from the NAIF Node though HiROC's HiSPICE subsystem. Reconstructed SPICE kernels are generally provided to the MRO science teams one to two weeks after the observation was acquired. The HiGeomInit pipeline extracts the spacecraft ephemeris kernel (SPK) and C-matrix pointing kernel (CK) data from the SPICE files and transfers the data to the CCD image files for geometry processing by the pipelines that follow. Additionally HiGeomInit populates the observation geometry table with viewing geometry and coordinate metadata. See [4] for more information about the contents of the observation geometry table. The RedGeom and ColorGeom pipelines perform geometric processing on individual CCD images (see Section 4.1.2). The RedMosaic and ColorMosaic pipelines mosaic the projected CCD images to form an observational image (see Figure 4.1.1). Additionally these pipelines create RDR-product browse and thumbnail jpeg images for HiRISE and PDS Imaging Node web-based distribution services. The last pipeline step, RDRgen, creates the JPEG2000 image accompanied by a PDS detached label and populates the RDR product table with information about the product. Following a final validation step the EDR and RDR products are releasable to the PDS and science community.

4.1.1 Radiometric Calibration Correction

The radiometric calibration-correction procedure is described here at a high level. A detailed description will be provided in a future HiRISE calibration paper. The radiometric calibration correction is performed on each individual HiRISE channel file (EDR) correcting for instrument offset, dark current, and gain then converting to I/F reflectance.

The first step in the calibration, carried out by the ISIS *hiclean* program, corrects for instrument dark current and offset. The hiclean program uses the ancillary

calibration data (dark and mask pixels) [3] that accompany the science data to compute corrections in both the column (sample) and row (line) directions. The mask pixels, positioned at the start of the instrument output, provide dark current information for each column. The dark pixels, positioned at the end of each image row, capture the time dependent dark current and offset instrument drift.

The ISIS *hical* program then applies an intra-channel B0 (additive dark current matrix) and A0 (multiplicative gain matrix) correction for each column in the image array. The *hical* then converts the pixel values to I/F (intensity/flux, I/F = 1 for a 100% ideal lambertian reflector viewed normal to the surface) as described below:

For:

```
H  = dark current and offset corrected image, output of hiclean
B0 = intra-channel dark current correction (TDI & BIN dependent)
A0 = intra-channel gain correction (TDI and BIN dependent)
G  = global gain correction, normalizes CCD/channels
L  = observation line time
I  = I/F conversion factor at Sun-Target distance of 1.5 AU
AU = Mars-to-Sun distance (AU) at time of observation
Z  = radiometrically corrected image in I/F units
```

The correction is:

$$Z = ([H-(B0 \bullet L)]/L) \bullet A0 \bullet G * I * (1.5/AU)^2$$

Instrument instabilities result in radiometric mismatches requiring additional corrections for the varying column-to-column, channel-to-channel, and CCD-to-CCD sensitivities. Residual column-to-column variations are corrected by first computing the mean value for each column in an image array. The mean-value one-dimensional array is then high-pass filtered to eliminate low-frequency information due to scene content. The result of the high pass filter is then subtracted from the image array. CCD channels are adjusted to radiometrically match at the seam where the two channels come together (performed by the HiStitch pipeline). The CCDs are then radiometrically matched one to the other by matching the overlapping areas of adjacent CCDs (performed in the HiccdStitch pipeline).

4.1.2 Converting DN to I/F

There are two keywords in the PDS label (see section 4.5) that provide a mechanism to translate the DN integer value of the RDR image to I/F. The `SCALING_FACTOR` and `OFFSET` values in the IMAGE object are used for the conversion. The equation is as follows:

```
I/F = (DN * SCALING_FACTOR) + OFFSET
```

4.1.3 Geometric Processing

The geometric processing [13] corrects for the optical distortion and projects the observation from spacecraft viewing orientation to a map coordinate system. For RDR products the Equirectangular or Polar Stereographic projections are used (see Section 3.5). The geometry processing, carried out by ISIS program cam2map, uses cubic convolution resampling [14]. Geometry processing employs the NAIF toolkit (http://naif.jpl.nasa.gov) and uses reconstructed SPICE kernels generated by the MRO project. The geometry processing uses the MOLA Digital Terrain Model [15] to improve the camera pointing intercept position on the Martian surface.

In the geometric processing, individual channel images are stitched together to form CCD images using the ISIS program *histitch*. The *spiceinit* program searches through the available NAIF kernel set and applies planet and spacecraft ephemeris data to establish geometric properties of each CCD image. CCD images are then individually map projected with cam2map and mosaicked together using *himos* forming an image of the entire observation. Resulting image maps vary in size depending on the number of CCDs commanded, number of lines acquired and the binning mode of the images. RDR products can be very large, at times exceeding 40,000 x 100,000 pixels. Observations with mixed binning modes are resampled to the same pixel scale depending on the minimum binning used in the observation. For the Transition Orbit Phase (TRA) and Primary Science Phase (PSP), observations with unbinned imaging are uniformly mapped to a constant 0.25 m/pixel resolution (0.50 m/pixel for minimum binning 2 and 1.0 for binning 4). The Aerobraking phase images (AEB) are mapped to a pixel scale depending on the spacecraft altitude and the minimum binning. Figure 4.1.1 shows the geometry processing on Aerobraking-observation AEB_000002_0000, commanded to acquire imaging with CCDs RED4, RED5, and RED6, and the blue-green and near-infrared CCDS resulting in 14 EDR products, one for each channel. The single-color RDR is identified as product AEB_000002_0000_RED.

EDR Products → Geometry Processing → RDR Product
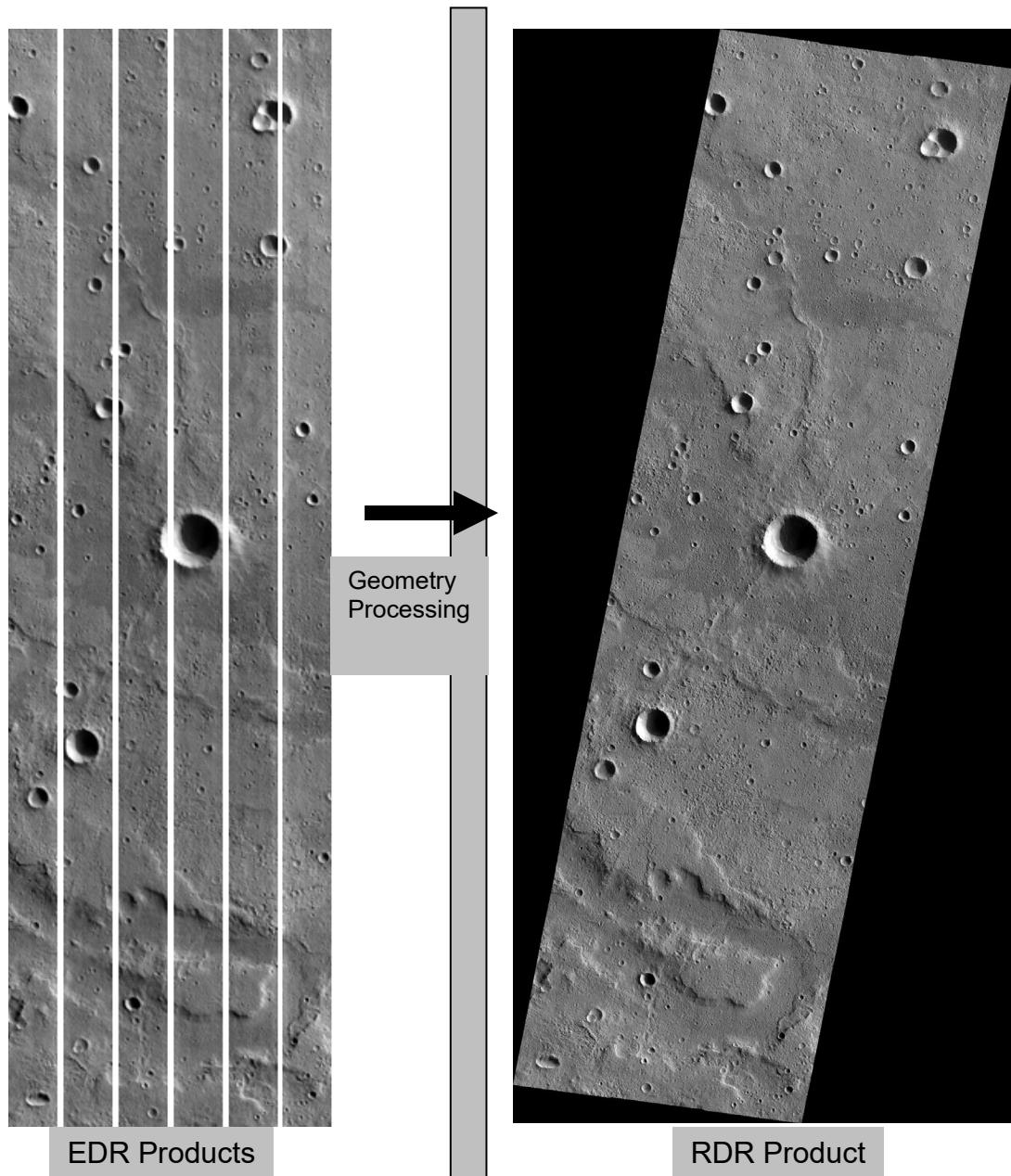
Figure 4.1.1 - Geometry processing on Observation AEB_000002_0000. Commanded CCDs RED4, RED5, RED6 images are used to construct the Red-filter RDR product. Each channel is 1,240(s) x 23,000(l). Geometry processing creates an Equirectangular projection at a pixel scale of 2.485 meters/pixel centered at Planetocentric Latitude -33.6, East Longitude 146.0. Resulting images is 10,743(s) x 23,488(l).

For three-color imaging additional processing steps are required to create the three-color RDR products. Spacecraft jitter exists at a higher frequency than can be captured by the reconstructed pointing kernels. The color CCDs see a point on the planet surface separated by ~120 milliseconds resulting in jitter-induced pointing misalignments not captured by the reconstructed pointing matrix. To minimize color misregistration the blue-green and near-infrared filters are spatially matched through a two-step empirical approach. In the first step the

blue-green and near-infrared filter CCD images (usually acquired at a higher binning level than the red-filter CCDs) are scaled to match the binning of the red-filter CCD imaging. Next, an ISIS program, *hijitreg*, applies an image coregistration process constructing a control network that spatially maps the blue-green and near-infrared filter imaging to the red filter imaging. The control network is provided to the second step responsible for resampling the blue-green and near-infrared filter images to the red. The program, *slither*, performs a one-dimensional cubic-spline transformation performing translational shifts on otherwise undistorted individual lines. Once the blue-green and near-infrared images are spatially registered to match the red imaging, the images go through the same geometric processing to create a map-projected image as described above.

The CENTER_FILTER_WAVELENGTH keyword provides information about the spectral center wavelength (see Section 4.5 and Appendix A). The storage order for the three-color products is near-infrared (band 1), red (band 2), and blue-green (band 3).

4.2 Data Volumes

Approximately 10,000 observations will be acquired during the two-year Primary Science Phase. Each observation will typically have a RED and COLOR RDR product. The total volume for the RDR products is estimated to be 18,000 gigabytes (see [4] for more information about data product volumes).

4.3 Data Validation

The MRO Data Archive Working Group (DARWG) oversees and coordinates the validation of instrument team data products for release to the PDS [2] in a process by which the science teams and the PDS participate.

HiROC's HiVali subsystem enables the HiRISE team to validate EDR and RDR products. EDR product validation verifies image data are properly formatted, the PDS label is properly constructed, and the metadata describing the observation are accurate. If an EDR can successfully be created from the raw science data then the EDR will be released to the PDS regardless of data quality. So for example, even if an observation contained virtually all saturated data then it would still be released to the PDS as long as the EDR could be properly constructed. There are rare cases when an EDR product cannot be generated from the raw science observational data when there are significant data gaps due to loss of telemetry packets. EDR product generation can fail when data gaps prevent the FELICS decompression software from properly decompressing the image data or there is a loss of critical engineering data that would prevent the EDR generation software from creating an EDR.

RDR products go through the same validation to verify the products are properly constructed, the PDS labels are properly constructed, and the metadata describing the observation are accurate. There are cases when an RDR product cannot be created from EDR products. In rare cases, SPICE kernel data may not be available for an observation so geometry processing cannot be performed. In other cases the instrument calibration step fails to calibrate an image due to high instrument noise levels such as seen in channel 1 of CCDs IR10 and RED9 EDR products. If an EDR channel product cannot be calibrated then it is excluded from the RDR processing. In rare cases the ISIS hijitreg program (see section 4.1.3) fails to co-register the color imaging resulting in a color RDR product not being generated. The hijitreg can fail under certain circumstances such as when the spacecraft jitter exceeds tolerable levels or when the image correlation routines fail to co-locate common features in the within the three color imaging.

4.4 RDR File Naming Convention

HiRISE Observation IDs are 15 characters in length containing three fields: a mission phase Identification, orbit number (or sequence code for Aerobraking images), and target code.

The mission phase identification is a three-character abbreviation. For Mars orbit observations these identifications are:

    AEB   - Aerobraking Phase
    TRA   - Transition Orbit Phase
    PSP   - Primary Science Phase
    REL   - Relay Phase (if needed)
    E01   - 1st Extended Mission Phase (if needed)
    Exx   - Any possible extended mission phase (if needed)

The orbit number is a six-digit, zero-padded number (example "001000"). For Aerobraking images (only 8 images were acquired during this phase) the field represents a sequence identification chronologically ordered.

The target code is a four-digit zero-padded chronologically ordered number within an orbit. For values 0000 – 3595, it is the angle between the nighttime equator (starting position of an MRO orbit) and the latitude of the center of the observation, multiplied by 10. It is measured to the nearest half-degree. The nighttime equator is 0000, the South Pole is 0900, the daytime equator is 1800, and the North Pole is 2700. If the target code is between 9000 and 9303, it indicates an off-planet observation such as Deimos, Phobos, or a star.

As an example, the Observation ID: PSP_002170_0990, is a Primary Science

Phase observation, acquired on orbit 2170. The observation was acquired near the South Pole.

The RDR product file names are constructed by appending "_RED" or "_COLOR" to the Observation ID. The "_RED" designation is a single-band image compiled from the Red-filter images operating during the observation. The "_COLOR" designation is a three-color image complied from the overlapping blue-green, red, and near-infrared detectors. There are two files associated with each product differentiated by a file name extension. A file extension "JP2" is the JPEG2000 image, ".LBL" is the detached PDS label file (see Section 4.5). The RDR products are organized in a directory structure described in [4]. Example RDR product files names are:

TRA_000823_1720_RED.JP2 – The JPEG2000 image containing a single band of the red-filter CCDs. The detached label has the same file name but with extension ".LBL". This is a Transition Orbit Phase image acquired in orbit 823 with the target code 1720.

PSP_001333_2485_COLOR.JP2 – The JPEG2000 image containing three-color bands generated from the overlapping blue-green, red, and near-infrared CCDs. The detached label has the same file name but with extension ".LBL". This is a Primary Science Phase image acquired in orbit 1333 with the target code 2485.

4.5 PDS labels

The PDS label shown below is an example from a RDR product. The PDS label for a RDR product is detached from the JPEG2000 file. Appendix A provides a definition of each keyword listed in the PDS label.

*************************** Example PDS Label ***************************

```
PDS_VERSION_ID            = PDS3
/*  Identification Information  */
NOT_APPLICABLE_CONSTANT   = -9998
DATA_SET_ID               = "MRO-M-HIRISE-3-RDR-V1.0"
DATA_SET_NAME             = "MRO MARS HIGH RESOLUTION IMAGE SCIENCE EXPERIMENT
                             RDR V1.0"
PRODUCER_INSTITUTION_NAME = "UNIVERSITY OF ARIZONA"
PRODUCER_ID               = "UA"
PRODUCER_FULL_NAME        = "ALFRED MCEWEN"
OBSERVATION_ID            = "TRA_000823_1720"
PRODUCT_ID                = "TRA_000823_1720_RED"
PRODUCT_VERSION_ID        = "1.0"
INSTRUMENT_HOST_NAME      = "MARS RECONNAISSANCE ORBITER"
INSTRUMENT_HOST_ID        = "MRO"
INSTRUMENT_NAME           = "HIGH RESOLUTION IMAGING SCIENCE EXPERIMENT"
INSTRUMENT_ID             = "HIRISE"
TARGET_NAME               = "MARS"
MISSION_PHASE_NAME        = "TRANSITION"
ORBIT_NUMBER              = 823
SOURCE_PRODUCT_ID         = (TRA_000823_1720_RED0_1, TRA_000823_1720_RED0_0,
                             TRA_000823_1720_RED1_1, TRA_000823_1720_RED1_0,
                             TRA_000823_1720_RED2_1, TRA_000823_1720_RED2_0,
                             TRA_000823_1720_RED3_1, TRA_000823_1720_RED3_0,
```

```
                              TRA_000823_1720_RED4_1, TRA_000823_1720_RED4_0,
                              TRA_000823_1720_RED5_1, TRA_000823_1720_RED5_0,
                              TRA_000823_1720_RED6_1, TRA_000823_1720_RED6_0,
                              TRA_000823_1720_RED7_1, TRA_000823_1720_RED7_0,
                              TRA_000823_1720_RED8_1, TRA_000823_1720_RED8_0,
                              TRA_000823_1720_RED9_1, TRA_000823_1720_RED9_0)
   RATIONALE_DESC             = "First ITL image; Layered deposits in Iu Chasma
                                floor"
   SOFTWARE_NAME              = "Isis 3.1.11 | 2007-04-20 hirdrgen"
   OBJECT = IMAGE_MAP_PROJECTION
       ^DATA_SET_MAP_PROJECTION    = "DSMAP.CAT"
       MAP_PROJECTION_TYPE         = "EQUIRECTANGULAR"
       PROJECTION_LATITUDE_TYPE    = PLANETOCENTRIC
       /*  NOTE: The EQUIRECTANGULAR projection is based on the formula   */
       /*  for a sphere. To eliminate confusion in the                    */
       /*  IMAGE_MAP_PROJECTION object we have set all three radii,       */
       /*  A_AXIS_RADIUS, B_AXIS_RADIUS, and C_AXIS_RADIUS to the same    */
       /*  number. The value recorded in the three radii is the local     */
       /*  radius at the CENTER_LATITUDE on the Mars ellipsoid. That is,  */
       /*  equatorial radius of 3396.190000 km and polar radius of        */
       /*  3376.200000 kilometers. Using the local radius of the          */
       /*  ellipsoid implies that the MAP_SCALE and MAP_RESOLUTION are    */
       /*  true at the CENTER_LATITUDE.                                   */
       A_AXIS_RADIUS               = 3396.036813 <KM>
       B_AXIS_RADIUS               = 3396.036813 <KM>
       C_AXIS_RADIUS               = 3396.036813 <KM>
       COORDINATE_SYSTEM_NAME      = PLANETOCENTRIC
       POSITIVE_LONGITUDE_DIRECTION = EAST
       KEYWORD_LATITUDE_TYPE       = PLANETOCENTRIC
       /*  NOTE:  CENTER_LATITUDE and CENTER_LONGITUDE describe the location  */
       /*  of the center of projection, which is not necessarily equal to the */
       /*  location of the center point of the image.                        */
       CENTER_LATITUDE             = -5.000000 <DEG>
       CENTER_LONGITUDE            = 279.497000 <DEG>
       LINE_FIRST_PIXEL            = 1
       LINE_LAST_PIXEL             = 23520
       SAMPLE_FIRST_PIXEL          = 1
       SAMPLE_LAST_PIXEL           = 23707
       MAP_PROJECTION_ROTATION     = 0.000000 <DEG>
       MAP_RESOLUTION              = 237088.095595 <PIX/DEG>
       MAP_SCALE                   = 0.2500 <METERS/PIXEL>
       MAXIMUM_LATITUDE            = -7.692761 <DEG>
       MINIMUM_LATITUDE            = -7.791952 <DEG>
       LINE_PROJECTION_OFFSET      = -1823859.50000 <PIXEL>
       SAMPLE_PROJECTION_OFFSET    = 11788.50000 <PIXEL>
       EASTERNMOST_LONGITUDE       = 279.547459 <DEG>
       WESTERNMOST_LONGITUDE       = 279.447099 <DEG>
   END_OBJECT = IMAGE_MAP_PROJECTION
   /*  All xxx_COUNT values are for the MRO spacecraft clock (SCLK)       */
   /*  in seconds:subseconds form. A subsecond tick = 15.2588 microseconds. */
   /*  All xxx_TIME values are referenced to UTC.                         */
   GROUP = TIME_PARAMETERS
       /*  Time when the observation first started  */
       MRO:OBSERVATION_START_TIME  = 2006-09-29T15:16:33.204
       /*  Time of the first image line  */
       START_TIME                  = 2006-09-29T15:16:33.333
       SPACECRAFT_CLOCK_START_COUNT = "844010212:09362"
       /*  Time of the last image line  */
       STOP_TIME                   = 2006-09-29T15:16:35.047
       SPACECRAFT_CLOCK_STOP_COUNT = "844010213:56143"
       /*  Time when this RDR product was created  */
       PRODUCT_CREATION_TIME       = 2007-05-17T20:03:20.0
   END_GROUP = TIME_PARAMETERS
   GROUP = INSTRUMENT_SETTING_PARAMETERS
       MRO:CCD_FLAG                = (ON, ON, ON, ON, ON, ON, ON, ON, ON, ON, ON,
                                     ON, ON, ON)
       MRO:BINNING                 = (2, 2, 2, 2, 1, 1, 1, 2, 2, 2, -9998, -9998,
                                     -9998, -9998)
       MRO:TDI                     = (64, 64, 64, 64, 128, 128, 128, 64, 64, 64,
                                     -9998, -9998, -9998, -9998)
       MRO:SPECIAL_PROCESSING_FLAG = (NOMINAL, NOMINAL, NOMINAL, NOMINAL,
```

```
                                NOMINAL, NOMINAL, NOMINAL, NOMINAL, NOMINAL,
                                NOMINAL, NULL, NULL, NULL, NULL)
END_GROUP = INSTRUMENT_SETTING_PARAMETERS
GROUP = VIEWING_PARAMETERS
    INCIDENCE_ANGLE   = 59.635459 <DEG>
    EMISSION_ANGLE    = 0.050510 <DEG>
    PHASE_ANGLE       = 59.640054 <DEG>
    LOCAL_TIME        = 15.48579 <LOCALDAY/24>
    SOLAR_LONGITUDE   = 113.547466 <DEG>
    SUB_SOLAR_AZIMUTH = 212.278322 <DEG>
    NORTH_AZIMUTH     = 269.999999 <DEG>
END_GROUP = VIEWING_PARAMETERS

/* The JPEG2000 image data file associated with this label. */
OBJECT = COMPRESSED_FILE
    FILE_NAME                   = "TRA_000823_1720_RED.JP2"
    RECORD_TYPE                 = UNDEFINED
    ENCODING_TYPE               = "JP2"
    ENCODING_TYPE_VERSION_NAME  = "ISO/IEC15444-1:2004"
    INTERCHANGE_FORMAT          = BINARY
    /* The name of the original source file. */
    UNCOMPRESSED_FILE_NAME      = "TRA_000823_1720_RED.IMG"
    /* The amount of original image data. */
    REQUIRED_STORAGE_BYTES      = 1115177280 <BYTES>
    ^DESCRIPTION                = "JP2INFO.TXT"
END_OBJECT = COMPRESSED_FILE

/* The source image data definition. */
OBJECT = UNCOMPRESSED_FILE
    FILE_NAME    = "TRA_000823_1720_RED.IMG"
    RECORD_TYPE  = FIXED_LENGTH
    RECORD_BYTES = 47414 <BYTES>
    FILE_RECORDS = 23520
    ^IMAGE       = "TRA_000823_1720_RED.IMG"
    OBJECT = IMAGE
        DESCRIPTION              = "HiRISE projected and mosaicked product"
        LINES                    = 23520
        LINE_SAMPLES             = 23707
        BANDS                    = 1
        SAMPLE_TYPE              = MSB_UNSIGNED_INTEGER
        SAMPLE_BITS              = 16
        SAMPLE_BIT_MASK          = 2#0000001111111111#
        /*  NOTE: The conversion from DN to I/F (intensity/flux) is:  */
        /*  I/F = (DN * SCALING_FACTOR) + OFFSET                       */
        /*  I/F is defined as the ratio of the observed radiance and  */
        /*  the radiance of a 100% lambertian reflector with the sun  */
        /*  and camera orthogonal to the observing surface.           */
        SCALING_FACTOR           = 1.09905280703979e-04
        OFFSET                   = 0.054890907183266
        BAND_STORAGE_TYPE        = BAND_SEQUENTIAL
        CORE_NULL                = 0
        CORE_LOW_REPR_SATURATION   = 1
        CORE_LOW_INSTR_SATURATION  = 2
        CORE_HIGH_REPR_SATURATION  = 1023
        CORE_HIGH_INSTR_SATURATION = 1022
        CENTER_FILTER_WAVELENGTH = 700 <NM>
        MRO:MINIMUM_STRETCH      = 3
        MRO:MAXIMUM_STRETCH      = 1021
        FILTER_NAME              = "RED"
    END_OBJECT = IMAGE
END_OBJECT = UNCOMPRESSED_FILE
END
```

4.6 Conversion to PDS 4

For PDS 4, archiving standards have been updated to require formats for

standard products that are not encoded. This includes compression or other encoding that may adversely impact long term access to archival standard products. The JPEG2000 standard is such a format and must be abandoned for acceptance in PDS4. Note: Ancillary products are not restricted in this way, and JPEG2000 is still be used in the HiRISE archive for these products. For PDS 4, the PDS 3 JPEG2000 standard RDRs will be converted into GeoTIFF products. These products will be compliant with version 6 of the TIFF standard as this version of the standard includes the specification for including geospatial information in the the TIFF file. The "GeoTIFF Box" stored in the JPEG2000 PDS3 files will be reproduced (and/or updated) to match the current GeoTIFF standard and will be stored in the header of the GeoTIFF file.

The baseline file naming convention specified in section 4.4 will be maintained, however, the GeoTIFF files will have a ".tif" extension and the PDS4 labels will have a ".xml" extension.

**************************** Example PDS 4 Label ****************************

```
<?xml version="1.0" encoding="UTF-8"?>
<?xml-model href="https://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1J00.sch"
schematypens="http://purl.oclc.org/dsdl/schematron"?>
<?xml-model href="./PDS4_MRO_1I00_1300.sch"
schematypens="http://purl.oclc.org/dsdl/schematron"?>
<?xml-model href="http://pds.nasa.gov/pds4/disp/v1/PDS4_DISP_1J00_1510.sch"
schematypens="http://purl.oclc.org/dsdl/schematron"?>
<?xml-model href="http://pds.nasa.gov/pds4/cart/v1/PDS4_CART_1J00_1970.sch"
schematypens="http://purl.oclc.org/dsdl/schematron"?>
<?xml-model href="http://pds.nasa.gov/pds4/img/v1/PDS4_IMG_1J00_1870.sch"
schematypens="http://purl.oclc.org/dsdl/schematron"?>
<?xml-model href="https://pds.nasa.gov/pds4/proc/v1/PDS4_PROC_1I00_1210.sch"
schematypens="http://purl.oclc.org/dsdl/schematron"?>
<?xml-model href="https://pds.nasa.gov/pds4/geom/v1/PDS4_GEOM_1J00_1960.sch"
schematypens="http://purl.oclc.org/dsdl/schematron"?>
<Product_Observational xmlns="http://pds.nasa.gov/pds4/pds/v1"
xmlns:pds="http://pds.nasa.gov/pds4/pds/v1"
xmlns:disp="http://pds.nasa.gov/pds4/disp/v1"
xmlns:cart="http://pds.nasa.gov/pds4/cart/v1"
xmlns:mro="http://pds.nasa.gov/pds4/mission/mro/v1"
xmlns:img="http://pds.nasa.gov/pds4/img/v1"
xmlns:proc="http://pds.nasa.gov/pds4/proc/v1"
xmlns:geom="http://pds.nasa.gov/pds4/geom/v1"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://pds.nasa.gov/pds4/pds/v1
https://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1J00.xsd
```

```
http://pds.nasa.gov/pds4/mission/mro/v1 ./PDS4_MRO_1I00_1300.xsd
http://pds.nasa.gov/pds4/disp/v1
http://pds.nasa.gov/pds4/disp/v1/PDS4_DISP_1J00_1510.xsd
http://pds.nasa.gov/pds4/cart/v1
http://pds.nasa.gov/pds4/cart/v1/PDS4_CART_1J00_1970.xsd
http://pds.nasa.gov/pds4/img/v1
https://pds.nasa.gov/pds4/img/v1/PDS4_IMG_1J00_1870.xsd
http://pds.nasa.gov/pds4/geom/v1
https://pds.nasa.gov/pds4/geom/v1/PDS4_GEOM_1J00_1960.xsd
http://pds.nasa.gov/pds4/proc/v1
https://pds.nasa.gov/pds4/proc/v1/PDS4_PROC_1I00_1210.xsd">
<Identification_Area>

<logical_identifier>urn:nasa:pds:hirise.mro:map_projected_rdr:esp_044885_2055</logical_identifier>
    <version_id>1.0</version_id>
    <!-- Note the title below may need to be parameterized if the projections can be made
to use the same template -->
    <title>MRO MARS HIGH RESOLUTION IMAGING SCIENCE EXPERIMENT
REDUCED DATA RECORD EQUIRECTANGULAR PROJECTION</title>
    <information_model_version>1.19.0.0</information_model_version>
    <product_class>Product_Observational</product_class>
    <Alias_List>
     <Alias>
       <alternate_id>ESP_044885_2055_COLOR.tif</alternate_id>
       <comment>Original filename at PDS4 archive, on-line at HiRISE Node</comment>
     </Alias>
    </Alias_List>
    <Modification_History>
     <Modification_Detail>
       <modification_date>2023-05-15</modification_date>
       <version_id>1.0</version_id>
       <description>This PDS4 labeled (detached label) product is a result
                of develment activity for eventual HiRISE migration to PDS4.
          </description>
     </Modification_Detail>
    </Modification_History>
  </Identification_Area>
  <Observation_Area>
   <Time_Coordinates>
     <start_date_time>2016-02-22T22:39:43.433Z</start_date_time>
     <stop_date_time>2016-02-22T22:39:45.654Z</stop_date_time>
     <local_true_solar_time>14.94540</local_true_solar_time>
```

```xml
    <solar_longitude unit="deg">112.837127</solar_longitude>
  </Time_Coordinates>
  <Primary_Result_Summary>
    <purpose>Science</purpose>
    <processing_level>Derived</processing_level>
    <description>Calibrated, mosaicked and map-projected HiRISE observation of the
target in GeoTIFF format</description>
  </Primary_Result_Summary>
  <Investigation_Area>
    <name>Product_Observational</name>
    <type>Mission</type>
    <Internal_Reference>

<lid_reference>urn:nasa:pds:context:investigation:mission.mars_reconnaissance_orbiter
</lid_reference>
      <reference_type>data_to_investigation</reference_type>
      <comment>This is the PDS4 logical identifier for MRO</comment>
    </Internal_Reference>
  </Investigation_Area>
  <Observing_System>
    <Observing_System_Component>
      <name>HIGH RESOLUTION IMAGING SCIENCE EXPERIMENT</name>
      <type>Instrument</type>
      <Internal_Reference>
        <lid_reference>urn:nasa:pds:context:instrument:hirise.mro</lid_reference>
        <reference_type>is_instrument</reference_type>
      </Internal_Reference>
    </Observing_System_Component>
  </Observing_System>
  <Target_Identification>
    <name>Mars</name>
    <type>Planet</type>
    <description>Mini cinder cones in Aetheria region</description>
    <!-- using this field for RATIONALE_DESC -->
    <Internal_Reference>
      <lid_reference>urn:nasa:pds:context:target:planet.mars</lid_reference>
      <reference_type>data_to_target</reference_type>
    </Internal_Reference>
  </Target_Identification>
  <Mission_Area>
    <mro:MRO_Parameters>
      <!-- parameters for all MRO products -->
      <mro:product_type>RDR</mro:product_type>
```

```xml
<mro:product_version_id>1.0</mro:product_version_id>
<mro:orbit_number>44885</mro:orbit_number>
<mro:mission_phase_name>Extended Science</mro:mission_phase_name>
<!-- The partition value is currently a place holder, the naif tool chronos
     can be used to compute it...just need to integrate it into the converstion script -
->
<mro:spacecraft_clock_count_partition>1</mro:spacecraft_clock_count_partition>

<mro:spacecraft_clock_start_count>1140648026:18327</mro:spacecraft_clock_start_count>

<mro:spacecraft_clock_stop_count>1140648028:28984</mro:spacecraft_clock_stop_count>
<mro:producer_institution_name>University of
Arizona</mro:producer_institution_name>
<!-- parameters for HiRISE products -->
<mro:HiRISE_Time_Parameters>
  <mro:observation_start_time>2016-02-
22T22:39:43.380Z</mro:observation_start_time>
</mro:HiRISE_Time_Parameters>
<mro:HiRISE_Instrument_Setting_Parameters/>
<mro:HiRISE_Temperature_Parameters/>
<mro:HiRISE_Power_Parameters/>
<mro:HiRISE_RDR_Parameters>
 <mro:ccd_flag_red0>ON</mro:ccd_flag_red0>
 <mro:ccd_flag_red1>ON</mro:ccd_flag_red1>
 <mro:ccd_flag_red2>ON</mro:ccd_flag_red2>
 <mro:ccd_flag_red3>ON</mro:ccd_flag_red3>
 <mro:ccd_flag_red4>ON</mro:ccd_flag_red4>
 <mro:ccd_flag_red5>ON</mro:ccd_flag_red5>
 <mro:ccd_flag_red6>ON</mro:ccd_flag_red6>
 <mro:ccd_flag_red7>ON</mro:ccd_flag_red7>
 <mro:ccd_flag_red8>ON</mro:ccd_flag_red8>
 <mro:ccd_flag_red9>OFF</mro:ccd_flag_red9>
 <mro:ccd_flag_ir10>ON</mro:ccd_flag_ir10>
 <mro:ccd_flag_ir11>ON</mro:ccd_flag_ir11>
 <mro:ccd_flag_bg12>ON</mro:ccd_flag_bg12>
 <mro:ccd_flag_bg13>ON</mro:ccd_flag_bg13>
 <mro:binning_red0 xsi:nil="true" nilReason="inapplicable"/>
 <mro:binning_red1 xsi:nil="true" nilReason="inapplicable"/>
 <mro:binning_red2 xsi:nil="true" nilReason="inapplicable"/>
 <mro:binning_red3 xsi:nil="true" nilReason="inapplicable"/>
 <mro:binning_red4>1</mro:binning_red4>
```

```
<mro:binning_red5>1</mro:binning_red5>
<mro:binning_red6 xsi:nil="true" nilReason="inapplicable"/>
<mro:binning_red7 xsi:nil="true" nilReason="inapplicable"/>
<mro:binning_red8 xsi:nil="true" nilReason="inapplicable"/>
<mro:binning_red9 xsi:nil="true" nilReason="inapplicable"/>
<mro:binning_ir10>2</mro:binning_ir10>
<mro:binning_ir11>2</mro:binning_ir11>
<mro:binning_bg12>2</mro:binning_bg12>
<mro:binning_bg13>2</mro:binning_bg13>
<mro:tdi_red0 xsi:nil="true" nilReason="inapplicable"/>
<mro:tdi_red1 xsi:nil="true" nilReason="inapplicable"/>
<mro:tdi_red2 xsi:nil="true" nilReason="inapplicable"/>
<mro:tdi_red3 xsi:nil="true" nilReason="inapplicable"/>
<mro:tdi_red4>128</mro:tdi_red4>
<mro:tdi_red5>128</mro:tdi_red5>
<mro:tdi_red6 xsi:nil="true" nilReason="inapplicable"/>
<mro:tdi_red7 xsi:nil="true" nilReason="inapplicable"/>
<mro:tdi_red8 xsi:nil="true" nilReason="inapplicable"/>
<mro:tdi_red9 xsi:nil="true" nilReason="inapplicable"/>
<mro:tdi_ir10>128</mro:tdi_ir10>
<mro:tdi_ir11>128</mro:tdi_ir11>
<mro:tdi_bg12>128</mro:tdi_bg12>
<mro:tdi_bg13>128</mro:tdi_bg13>
<mro:special_processing_flag_red0>NULL</mro:special_processing_flag_red0>
<mro:special_processing_flag_red1>NULL</mro:special_processing_flag_red1>
<mro:special_processing_flag_red2>NULL</mro:special_processing_flag_red2>
<mro:special_processing_flag_red3>NULL</mro:special_processing_flag_red3>

<mro:special_processing_flag_red4>NOMINAL</mro:special_processing_flag_red4>
<mro:special_processing_flag_red5>NULL</mro:special_processing_flag_red5>
<mro:special_processing_flag_red6>NULL</mro:special_processing_flag_red6>
<mro:special_processing_flag_red7>NULL</mro:special_processing_flag_red7>
<mro:special_processing_flag_red8>NULL</mro:special_processing_flag_red8>
<mro:special_processing_flag_red9>NULL</mro:special_processing_flag_red9>

<mro:special_processing_flag_ir10>NOMINAL</mro:special_processing_flag_ir10>
<mro:special_processing_flag_ir11>NULL</mro:special_processing_flag_ir11>

<mro:special_processing_flag_bg12>NOMINAL</mro:special_processing_flag_bg12>
<mro:special_processing_flag_bg13>NULL</mro:special_processing_flag_bg13>
<mro:minimum_stretch>3</mro:minimum_stretch>
<mro:maximum_stretch>1021</mro:maximum_stretch>
</mro:HiRISE_RDR_Parameters>
```

```
        </mro:MRO_Parameters>
      </Mission_Area>
      <Discipline_Area>
        <img:Imaging>
          <Local_Internal_Reference>
            <local_identifier_reference>DATA_FILE</local_identifier_reference>

<local_reference_type>imaging_parameters_to_image_object</local_reference_type>
          </Local_Internal_Reference>
          <img:Optical_Filter>
            <img:filter_name>NEAR-INFRARED</img:filter_name>
            <img:bandwidth unit="nm">100</img:bandwidth>
            <img:center_filter_wavelength unit="nm">900</img:center_filter_wavelength>
          </img:Optical_Filter>
          <img:Optical_Filter>
            <img:filter_name>RED</img:filter_name>
            <img:bandwidth unit="nm">300</img:bandwidth>
            <img:center_filter_wavelength unit="nm">700</img:center_filter_wavelength>
          </img:Optical_Filter>
          <img:Optical_Filter>
            <img:filter_name>BLUE-GREEN</img:filter_name>
            <img:bandwidth unit="nm">150</img:bandwidth>
            <img:center_filter_wavelength unit="nm">500</img:center_filter_wavelength>
          </img:Optical_Filter>
        </img:Imaging>
        <proc:Processing_Information>
          <Local_Internal_Reference>
            <local_identifier_reference>DATA_FILE</local_identifier_reference>

<local_reference_type>processing_information_to_data_object</local_reference_type>
          </Local_Internal_Reference>
          <proc:Input_Product_List>
            <proc:Input_Product>
              <Internal_Reference>

<lid_reference>urn:nasa:pds:hirise.mro.data:edr:esp_044885_2055_bg12_0</lid_reference>
                <reference_type>lid_reference</reference_type>
              </Internal_Reference>
            </proc:Input_Product>
            <proc:Input_Product>
              <Internal_Reference>
```

```
<lid_reference>urn:nasa:pds:hirise.mro.data:edr:esp_044885_2055_bg12_1</lid_referen
ce>
         <reference_type>lid_reference</reference_type>
       </Internal_Reference>
      </proc:Input_Product>
      <proc:Input_Product>
       <Internal_Reference>

<lid_reference>urn:nasa:pds:hirise.mro.data:edr:esp_044885_2055_red4_0</lid_referen
ce>
         <reference_type>lid_reference</reference_type>
       </Internal_Reference>
      </proc:Input_Product>
      <proc:Input_Product>
       <Internal_Reference>

<lid_reference>urn:nasa:pds:hirise.mro.data:edr:esp_044885_2055_red4_1</lid_referen
ce>
         <reference_type>lid_reference</reference_type>
       </Internal_Reference>
      </proc:Input_Product>
      <proc:Input_Product>
       <Internal_Reference>

<lid_reference>urn:nasa:pds:hirise.mro.data:edr:esp_044885_2055_ir10_0</lid_referenc
e>
         <reference_type>lid_reference</reference_type>
       </Internal_Reference>
      </proc:Input_Product>
      <proc:Input_Product>
       <Internal_Reference>

<lid_reference>urn:nasa:pds:hirise.mro.data:edr:esp_044885_2055_ir10_1</lid_referenc
e>
         <reference_type>lid_reference</reference_type>
       </Internal_Reference>
      </proc:Input_Product>
      <proc:Input_Product>
       <Internal_Reference>

<lid_reference>urn:nasa:pds:hirise.mro.data:edr:esp_044885_2055_bg13_0</lid_referen
ce>
```

```xml
          <reference_type>lid_reference</reference_type>
        </Internal_Reference>
      </proc:Input_Product>
      <proc:Input_Product>
        <Internal_Reference>

<lid_reference>urn:nasa:pds:hirise.mro.data:edr:esp_044885_2055_bg13_1</lid_reference>
          <reference_type>lid_reference</reference_type>
        </Internal_Reference>
      </proc:Input_Product>
      <proc:Input_Product>
        <Internal_Reference>

<lid_reference>urn:nasa:pds:hirise.mro.data:edr:esp_044885_2055_red5_0</lid_reference>
          <reference_type>lid_reference</reference_type>
        </Internal_Reference>
      </proc:Input_Product>
      <proc:Input_Product>
        <Internal_Reference>

<lid_reference>urn:nasa:pds:hirise.mro.data:edr:esp_044885_2055_red5_1</lid_reference>
          <reference_type>lid_reference</reference_type>
        </Internal_Reference>
      </proc:Input_Product>
      <proc:Input_Product>
        <Internal_Reference>

<lid_reference>urn:nasa:pds:hirise.mro.data:edr:esp_044885_2055_ir11_0</lid_reference>
          <reference_type>lid_reference</reference_type>
        </Internal_Reference>
      </proc:Input_Product>
      <proc:Input_Product>
        <Internal_Reference>

<lid_reference>urn:nasa:pds:hirise.mro.data:edr:esp_044885_2055_ir11_1</lid_reference>
          <reference_type>lid_reference</reference_type>
        </Internal_Reference>
      </proc:Input_Product>
```

```xml
        </proc:Input_Product_List>
      </proc:Processing_Information>
      <cart:Cartography>
       <Local_Internal_Reference>
         <local_identifier_reference>Array_3D_Image</local_identifier_reference>

<local_reference_type>cartography_parameters_to_image_object</local_reference_type>
>
       </Local_Internal_Reference>
       <cart:Spatial_Domain>
        <cart:Bounding_Coordinates>
         <cart:west_bounding_coordinate
unit="deg">110.426666765393009</cart:west_bounding_coordinate>
         <cart:east_bounding_coordinate
unit="deg">110.466362665588775</cart:east_bounding_coordinate>
         <cart:north_bounding_coordinate
unit="deg">25.129079271654323</cart:north_bounding_coordinate>
         <cart:south_bounding_coordinate
unit="deg">25.0238386531276724</cart:south_bounding_coordinate>
        </cart:Bounding_Coordinates>
       </cart:Spatial_Domain>
       <cart:Spatial_Reference_Information>
        <cart:Horizontal_Coordinate_System_Definition>
         <cart:Planar>
          <cart:Map_Projection>
           <cart:map_projection_name>Equirectangular</cart:map_projection_name>
           <cart:Equirectangular>
            <cart:latitude_of_projection_origin
unit="deg">0</cart:latitude_of_projection_origin>
            <cart:standard_parallel_1 unit="deg">25</cart:standard_parallel_1>
            <cart:longitude_of_central_meridian
unit="deg">180</cart:longitude_of_central_meridian>
           </cart:Equirectangular>
          </cart:Map_Projection>
          <cart:Planar_Coordinate_Information>
           <cart:planar_coordinate_encoding_method>Coordinate
Pair</cart:planar_coordinate_encoding_method>
           <cart:Coordinate_Representation>
            <cart:pixel_resolution_x unit="m/pixel">0.25</cart:pixel_resolution_x>
            <cart:pixel_resolution_y unit="m/pixel">0.25</cart:pixel_resolution_y>
            <cart:pixel_scale_x
unit="pixel/deg">236847.714779331698</cart:pixel_scale_x>
```

```xml
          <cart:pixel_scale_y
unit="pixel/deg">236847.714779331698</cart:pixel_scale_y>
          </cart:Coordinate_Representation>
        </cart:Planar_Coordinate_Information>
        <cart:Geo_Transformation>
          <cart:upperleft_corner_x unit="m">-3733599.5</cart:upperleft_corner_x>
          <cart:upperleft_corner_y unit="m">1487941.25</cart:upperleft_corner_y>
        </cart:Geo_Transformation>
      </cart:Planar>
      <cart:Geodetic_Model>
        <cart:latitude_type>Planetocentric</cart:latitude_type>
        <cart:spheroid_name>MARS</cart:spheroid_name>
        <cart:a_axis_radius unit="m">3392593.61104349978</cart:a_axis_radius>
        <cart:b_axis_radius unit="m">3392593.61104349978</cart:b_axis_radius>
        <cart:c_axis_radius unit="m">3392593.61104349978</cart:c_axis_radius>
        <cart:longitude_direction>Positive East</cart:longitude_direction>
      </cart:Geodetic_Model>
    </cart:Horizontal_Coordinate_System_Definition>
   </cart:Spatial_Reference_Information>
  </cart:Cartography>
  <geom:Geometry>
   <geom:Image_Display_Geometry>
    <geom:Display_Direction>
     <geom:horizontal_display_axis>Sample</geom:horizontal_display_axis>
     <geom:horizontal_display_direction>Left to
Right</geom:horizontal_display_direction>
     <geom:vertical_display_axis>Line</geom:vertical_display_axis>
     <geom:vertical_display_direction>Top to
Bottom</geom:vertical_display_direction>
    </geom:Display_Direction>
    <geom:Object_Orientation_North_East>
     <geom:north_azimuth unit="deg">270</geom:north_azimuth>
     <geom:east_azimuth unit="deg">0</geom:east_azimuth>
     <geom:Reference_Frame_Identification>
      <geom:name>clockwise from right hand side</geom:name>
     </geom:Reference_Frame_Identification>
    </geom:Object_Orientation_North_East>
   </geom:Image_Display_Geometry>
   <geom:Geometry_Orbiter>
    <geom:geometry_start_time_utc>2016-02-
22T22:39:43.433Z</geom:geometry_start_time_utc>
     <geom:geometry_stop_time_utc>2016-02-
22T22:39:45.654Z</geom:geometry_stop_time_utc>
```

```xml
        <geom:Surface_Geometry>
         <geom:Surface_Geometry_Specific>
           <geom:subsolar_azimuth unit="deg">186.735764</geom:subsolar_azimuth>
         </geom:Surface_Geometry_Specific>
        </geom:Surface_Geometry>
        <geom:Illumination_Geometry>
         <geom:Illumination_Specific>
           <geom:Reference_Pixel>
            <!-- center pixel -->
            <geom:vertical_coordinate_pixel
unit="pixel">12463</geom:vertical_coordinate_pixel>
            <geom:horizontal_coordinate_pixel
unit="pixel">4260.5</geom:horizontal_coordinate_pixel>
           </geom:Reference_Pixel>
           <geom:emission_angle unit="deg">20.752833</geom:emission_angle>
           <geom:incidence_angle unit="deg">40.204977</geom:incidence_angle>
           <geom:phase_angle unit="deg">60.437113</geom:phase_angle>
         </geom:Illumination_Specific>
        </geom:Illumination_Geometry>
       </geom:Geometry_Orbiter>
      </geom:Geometry>
      <disp:Display_Settings>
       <Local_Internal_Reference>
         <local_identifier_reference>Array_3D_Image</local_identifier_reference>
         <local_reference_type>display_settings_to_array</local_reference_type>
       </Local_Internal_Reference>
       <disp:Display_Direction>
         <disp:horizontal_display_axis>Sample</disp:horizontal_display_axis>
         <disp:horizontal_display_direction>Left to
Right</disp:horizontal_display_direction>
         <disp:vertical_display_axis>Line</disp:vertical_display_axis>
         <disp:vertical_display_direction>Top to Bottom</disp:vertical_display_direction>
       </disp:Display_Direction>
       <disp:Color_Display_Settings>
         <disp:color_display_axis>Band</disp:color_display_axis>
         <disp:red_channel_band>1</disp:red_channel_band>
         <disp:green_channel_band>2</disp:green_channel_band>
         <disp:blue_channel_band>3</disp:blue_channel_band>
       </disp:Color_Display_Settings>
      </disp:Display_Settings>
     </Discipline_Area>
    </Observation_Area>
    <Reference_List>
```

```xml
      <Internal_Reference>

<lid_reference>urn:nasa:pds:bundle_naming_tbd:collection_naming_tbd:hirise_rdr_sis</lid_reference>
        <reference_type>data_to_document</reference_type>
        <comment>documentation and citation(s) for this data product</comment>
      </Internal_Reference>
      <External_Reference>
        <doi>10.1029/2005JE002605</doi>
        <reference_text>McEwen, Alfred S. ; Eliason, Eric M. ; Bergstrom, James W. ;
            Bridges, Nathan T. ; Hansen, Candice J. ; Delamere, W. Alan ; Grant, John A.
;
            Gulick, Virginia C. ; Herkenhoff, Kenneth E. ; Keszthelyi, Laszlo ;
            Kirk, Randolph L. ; Mellon, Michael T. ; Squyres, Steven W. ; Thomas, Nicolas
;
            Weitz, Catherine M. (2007) Mars Reconnaissance Orbiter's High Resolution
Imaging Science
            Experiment (HiRISE) Journal of Geophysical Research, Volume 112, Issue E5
          </reference_text>
        <description>instrument overview</description>
      </External_Reference>
    </Reference_List>
    <File_Area_Observational>
      <File>
        <file_name>ESP_044885_2055_COLOR.tif</file_name>
        <local_identifier>DATA_FILE</local_identifier>
        <creation_date_time>2016-03-02T14:53:08Z</creation_date_time>
        <file_size unit="byte">1274816503</file_size>
      </File>
      <Header>
        <offset unit="byte">0</offset>
        <object_length unit="byte">449827</object_length>
        <parsing_standard_id>TIFF 6.0</parsing_standard_id>
        <description>TIFF/GeoTIFF header. The TIFF/GeoTIFF format is used throughout
the geospatial and science communities to share geographic image data. </description>
      </Header>
      <Array_3D_Image>
        <local_identifier>Array_3D_Image</local_identifier>
        <offset unit="byte">449827</offset>
        <axes>3</axes>
        <axis_index_order>Last Index Fastest</axis_index_order>
        <Element_Array>
          <data_type>UnsignedLSB2</data_type>
```

```xml
          <scaling_factor>0.00015684048038255399</scaling_factor>
          <value_offset>0.0461876998381720028</value_offset>
        </Element_Array>
        <Axis_Array>
          <axis_name>Band</axis_name>
          <elements>3</elements>
          <sequence_number>1</sequence_number>
        </Axis_Array>
        <Axis_Array>
          <axis_name>Line</axis_name>
          <elements>24926</elements>
          <sequence_number>2</sequence_number>
        </Axis_Array>
        <Axis_Array>
          <axis_name>Sample</axis_name>
          <elements>8521</elements>
          <sequence_number>3</sequence_number>
        </Axis_Array>
        <Special_Constants>
          <missing_constant>0</missing_constant>
          <invalid_constant>0</invalid_constant>
          <high_instrument_saturation>1022</high_instrument_saturation>
          <high_representation_saturation>1023</high_representation_saturation>
          <low_instrument_saturation>2</low_instrument_saturation>
          <low_representation_saturation>1</low_representation_saturation>
        </Special_Constants>
      </Array_3D_Image>
    </File_Area_Observational>
    <File_Area_Observational_Supplemental>
      <File>
        <file_name>ESP_044885_2055_COLOR.LBL</file_name>
        <comment>Original PDS3 label for this data product</comment>
      </File>
      <Stream_Text>
        <offset unit="byte">0</offset>
        <parsing_standard_id>PDS3</parsing_standard_id>
        <record_delimiter>Carriage-Return Line-Feed</record_delimiter>
      </Stream_Text>
    </File_Area_Observational_Supplemental>
  </Product_Observational>
```

5 Addendum to HiRISE RDR – DTM Products

The terms Digital Elevation Model (DEM) and Digital Terrain Model (DTM) are often used interchangeably in the sense of the products described in this document. The distinction between the two terms can refer to the representation of all objects on the ground including trees, buildings or other man-made objects (i.e. DEM) versus a representation of just the terrain (i.e. DTM). To be consistent, we will use DTM throughout this addendum.

This addendum describes the HiRISE DTM object, as well as the accompanying orthoimages and their labels created with the DTM. Sample PDS labels for both types of object are included in section 5.8. Label definitions for the DTM and orthoimages are listed in Appendices B and C, respectively.

5.1 Definition and Scope of the DTM Dataset

Digital Terrain Models (DTMs) are a derived data product. A DTM is not an image, but a gridded (raster) product that records elevation values of a given terrain in each pixel. Corresponding metadata include map projection information so pixels can be associated with latitude and longitude. Values are either measured from the body center (i.e.radii), or relative to a given planetary geoid (i.e. elevation).

The information about HiRISE instrument characteristics in Section 2 of this document applies here, and is crucial to describing and understanding the HiRISE DTM dataset released through the PDS. Where applicable, associated products such as orthoimages, will conform to the RDR conventions and JPEG2000 standards described in Sections 4 and 3.2, respectively.

The products described here are derived from a HiRISE stereo pair, where each observation has been taken of the same ground location, but from different viewing angles. Pixel values correspond to elevations in meters above the Mars 2000 datum as defined in [19]. Pixel scale, or Ground Sample Distance (GSD) corresponds to the horizontal spacing of elevation measurements (also referred to as "post-spacing").

DTM production is time intensive, and cannot be fully automated. It requires careful data pre-processing, sophisticated software, specialized training, considerable computing resources and can take many hours of operator time. The goal is to create the most accurate terrain model possible. The processes used to create HiRISE DTMs are continually being improved, as long as they increase the accuracy of the DTM and decrease the amount of operator hours required. The software and procedures are described in detail in [20], and are outlined here in section 5.4. These products are intended to increase scientific productivity by making a valuable derived data product publicly and freely available that would be difficult for the average data user to produce.

There are two types of products associated with the DTMs. The primary PDS image object is a DTM in a grid, or raster, format. Pixel values correspond to elevations. Associated products are the orthoimages produced by orthorectifying each of the observations in the HiRISE stereo pair used to create the DTM. Orthographic rectification minimizes distortions in the image due to topography. Each orthographic image is in the same map projection as the corresponding DTM.

5.2 DTM Data Volume

As of the end of the Primary Science Phase of the MRO mission, over 1,000 HiRISE stereo pairs have been acquired. Image acquisition continues in the Extended Science Phase. Each stereo pair has the potential to be used to create a DTM, so the potential total data volume could be 4+ TB for the DTM files and their accompanying orthoimages. See [4] for additional information about the DTM storage structure.

5.2.1 DTM File Type and Storage

HiRISE DTMs are produced in a gridded, or raster, format. The DTM itself is stored in a PDS standard .IMG format with an attached PDS label. See Appendix B for label keyword definitions. This format is a standard PDS (image) format that is readable by many software packages. Pixel values are 32-bit DN.

5.2.2 Orthoimage File Type and Storage

An orthoimage for each observation used to create the DTM is produced, at each of two resolutions. One resolution is equal to the GSD of the DTM. The other is at the nominal full resolution of the original observation. The file type is JPEG2000, as described in section 3.2. This format was chosen to maintain consistency with the HiRISE RDR data standards, and for the efficient data compression of these potentially very large files. Each .JP2 object will have a detached PDS label. See Appendix C for label keyword definitions.

Pixel values are 8-bit (or possibly 16-bit) DN with the offset value and scale factor provided in the labels should the user wish to convert them to I/F (see section 4.1.2). The orthoimages are either single-band mosaics of the RED CCDs, centered on 700 nm, or three-band images comprised of the near-infrared (band 1), red visible (band 2), and blue-green visible (band 3), i.e. IRB. Each of the three color bands can be converted from DN to I/F using the same formula as for the single band image.

The orthoimages will also contain GeoTIFF information, which is recorded in the PDS label. See section 3.2.2 for the GeoTIFF standards.

5.3 DTM Cartographic Standards

The cartographic standards, map projection and mapping keywords and values for the DTMs and orthoimages are the same as in the RDR products, as defined in section 3.5.

5.4 DTM Data Processing

The image data that are the starting points for DTM production are the radiometrically and geometrically calibrated individual RED CCDs. They have gone through the normal HiRISE image processing pipeline up to the HiStitch stage, as described in Section 4, above. Generally, the color CCDs are not used for DTM production. Lens distortion is removed from the RED CCDs using the ISIS3 program *noproj*. After *noproj,* the individual CCDs are put into a mosaic and then converted to 8-bit raw format. The 8-bit raw images are then imported into the commercial software package Socet Set © by BAE, Inc. to create the DTM. SPICE information for the RED5 CCD is gathered to provide pointing information for the image to be imported into Socet Set ©. The stereo pair is then triangulated and controlled to MOLA elevation values. When possible, the stereo pair is further controlled to MOLA tracks as the reference points for elevation and horizontal alignment. At equatorial latitudes, sometimes the MOLA tracks do not completely span the HiRISE image footprint. In polar regions, although the MOLA tracks are more densely spaced, seasonal changes in snow/frost coverage create variability on the scale of a few meters. In both of these cases the producer uses their best judgement to tie the HiRISE DTM to the MOLA tracks. Terrain extraction is performed in Socet Set © using their proprietary algorithms. After the terrain model is produced, it is examined for obvious errors and artifacts. These are edited to the extent required by the project, but within reasonable time constraints.

Socet Set © is used to create the orthoimages for each image in the stereo pair. Orthophotos are produced at two resolutions. The first is the full nominal resolution of the original imagery (e.g. 0.25 m for bin1, or unbinned, images – see Section 2). The second is produced at the same GSD as the DTM. A typical HiRISE DTM produced from two bin1 images can have a GSD (or post spacing) of 1 m.

Images of an area covered by a pre-existing HiRISE DTM can be orthorectified in SOCET Set ©, using the original stereo pair and the DTM derived from it. The additional image(s) is(are) tied to the original stereo pair, and allowed to be controlled to it, while holding the original pair fixed.

Color orthoimages are produced by preparing the radiometrically calibrated color products that have been corrected for jitter relative to the RED CCDs. These products have gone through the color pipeline, but still have lens distortions. The three bands of each color stack are separated and processed through noproj to

remove lens distortion, similar to the pre-processing step for the RED data. The solution obtained in Socet Set for the RED image in the triangulation step is applied to the three bands of the corresponding color data upon import. They are then orthorectified and exported.

The DTM and orthophotos are exported from Socet Set to the ISIS3 cube format in order to populate the labels with correct scaling and mapping values for subsequent PDS format conversion. Post processing for the color orthoimages is similar to that for the RED orthophotos, except for the band stretching. Each band is "unstretched" from the 8-bit DN values back to the source I/F values using the values stored from the pre-processing steps. Then the minimum and maximum stretch values from all three bands are selected. Each band is then stretched back to 8-bit DN using the overall minimum and maximum values for that image. This allows one set of values to be used for the scaling and offset keywords to return the color image back to I/F values.

5.5 DTM Data Release Plan

Of the 1000+ stereo pairs acquired by HiRISE, not all will turn out to be optimal for producing DTMs. The prioritization of production depends on research needs and data quality. A DTM and associated products will be released to the PDS one year from production, to be timed with scheduled releases to the PDS volume.

5.6 DTM Data Validation

Several institutions with similar data processing capabilities (i.e. Socet Set © workstations) will be producing DTMs with HiRISE. This will maximize the number of DTMs that can be produced and made available via the PDS. The mechanisms and tools to create PDS products will be made available to the various institutions producing HiRISE DTMs. All DTM products and labels will be validated at HiROC before PDS release.

5.7 DTM Product Naming Convention

The naming conventions detailed below apply to the DTM and orthoimage products. This naming convention accommodates cases where images other than the source stereo pair are orthorectified to the DTM. The source DTM ID is identified in the label of the orthoimage. In the case where the same HiRISE observation is orthorectified to two or more different DTMs (i.e. different stereo pairs are acquired over the same location), a sequence number differentiates the orthoimages. The DTM to which the image is orthorectified is identified in the label in the SOURCE_PRODUCT_ID keyword.

DTM Naming convention:

```
PRODUCT_ID = aabcd_xxxxxx_xxxx_yyyyyy_yyyy_Vnn
where
aa = DT, indicating it's a DTM product
b = type of data
        E = areoid elevations
        R = radii
c = projection (others are possible but these are the important ones)
        E = Equirectangular
        P = Polar Stereographic
d = grid spacing
        A = 0.25 m
        B = 0.5 m
        C = 1.0 m
        D = 2.0 m
        E = 4.0 m
        etc.
xxxxxx_xxxx = orbit number and target code from SOURCE_PRODUCT_ID[1]
yyyyyy_yyyy = orbit number and target code from SOURCE_PRODUCT_ID[2]
V = letter indicating producing institution
        U = USGS
        A = University of Arizona
        C = CalTech
        N = NASA Ames
        J = JPL
        O = Ohio State
        P = Planetary Science Institute
        Z = Other
nn = 2 digit version number
```

Orthoimage Naming convention:

```
PRODUCT_ID = XSP_xxxxxx_xxxx_CCC_S_NN_ORTHO
where
XSP_xxxxxx_xxxx = HiRISE source observation ID (mission phase_orbit number_target code)
CCC = color content
        RED = visible RED, 1 band image
        IRB = 3 band enhanced color (IR, RED, BG)
S = grid spacing (comparable to the DTM naming convention above)
        A = 0.25 m
        B = 0.5 m
        C = 1.0 m
        D = 2.0 m
        etc.
NN = two digit sequence number starting with 01 (to distinguish images orthorectified to
different DTMs)
ORTHO indicates that the image has been orthorectified
```

5.7.1 Sample product IDs

The table below provides examples demonstrating the naming convention for a DTM and orthoimages created from HiRISE observations PSP_008669_1705 and PSP_009025_1705. The pixel scale for each object is in parentheses.

Table 5.1 Sample Product IDs

DTM image object (1 m)	DTEEC_008669_1705_009025_1705_A01.IMG
Left orthoimage (1 m)	PSP_008669_1705_RED_C_01_ORTHO.JP2
	PSP_008669_1705_RED_C_01_ORTHO.LBL

Left orthoimage (.25 m)	PSP_008669_1705_RED_A_01_ORTHO.JP2
	PSP_008669_1705_RED_A_01_ORTHO.LBL
Right orthoimage (1 m)	PSP_009025_1705_RED_C_01_ORTHO.JP2
	PSP_009025_1705_RED_C_01_ORTHO.LBL
Right orthoimage (.25 m)	PSP_009025_1705_RED_A_01_ORTHO.JP2
	PSP_009025_1705_RED_A_01_ORTHO.LBL
Color Right orthoimage (.25 m)	PSP_009025_1705_IRB_A_01_ORTHO.JP2
	PSP_009025_1705_IRB_A_01_ORTHO.LBL

5.8 DTM PDS Label

Below is a template PDS attached label for a HiRISE DTM in Equirectangular projection. If the product is in Polar Stereographic projection, the only significant difference besides the value for the MAP_PROJECTION_TYPE is the omission of the comment about the Equirectangular projection.

```
PDS_VERSION_ID  = PDS3

/*File format and length */
RECORD_TYPE    = FIXED_LENGTH
RECORD_BYTES   = nnnn
FILE_RECORDS   = nnnn
^IMAGE         = 2

OBJECT = IMAGE
  LINES            = nnnnn
  LINE_SAMPLES     = nnnn
  BANDS            = 1
  OFFSET           = 0.0
  SCALING_FACTOR   = 1.0
  NOTE = "Pixel values in this file represent elevations in meters
   above the martian equipotential surface (Mars 2000 Datum) defined
   by Smith, et al. (2001). Conversion from pixel units to geophysical
   units is given by the keyvalues for SCALING_FACTOR and OFFSET. This
   DTM was produced using ISIS and SOCET Set (copyright BAE Systems)
   software as described in Kirk et al. (2008)."
  SAMPLE_BITS          = 32
  SAMPLE_BIT_MASK = 2#11111111111111111111111111111111#
  SAMPLE_TYPE          = PC_REAL
  MISSING_CONSTANT = 16#FF7FFFFB#
  VALID_MINIMUM    = nnnn.nn
  VALID_MAXIMUM    = nnnn.nn
 END_OBJECT = IMAGE

/* Identification Information */
DATA_SET_ID             = "MRO-M-HIRISE-5-DTM-V1.0"
DATA_SET_NAME           = "MRO MARS HIGH RESOLUTION IMAGING SCIENCE EXPERIMENT DTM
V1.0"
PRODUCER_INSTITUTION_NAME = "UNIVERSITY OF ARIZONA"
PRODUCER_ID             = "UA"
PRODUCER_FULL_NAME      = "ALFRED MCEWEN, SARAH MATTSON "
PRODUCT_ID              = "DTbcd_LLLLLL_NNNN_RRRRRR_NNNN_Vnn"
PRODUCT_VERSION_ID      = "1.0"
INSTRUMENT_HOST_NAME    = "MARS RECONNAISSANCE ORBITER"
INSTRUMENT_HOST_ID      = "MRO"
INSTRUMENT_NAME         = "HIGH RESOLUTION IMAGING SCIENCE EXPERIMENT"
INSTRUMENT_ID           = "HIRISE"
TARGET_NAME             = "MARS"
SOURCE_PRODUCT_ID       = (XSP_LLLLLL_NNNN, XSP_RRRRRR_NNNN)
RATIONALE_DESC          = "Brief descriptive text  "
SOFTWARE_NAME           = "SOCET Set 5.4.1"

OBJECT = IMAGE_MAP_PROJECTION
```

```
        ^DATA_SET_MAP_PROJECTION    = "DSMAP.CAT"
        MAP_PROJECTION_TYPE         = "EQUIRECTANGULAR"
        PROJECTION_LATITUDE_TYPE    = PLANETOCENTRIC
        /* NOTE: The EQUIRECTANGULAR projection is based on the formula  */
        /* for a sphere. To eliminate confusion in the                  */
        /* IMAGE_MAP_PROJECTION object we have set all three radii,      */
        /* A_AXIS_RADIUS, B_AXIS_RADIUS, and C_AXIS_RADIUS to the same   */
        /* number. The value recorded in the three radii is the local    */
        /* radius at the center latitude on the Mars ellipsoid. That is, */
        /* equatorial radius of 3396.190000 km and polar radius of       */
        /* 3376.200000 kilometers. Using the local radius of the         */
        /* ellipsoid implies that the MAP_SCALE and MAP_RESOLUTION are    */
        /* true at the center latitude.                                  */
        A_AXIS_RADIUS               = nnnn.nn  <KM>
        B_AXIS_RADIUS               = nnnn.nn  <KM>
        C_AXIS_RADIUS               = nnnn.nn   <KM>
        COORDINATE_SYSTEM_NAME      = PLANETOCENTRIC
        POSITIVE_LONGITUDE_DIRECTION = EAST
        KEYWORD_LATITUDE_TYPE       = PLANETOCENTRIC
        /* NOTE:  CENTER_LATITUDE and CENTER_LONGITUDE describe the location  */
        /* of the center of projection, which is not necessarily equal to the */
        /* location of the center point of the image.                        */
        CENTER_LATITUDE             = nn.0 <DEG>
        CENTER_LONGITUDE            = nnn.nn <DEG>
        LINE_FIRST_PIXEL            = 1
        LINE_LAST_PIXEL             = nnnnn
        SAMPLE_FIRST_PIXEL          = 1
        SAMPLE_LAST_PIXEL           = nnnnn
        MAP_PROJECTION_ROTATION     = 0.0 <DEG>
        MAP_RESOLUTION              = nnnnnn.nnnnnnnn <PIX/DEG>
        MAP_SCALE                   = n.nnnnnnnnnnnn <METERS/PIXEL>
        MAXIMUM_LATITUDE            = nnn.nnnnnnnn <DEG>
        MINIMUM_LATITUDE            = nnn.nnnnnnnn <DEG>
        LINE_PROJECTION_OFFSET      = nnnnnnnn.n <PIXEL>
        SAMPLE_PROJECTION_OFFSET    = nnnnnnnn.n <PIXEL>
        EASTERNMOST_LONGITUDE       = nnn.nnnnnnnn <DEG>
        WESTERNMOST_LONGITUDE       = nnn.nnnnnnnn <DEG>
END_OBJECT = IMAGE_MAP_PROJECTION

OBJECT = VIEWING_PARAMETERS
  NORTH_AZIMUTH = nnn.nnnnnn <DEG>
END_OBJECT = VIEWING_PARAMETERS

END
```

5.9 Orthoimage Label

The label for the associated orthoimage differs from the DTM label in that it contains more image-specific keywords that are not required for the DTM object. It also contains the JPEG2000 compression information.

```
PDS_VERSION_ID  = PDS3

/* Identification Information */
DATA_SET_ID              = "MRO-M-HIRISE-5-DTM-V1.0"
DATA_SET_NAME            = "MRO MARS HIGH RESOLUTION IMAGING SCIENCE EXPERIMENT DTM
V1.0"
PRODUCER_INSTITUTION_NAME = "UNIVERSITY OF ARIZONA"
PRODUCER_ID              = "UA"
PRODUCER_FULL_NAME       = "ALFRED MCEWEN, SARAH MATTSON "
PRODUCT_ID               = "XSP_xxxxxx_xxxx_CCC S_NN.ORTHO"
PRODUCT_VERSION_ID       = "1.0"
INSTRUMENT_HOST_NAME     = "MARS RECONNAISSANCE ORBITER"
```

```
INSTRUMENT_HOST_ID       = "MRO"
INSTRUMENT_NAME          = "HIGH RESOLUTION IMAGING SCIENCE EXPERIMENT"
INSTRUMENT_ID            = "HIRISE"
TARGET_NAME              = "MARS"
SOURCE_PRODUCT_ID        = (XSP_xxxxxx_xxxx, DTbcd_LLLLLL_NNNN_RRRRRR_NNNN_Vnn)
RATIONALE_DESC           = "Brief descriptive text "
SOFTWARE_NAME            = "SOCET_SET 5.4.1"


OBJECT = IMAGE_MAP_PROJECTION
    ^DATA_SET_MAP_PROJECTION     = "DSMAP.CAT"
    MAP_PROJECTION_TYPE          = "EQUIRECTANGULAR"
    PROJECTION_LATITUDE_TYPE     = PLANETOCENTRIC
    /* NOTE: The EQUIRECTANGULAR projection is based on the formula  */
    /* for a sphere. To eliminate confusion in the                  */
    /* IMAGE_MAP_PROJECTION object we have set all three radii,      */
    /* A_AXIS_RADIUS, B_AXIS_RADIUS, and C_AXIS_RADIUS to the same   */
    /* number. The value recorded in the three radii is the local   */
    /* radius at the CENTER_LATITUDE on the Mars ellipsoid. That is, */
    /* equatorial radius of 3396.190000 km and polar radius of       */
    /* 3376.200000 kilometers. Using the local radius of the         */
    /* ellipsoid implies that the MAP_SCALE and MAP_RESOLUTION are   */
    /* true at the CENTER_LATITUDE.                                  */
    A_AXIS_RADIUS                = nnnn.nn  <KM>
    B_AXIS_RADIUS                = nnnn.nn  <KM>
    C_AXIS_RADIUS                = nnnn.nn   <KM>
    COORDINATE_SYSTEM_NAME       = PLANETOCENTRIC
    POSITIVE_LONGITUDE_DIRECTION = EAST
    KEYWORD_LATITUDE_TYPE        = PLANETOCENTRIC
    /* NOTE:  CENTER_LATITUDE and CENTER_LONGITUDE describe the location  */
    /* of the center of projection, which is not necessarily equal to the */
    /* location of the center point of the image.                   */
    CENTER_LATITUDE              = n.0 <DEG>
    CENTER_LONGITUDE             = 180.0 <DEG>
    LINE_FIRST_PIXEL             = 1
    LINE_LAST_PIXEL              = nnnnn
    SAMPLE_FIRST_PIXEL           = 1
    SAMPLE_LAST_PIXEL            = nnnnn
    MAP_PROJECTION_ROTATION      = 0.0 <DEG>
    MAP_RESOLUTION               = nnnnn.nnnnnnnn <PIX/DEG>
    MAP_SCALE                    = n.nnnnnnnnnnnn <METERS/PIXEL>
    MAXIMUM_LATITUDE             = nnn.nnnnnnnn <DEG>
    MINIMUM_LATITUDE             = nnn.nnnnnnnn <DEG>
    LINE_PROJECTION_OFFSET       = nnnnnnnn.n <PIXEL>
    SAMPLE_PROJECTION_OFFSET     = nnnnnnnn.n <PIXEL>
    EASTERNMOST_LONGITUDE        = nnn.nnnnnnnn <DEG>
    WESTERNMOST_LONGITUDE        = nnn.nnnnnnnn <DEG>
END_OBJECT = IMAGE_MAP_PROJECTION

OBJECT = VIEWING_PARAMETERS
  NORTH_AZIMUTH = nnn.nnnnnn <DEG>
END_OBJECT = VIEWING_PARAMETERS

/* The JPEG2000 image data file associated with this label. */
OBJECT = COMPRESSED_FILE
    FILE_NAME                 = "DTbcd_LLLLLL_NNNN_RRRRRR_NNNN_Vnn.JP2"
    RECORD_TYPE               = UNDEFINED
    ENCODING_TYPE             = "JP2"
    ENCODING_TYPE_VERSION_NAME = "ISO/IEC15444-1:2004"
    INTERCHANGE_FORMAT        = BINARY
    /* The name of the original source file. */
    UNCOMPRESSED_FILE_NAME    = "DTbcd_LLLLLL_NNNN_RRRRRR_NNNN_Vnn.img"
    /* The amount of original image data. */
    REQUIRED_STORAGE_BYTES    = nnnnnnnnn <BYTES>
    ^DESCRIPTION              = "JP2INFO.TXT"
END_OBJECT = COMPRESSED_FILE

/* The source image data definition. */
OBJECT = UNCOMPRESSED_FILE
    FILE_NAME    = "XSP_xxxxxx_xxxx_CCC S_NN.ORTHO.IMG"
    RECORD_TYPE  = FIXED_LENGTH
    RECORD_BYTES = nnnnn <BYTES>
```

```
    FILE_RECORDS = nnnnnn
    ^IMAGE        = "XSP_xxxxxx_xxxx_CCC S_NN.ORTHO.IMG"
    OBJECT = IMAGE
        LINES                     = nnnnnn
        LINE_SAMPLES              = nnnnn
        BANDS                     = 1
        BAND_STORAGE_TYPE         = BAND_SEQUENTIAL
        OFFSET                    = 0.0
        SCALING_FACTOR            = 1.0
        SAMPLE_BITS               = 8
        SAMPLE_BIT_MASK           = 2#11111111#
        /* NOTE: The conversion from DN to I/F (intensity/flux) is: */
        /* I/F = (DN * SCALING_FACTOR) + OFFSET                     */
        /* I/F is defined as the ratio of the observed radiance and */
        /* the radiance of a 100% lambertian reflector with the sun */
        /* and camera orthogonal to the observing surface.          */
        SCALING_FACTOR            = n.nnnnnnnnnnnnnnnn
        OFFSET                    = n.nnnnnnnnnnnnnnnn
        SAMPLE_TYPE               = MSB_UNSIGNED_INTEGER
        CORE_NULL                 = 0
        CORE_LOW_REPR_SATURATION  = 1
        CORE_LOW_INSTR_SATURATION = 1
        CORE_HIGH_REPR_SATURATION = 255
        CORE_HIGH_INSTR_SATURATION = 255
        CENTER_FILTER_WAVELENGTH  = 700 <NM>
        FILTER_NAME               = "RED"
    END_OBJECT = IMAGE
END_OBJECT = UNCOMPRESSED_FILE
END
```

Appendix A – PDS Label Definitions

Table A – Definition of keywords used in the HiRISE Labels	
Keyword	Definition
PDS_VERSION_ID	The version number of the PDS standards documents that is valid when the data product is created. PDS3 is used for HiRISE Products.
NOT_APPLICABLE_CONSTANT	-9998 for HiRISE RDR lables. The not_applicable_constant element supplies the numeric value used to represent the figurative constant 'N/A'.'N/A' (Not Applicable) is defined as indicating when values within the domain of a particular data element do not apply in a specific instance.
DATA_SET_ID	MRO-M-HIRSE-3-RDR-V1.0 – products without GeoTIFF geospatial reference information. MRO-M-HIRSE-3-RDR-V1.1 – products with GeoTIFF geospatial reference information. The data_set_id element is a unique alphanumeric identifier for a data set or a data product. The data_set_id value for a given data set or product is constructed according to flight project naming conventions. In most cases the data_set_id is an abbreviation of the data_set_name.
DATA_SET_NAME	MRO MARS HIGH RESOLUTION IMAGE SCIENCE EXPERIMENT RDR V1.0 – products without GeoTIFF geospatial reference information. MRO MARS HIGH RESOLUTION IMAGE SCIENCE EXPERIMENT RDR V1.1 – products with GeoTIFF geospatial reference information. The data_set_name element provides the full name given to a data set or a data product. The data_set_name typically identifies the instrument that acquired the data, the target of that instrument, and the processing level of the data.
PRODUCER_INSTITUTION_NAME	UNIVERSITY OF ARIZONA The producer_institution_name element identifies university, research center, NASA center or other institution associated with the production of a data set. This would generally be an institution associated with the element producer_full_name.
PRODUCER_ID	UA The producer_id element provides a short name or acronym for the producer or producing team/group of a dataset
PRODUCER_FULL_NAME	The producer_full_name element provides the full_name of the individual mainly responsible for the production of a data set.
OBSERVATION_ID	The observation_id element uniquely identifies a scientific observation within a data set.
PRODUCT_ID	The product_id data element represents a permanent, unique identifier assigned to a data product by its producer. Note: In the PDS, the value assigned to product_id must be unique within its data set. Additional note: The product_id can describe the lowest-level data object that has a PDS label.
PRODUCT_VERSION_ID	The product_version_id element identifies the

	version of an individual product within a data set. Note: This is not the same as the data set version that is an element of the data_set_id value.
INSTRUMENT_HOST_NAME	MARS RECONNAISSANCE ORBITER The instrument_host_name element provides the full name of the host on which an instrument is based. This host can be either a spacecraft or an earth base.
INSTRUMENT_HOST_ID	MRO The instrument_host_id element provides a unique identifier for the host where an instrument is located. This host can be either a spacecraft or an earth base.
INSTRUMENT_NAME	HIGH RESOLUTION IMAGING SCIENCE EXPERIMENT The instrument_name element provides the full name of an instrument.
INSTRUMENT_ID	HIRISE The instrument_id element provides an abbreviated name or acronym that identifies an instrument.
TARGET_NAME	MARS, SKY, CAL, MOON The target_name element identifies a target. The target may be a planet, satellite, ring, region, feature, asteroid or comet.
MISSION_PHASE_NAME	The mission_phase_name element provides the commonly used identifier of a mission phase.
ORBIT_NUMBER	The orbit_number element identifies the number of the orbital revolution of the spacecraft around a target body.
SOURCE_PRODUCT_ID	The source_product_id data element identifies a product used as input to create a new product.
RATIONALE_DESC	The rationale_desc element describes the rationale for performing a particular observation.
IMAGE_MAP_PROJECTION	**Object within label**
^DATA_SET_MAP_PROJECTION	The data_set_map_projection object is one of two distinct objects that define the map projection used in creating the digital images in a PDS data set. The name of other associated object that completes the definition is called IMAGE_MAP_PROJECTION. The map projection information resides in these two objects, essentially to reduce data redundancy and at the same time allow the inclusion of elements needed to process the data at the image level. Static information applicable to the complete data set resides in the DATA_SET_MAP_PROJECTION object, while dynamic information that is applicable to the individual images reside in the IMAGE_MAP_PROJECTION object. The DATA_SET_MAP_PROJECTION object is to be included in an Archive Quality Data Product Label, and used to load the map projection catalog data into a PDS Catalog.
MAP_PROJECTION_TYPE	EQUIRECTANGLAR, POLAR STEROGRAPHIC The map_projection_type element identifies the type of projection characteristic of a given map.
PROJECTION_LATITUDE_TYPE	PLANETOCENTRIC For some map projections, identifies the type of latitude that is sampled in equal increments by successive image lines. These projections are sometimes known informally as 'database projections' because their simplicity and global applicability for storing data for an entire planet are of greater interest than their formal

	cartographic properties. The EQUIRECTANGULAR and SIMPLE CYLINDRICAL projections can exist with projection latitude types of PLANETOGRAPHIC or PLANETOCENTRIC projection) and do not require this keyword.
A_AXIS_RADIUS	3396.19 <KM> The a_axis_radius element provides the value of the semimajor axis of the ellipsoid that defines the approximate shape of a target body. 'A' is usually in the equatorial plane.
B_AXIS_RADIUS	3396.19 <KM> The b_axis_radius element provides the value of the intermediate axis of the ellipsoid that defines the approximate shape of a target body. 'B' is usually in the equatorial plane.
C_AXIS_RADIUS	3376.2 <KM> The c_axis_radius element provides the value of the semiminor axis of the ellipsoid that defines the approximate shape of a target body. 'C' is normal to the plane defined by 'A' and 'B'.
COORDINATE_SYSTEM_NAME	PLANETOCENTRIC The coordinate_system_name element provides the full name of the coordinate system to which the state vectors are referenced. PDS has currently defined body-fixed rotating coordinate systems. The Planetocentric system has an origin at the center of mass of the body. The planetocentric latitude is the angle between the equatorial plane and a vector connecting the point of interest and the origin of the coordinate system. Latitudes are defined to be positive in the northern hemisphere of the body, where north is in the direction of Earth's angular momentum vector, i.e., pointing toward the hemisphere north of the solar system invariant plane. Longitudes increase toward the east making the Planetocentric system right-handed. The Planetographic system has an origin at the center of mass of the body. The planetographic latitude is the angle between the equatorial plane and a vector through the point of interest, where the vector is normal to a biaxial ellipsoid reference surface. Planetographic longitude is defined to increase with time to an observer fixed in space above the object of interest. Thus, for prograde rotators (rotating counter clockwise as seen from a fixed observer located in the hemisphere to the north of the solar system invariant plane), planetographic longitude increases toward the west. For a retrograde rotator, planetographic longitude increases toward the east. Note: If this data element is not present in the PDS Image Map Projection Object (for pre-V3.1 PDS Standards), the default coordinate system is assumed to body-fixed rotating Planetographic.
POSITIVE_LONGITUDE_DIRECTION	EAST The positive_longitude_direction element identifies the direction of longitude (e.g. EAST, WEST) for a planet. The IAU definition for direction of positive longitude is adopted. Typically, for planets with prograde rotations, positive longitude direction is to the WEST. For planets with retrograde rotations, positive longitude direction is to the EAST.

KEYWORD_LATITUDE_TYPE	PLANETOCENTRIC Identifies the type of latitude (planetographic or planetocentric) used in the labels, e.g., for the maximum, minimum, center, reference, and standard-parallel latitudes. This can differ from the type of latitude that is equally sampled in certain database projections (see PROJECTION_LATITUDE_TYPE), though use of different values for the two keywords is not recommended. The IAU definition for direction of positive longitude should be adopted: for objects with prograde rotation, a positive longitude direction of west is used in conjunction with PLANETOGRAPHIC latitudes, whereas for objects with retrograde rotation positive east longitude is used with PLANETOGRAPHIC latitudes. By IAU convention east longitude may be used with PLANETOCENTRIC latitude for any body. The keyword COORDINATE_SYSTEM_NAME describes these IAU-approved combinations of latitude and longitude definitions. The keywords KEYWORD_LATITUDE_TYPE and POSITIVE_LONGITUDE_DIRECTION separately specify the definitions for latitude and longitude and hence may be used to describe not only the IAU-approved combinations but also non-IAU-approved combinations as needed. Adherence to the IAU standard is recommended by the PDS.
CENTER_LATITUDE	The center_latitude element provides a reference latitude of the map projection. The map_scale (or map_resolution) is typically defined at the center_latitude and center_longitude of the map projection.
CENTER_LONGITUDE	The center_longitude element provides a reference longitude for certain map projections. For example, in an Orthographic projection, the center_longitude along with the center_latitude defines the point or tangency between the sphere of the planet and the plane of the projection. The map_scale (or map_resolution) is typically defined at the center_latitude and center_longitude. In unprojected images, center_longitude represents the longitude at the center of the image frame.
LINE_FIRST_PIXEL	The line_first_pixel element provides the line (row) index for the first pixel that was physically recorded at the beginning of the image array. Note: In the PDS, for a fuller explanation on the use of this data element in the Image Map Projection Object, please refer to the PDS Standards Reference.
LINE_LAST_PIXEL	The line_last_pixel element provides the line (rows) index for the last pixel that was physically recorded at the end of the image array. Note: In the PDS, for a fuller explanation on the use of this data element in the Image Map Projection Object, please refer to the PDS Standards Reference.
SAMPLE_FIRST_PIXEL	The sample_first_pixel element provides the sample (column) index for the first pixel that was physically recorded at the beginning of the image array. Note: In the PDS, for a fuller explanation on the use of this data element in the Image Map Projection Object, please refer to the PDS Standards Reference.
SAMPLE_LAST_PIXEL	The line_last_pixel element provides the sample (column) index for the last pixel that was physically recorded at the end of the image array. Note: In the PDS, for a fuller explanation on the use of this data element in the Image Map Projection Object, please refer to the PDS Standards Reference.

MAP_PROJECTION_ROTATION	The map_projection_rotation element provides the clockwise rotation, in degrees, of the line and sample coordinates with respect to the map projection origin (line_projection_offset, line_projection_offset) This parameter is used to indicate where 'up' is in the projection. For example, in a polar stereographic projection does the zero meridian go center to bottom, center to top, center to left, or center to right? The polar projection is defined such that the zero meridian goes center to bottom. However, by rotating the map projection, the zero meridian can go in any direction. Note: 180 degrees is at the top of the North Pole and 0 degrees is at the top of the South Pole. For example, if 0 degrees is at the top of the North Pole than the map_projection_rotation would be 180 degrees.
MAP_RESOLUTION	The map_resolution element identifies the scale of a given map. Please refer to the definition for map_scale for a more complete definition. Note: For HiRISE RDR products the map_resolution is expressed in meters/pixel.
MAP_SCALE	The map_scale element identifies the scale of a given map in pixels/degree at the center latitude and longitude of the projection.
MAXIMUM_LATITUDE	The maximum_latitude element specifies the northernmost latitude of a spatial area, such as a map, mosaic, bin, feature, or region.
MINIMUM_LATITUDE	The minimum_latitude element specifies the southernmost latitude of a spatial area, such as a map, mosaic, bin, feature, or region.
LINE_PROJECTION_OFFSET	The line_projection_offset element provides the line offset value of the map projection origin position from the line and sample 1,1 (line and sample 1,1 is considered the upper left corner of the digital array) Note: that the positive direction is to the right and down.
SAMPLE_PROJECTION_OFFSET	The sample_projection_offset element provides the sample offset value of the map projection origin position from line and sample 1,1 (line and sample 1,1 is considered the upper left corner of the digital array). Note: that the positive direction is to the right and down.
EASTERNMOST_LONGITUDE	The following definitions describe easternmost longitude for the body-fixed, rotating coordinate systems: For Planetocentric coordinates and for Planetographic coordinates in which longitude increases toward the east, the easternmost (rightmost) longitude of a spatial area (e.g., a map, mosaic, bin, feature or region) is the maximum numerical value of longitude unless it crosses the Prime Meridian.
WESTERNMOST_LONGITUDE	The following definitions describe westernmost longitude for the body-fixed, rotating coordinate systems: For Planetocentric coordinates and for Planetographic coordinates in which longitude increases toward the east, the westernmost (leftmost) longitude of a spatial area (e.g., a map, mosaic, bin, feature or region) is the minimum numerical value of longitude unless it crosses the Prime Meridian.
TIME_PARAMETERS	**Group within label**
MRO:OBSERVATION_START_TIME	UTC start time of observation. This value indicates when the instrument flight software began the image acquisition sequence.
START_TIME	UTC time of the first image line in the

	observation.
SPACECRAFT_CLOCK_START_COUNT	Spacecraft clock count of first image line of the image observation.
STOP_TIME	UTC time of the last image line in image observation.
PRODUCT_CREATION_TIME	The product_creation_time element defines the UTC system format time when a product was created. Formation rule: YYYY-MM-DDThh:mm:ss[.fff]
INSTRUMENT_SETTING_PARAMETERS	**Group within label**
MRO:CCD_FLAG	ON, OFF The mro:ccd_flag element defines the HiRISE CCDs that were operating at the time of the observation. The order for the set is RED0, RED1, RED2, RED3, RED4, RED5, RED6, RED7, RED8, RED9, IR10, IR11, BG12, BG13.
MRO:BINNING	0, 1, 2, 3, 4, 8, 16 The mro:binning element identifies the binning mode of each operating CCD. A 0 value indicates the CCD was not operating. The order for the set is RED0, RED1, RED2, RED3, RED4, RED5, RED6, RED7, RED8, RED9, IR10, IR11, BG12, and BG13.
MRO:TDI	0, 8, 32, 64, 128 The mro:tdi element identifies the tdi mode of each operating CCD. A 0 value indicates the CCD was not operating. The order for the set is RED0, RED1, RED2, RED3, RED4, RED5, RED6, RED7, RED8, RED9, IR10, IR11, BG12, and BG13.
MRO:SPECIAL_PROCESSING_FLAG	The mro:special_processing_flag element indicates if special calibration processing was applied to a HiRISE CCD image. The HiRISE instrument may experience instability problems or a low-signal image may have been poorly calibrated requiring an alternate calibration strategy. There is a special processing flag for each CCD used in the observation. The ordering for the values is RED0, RED1, RED2, RED3, RED4, RED5, RED6, RED7, RED8, RED9, IR10, IR11, BG12, and BG13. Values are as follows: NOMINAL = the standard calibration processing was used for the CCD image. CUBENORM = the calibration processing used a columnar gain correction based on columnar statistics of the image. NULL = the CCD was not operating or was missing for this observation."
VIEWING_PARAMETERS	**Group within label**
INCIDENCE_ANGLE	The incidence_angle element provides a measure of the lighting condition at the intercept center of the image. Incidence angle is the angle between the local vertical at the intercept point (surface) and a vector from the intercept point to the sun. The incidence_angle varies from 0 degrees when the intercept point coincides with the sub_solar point to 90 degrees when the intercept point is at the terminator (i.e., in the shadowed or dark portion of the target body). Thus, higher values of incidence_angle indicate the existence of a greater number of surface shadows.
EMISSION_ANGLE	The emission_angle element provides the value of the angle between the surface normal vector at the image center and a vector from the intercept point to the spacecraft. The emission_angle varies from 0

	degrees when the spacecraft is viewing the subspacecraft point (nadir viewing) to 90 degrees when the intercept is tangent to the surface of the target body. Thus, higher values of emission_angle indicate more oblique viewing of the target. Values in the range of 90 to 180 degrees are possible for ring data.
PHASE_ANGLE	The phase_angle element provides a measure of the relationship between the instrument viewing position and incident illumination (such as solar light). Phase_angle is measured at the target; it is the angle between a vector to the illumination source and a vector to the instrument. If not specified, the target is assumed to be at the center of the instrument field of view. If illumination is from behind the instrument, phase_angle will be small.
LOCAL_TIME	The local_time element provides the local time of day at the center of the field of view of an instrument, measured in local hours from midnight. A local hour is defined as one twenty fourth of a local solar day.
SOLAR_LONGITUDE	The solar_longitude element provides the value of the angle between the body_Sun line at the time of interest and the body_sun line at the vernal equinox. This provides a measure of season on a target body, with values of 0 to 90 degrees representing northern spring, 90 to 180 degrees representing northern summer, 180 to 270 degrees representing northern autumn and 270 to 360 degrees representing northern winter.
SUB_SOLAR_AZIMUTH	The sub_solar_azimuth element provides the value of the angle between the line from the center of an image to the subsolar point and a horizontal reference line (in the image plane) extending from the image center to the middle right edge of the image. The values of this angle increase in a clockwise direction. This angle a relative to the RDR product described by the label.
NORTH_AZIMUTH	The north_azimuth element provides the value of the angle between the line from the center of an image to the north pole and a horizontal reference line (in the image plane) extending from the image center to the middle right edge of the image. The values of this angle increase in a clockwise direction. This angle a relative to the RDR product described by the label.
COMPRESSED_FILE	**Object within label**
FILE_NAME	File name of the compressed file. The file_name element provides the location independent name of a file. To promote portability across multiple platforms, PDS requires the file_name to be limited to a 27-character basename, a full stop (. period), and a 3-character extension. Valid characters include capital letters A - Z, numerals 0 - 9, and the underscore character (_).
RECORD_TYPE	UNDEFINED Designated record type of the compressed file.
ENCODING_TYPE	JP2 Encoding type of the compressed file. The JP2 designation indicates JPEG2000 standard JP2 file format.
ENCODING_TYPE_VERSION_NAME	ISO/IEC15444-1:2004 The ISO/IEC Standard version designation

INTERCHANGE_FORMAT	BINARY
	The compressed file is a binary file
UNCOMPRESSED_FILE_NAME	The name of the uncompressed file used to construct the compressed file.
REQUIRED_STORAGE_BYTES	Total number of bytes that make up the compressed file.
^DESCRIPTION	JP2INFO.TXT File containing supplemental information about the JPEG2000 file. This file can be found in the DOCUMENT directory of the PDS volume housing the RDR product.
UNCOMPRESSED_FILE	**Object within label**
FILE_NAME	File name of the source uncompressed file.
RECORD_TYPE	FIXED_LENGTH Record type of uncompressed image file
RECORD_BYTES	Number of bytes per record
^IMAGE	The ^image element provides the location of the image object of the uncompressed file.
IMAGE	**Object within label**
DESCRIPTION	Description of the RDR product. Always contains: HiRISE projected and mosaicked product
LINES	Number of image lines (rows) in the image object
LINE_SAMPLES	Number of samples (columns) per image line. This dimension is the fasted varying dimension of the image array.
BANDS	Number of bands
SAMPLE_TYPE	MSB_UNSIGNED_INTEGER Sample or pixel type.
SAMPLE_BITS	Always 16, number of bits per sample or pixel
SAMPLE_BIT_MASK	Examples: 2#0000001111111111# The sample_bit_mask element identifies the active bits in each sample. Note: In the PDS, the domain of sample_bit_mask is dependent upon the currently described value in the sample_bits element and only applies to integer values.
SCALING_FACTOR	The scaling_factor and offset elements provides the constant values by which the stored pixel values are converted to I/F. Note: Expressed as an equation: true value (I/F) = offset value + (scaling factor x stored value).
OFFSET	See scaling_factor keyword above
BAND_STORAGE_TYPE	BAND_SEQUENTIAL The band_storage_type element indicates the storage sequence of lines, samples and bands in an image. The values describe, for example, how different samples are interleaved in image lines, or how samples from different bands are arranged sequentially. Example values: BAND SEQUENTIAL, SAMPLE INTERLEAVED, LINE INTERLEAVED.
CENTER_FILTER_WAVELENGTH	The center_filter_wavelength element provides the mid_point wavelength value between the minimum and maximum instrument filter wavelength values.
CORE_NULL	The core_null element identifies a special value whose presence indicates missing data.
CORE_LOW_REPR_SATURATION	The core_low_repr_saturation element identifies a special value whose presence indicates the true value cannot be represented in the chosen data type and length.
CORE_LOW_INSTR_SATURATION	The core_low_instr_saturation element identifies a special value whose presence indicates the measuring instrument was saturated at the low end.
CORE_HIGH_REPR_SATURATION	The core_high_repr_saturation element identifies a special value whose presence indicates the true

	value cannot be represented in the chosen data type and length.
CORE_HIGH_INSTR_SATURATION	The core_high_instr_saturation element identifies a special value whose presence indicates the measuring instrument was saturated at the high end.
MRO:MINIMUM_STRETCH	This element provides contrast stretch values to be used in the display of a HiRISE Image. The parameter is the minimum DN value to map to the 0 DN (Black) value of the display. For color images, there will be three values, one for each color.
MRO:MAXIMUM_STRETCH	This element provides a contrast stretch value to be used in the display of a HiRISE Image. The parameter specifies the DN value to map to the 255 DN value of the display. For color images, there will be three values, one for each color.
FILTER_NAME	RED, BLUE-GREEN, NEAR-INFRARED The filter_name element provides the commonly used name of the instrument filter through which an image or measurement was acquired or which is associated with a given instrument mode.

Appendix B – DTM PDS Label Definitions

Keyword	Definition
Table B – Definitions of keywords used in the HiRISE DTM Labels	
Keyword	Definition
PDS_VERSION_ID	The version number of the PDS standards documents that is valid when the data product is created. PDS3 is used for HiRISE Products.
RECORD_TYPE	FIXED_LENGTH Designated record type of the file.
RECORD_BYTES	Number of bytes per record.
FILE_RECORDS	Number of records per file.
LABEL_RECORDS	Number of bytes per label.
^IMAGE	2 The ^image element provides the location of the image object of the file.
IMAGE	**Object within label**
LINES	Number of image lines (rows) in the image object.
LINE_SAMPLES	Number of samples (columns) per image line. This dimension is the fasted varying dimension of the image array.
BANDS	1 Number of bands.
OFFSET	0.0 See scaling_factor keyword below.
SCALING_FACTOR	1.0 The scaling_factor and offset elements provides the constant values by which the stored pixel values are converted to I/F. Note: The pixel values in the DTM are not scaled.
NOTE	"Pixel values in this file represent elevations in meters above the martian equipotential surface (Mars 2000 Datum) defined by Smith, et al. (2001). Conversion from pixel units to geophysical units is given by the keyvalues for SCALING_FACTOR and OFFSET. This DTM was produced using ISIS and SOCET Set (copyright BAE Systems) software as described in Kirk et al. (2008)." Explanatory note describing meaning of pixel values.
SAMPLE_BITS	32 Number of bits per sample or pixel.
SAMPLE_BIT_MASK	2#11111111111111111111111111111111# The sample_bit_mask element identifies the active bits in each sample. Note: In the PDS, the domain of sample_bit_mask is dependent upon the currently described value in the sample_bits element and only applies to integer values.

SAMPLE_TYPE	PC_REAL Sample or pixel type.
MISSING_CONSTANT	16#FF7FFFFB# The missing_constant element supplies the numeric value used to signify that no elevation data is contained in the pixel.
VALID_MINIMUM	The minimum valid elevation value (DN) in the file. This value is included to aid users in describing an appropriate stretch to the data.
VALID_MAXIMUM	The maximum valid elevation value (DN) in the file. This value is included to aid users in describing an appropriate stretch to the data.
Identification Information	**Group within label**
DATA_SET_ID	MRO-M-HIRSE-5-DTM-V1.0 The data_set_id element is a unique alphanumeric identifier for a data set or a data product. The data_set_id value for a given data set or product is constructed according to flight project naming conventions. In most cases the data_set_id is an abbreviation of the data_set_name.
DATA_SET_NAME	MRO MARS HIGH RESOLUTION IMAGE SCIENCE EXPERIMENT DTM V1.0 – Digital terrain models derived from HiRISE stereo pairs, and the orthoimages created from each image in the stereo pair. The data_set_name element provides the full name given to a data set or a data product. The data_set_name typically identifies the instrument that acquired the data, the target of that instrument, and the processing level of the data.
PRODUCER_INSTITUTION_NAME	UNIVERSITY OF ARIZONA The producer_institution_name element identifies university, research center, NASA center or other institution associated with the production of a data set. This would generally be an institution associated with the element producer_full_name.
PRODUCER_ID	UA The producer_id element provides a short name or acronym for the producer or producing team/group of a dataset
PRODUCER_FULL_NAME	The producer_full_name element provides the full_name of the individual mainly responsible for the production of a data set.
PRODUCT_ID	The product_id data element represents a permanent, unique identifier assigned to a data product by its producer. Note: In the PDS, the value assigned to product_id must be unique within its data set. Additional note: The product_id can describe the lowest-level data object that has a PDS label.
PRODUCT_VERSION_ID	The product_version_id element identifies the version of an individual product within a data set. Note: This is not the same as the data set version that is an element of the data_set_id value.

INSTRUMENT_HOST_NAME	MARS RECONNAISSANCE ORBITER The instrument_host_name element provides the full name of the host on which an instrument is based. This host can be either a spacecraft or an earth base.
INSTRUMENT_HOST_ID	MRO The instrument_host_id element provides a unique identifier for the host where an instrument is located. This host can be either a spacecraft or an earth base.
INSTRUMENT_NAME	HIGH RESOLUTION IMAGING SCIENCE EXPERIMENT The instrument_name element provides the full name of an instrument.
INSTRUMENT_ID	HIRISE The instrument_id element provides an abbreviated name or acronym that identifies an instrument.
TARGET_NAME	MARS, SKY, CAL, MOON The target_name element identifies a target. The target may be a planet, satellite, ring, region, feature, asteroid or comet.
SOURCE_PRODUCT_ID	The source_product_id data element identifies a product used as input to create a new product.
RATIONALE_DESC	The rationale_desc element describes the rationale for performing a particular observation.
IMAGE_MAP_PROJECTION	**Object within label**
^DATA_SET_MAP_PROJECTION	The data_set_map_projection object is one of two distinct objects that define the map projection used in creating the digital images in a PDS data set. The name of other associated object that completes the definition is called IMAGE_MAP_PROJECTION. The map projection information resides in these two objects, essentially to reduce data redundancy and at the same time allow the inclusion of elements needed to process the data at the image level. Static information applicable to the complete data set resides in the DATA_SET_MAP_PROJECTION object, while dynamic information that is applicable to the individual images reside in the IMAGE_MAP_PROJECTION object. The DATA_SET_MAP_PROJECTION object is to be included in an Archive Quality Data Product Label, and used to load the map projection catalog data into a PDS Catalog.
MAP_PROJECTION_TYPE	EQUIRECTANGLAR, POLAR STEROGRAPHIC The map_projection_type element identifies the type of projection characteristic of a given map.
PROJECTION_LATITUDE_TYPE	PLANETOCENTRIC For some map projections, identifies the type of latitude that is sampled in equal increments by successive image lines. These projections are sometimes known informally as 'database projections' because their simplicity and global applicability for storing data for an entire planet are of greater interest than their formal

	cartographic properties. The EQUIRECTANGULAR and SIMPLE CYLINDRICAL projections can exist with projection latitude types of PLANETOGRAPHIC or PLANETOCENTRIC projection) and do not require this keyword.
A_AXIS_RADIUS	nnnn.nn <KM> The a_axis_radius element provides the value of the semimajor axis of the ellipsoid that defines the approximate shape of a target body. 'A' is usually in the equatorial plane. NOTE: The EQUIRECTANGULAR projection is based on the formula for a sphere. To eliminate confusion in the IMAGE_MAP_PROJECTION object we have set all three radii, A_AXIS_RADIUS, B_AXIS_RADIUS, and C_AXIS_RADIUS to the same number. The value recorded in the three radii is the local radius at the center latitude on the Mars ellipsoid. That is, equatorial radius of 3396.190000 km and polar radius of 3376.200000 kilometers. Using the local radius of the ellipsoid implies that the MAP_SCALE and MAP_RESOLUTION are true at the center latitude.
B_AXIS_RADIUS	nnnn.nn <KM> The b_axis_radius element provides the value of the intermediate axis of the ellipsoid that defines the approximate shape of a target body. 'B' is usually in the equatorial plane.
C_AXIS_RADIUS	nnnn.nn <KM> The c_axis_radius element provides the value of the semiminor axis of the ellipsoid that defines the approximate shape of a target body. 'C' is normal to the plane defined by 'A' and 'B'.
COORDINATE_SYSTEM_NAME	PLANETOCENTRIC The coordinate_system_name element provides the full name of the coordinate system to which the state vectors are referenced. PDS has currently defined body-fixed rotating coordinate systems. The Planetocentric system has an origin at the center of mass of the body. The planetocentric latitude is the angle between the equatorial plane and a vector connecting the point of interest and the origin of the coordinate system. Latitudes are defined to be positive in the northern hemisphere of the body, where north is in the direction of Earth's angular momentum vector, i.e., pointing toward the hemisphere north of the solar system invariant plane. Longitudes increase toward the east making the Planetocentric system right-handed. The Planetographic system has an origin at the center of mass of the body. The planetographic latitude is the angle between the equatorial plane and a vector through the point of interest, where the vector is normal to a biaxial ellipsoid reference surface. Planetographic longitude is defined to increase with time to an observer fixed in space above the object of interest. Thus, for prograde rotators (rotating counter clockwise as seen from a fixed observer located in the hemisphere to the north of the solar system invariant plane), planetographic longitude increases toward the west. For a retrograde rotator, planetographic longitude increases toward

	the east. Note: If this data element is not present in the PDS Image Map Projection Object (for pre-V3.1 PDS Standards), the default coordinate system is assumed to body-fixed rotating Planetographic.
POSITIVE_LONGITUDE_DIRECTION	EAST The positive_longitude_direction element identifies the direction of longitude (e.g. EAST, WEST) for a planet. The IAU definition for direction of positive longitude is adopted. Typically, for planets with prograde rotations, positive longitude direction is to the WEST. For planets with retrograde rotations, positive longitude direction is to the EAST.
KEYWORD_LATITUDE_TYPE	PLANETOCENTRIC Identifies the type of latitude (planetographic or planetocentric) used in the labels, e.g., for the maximum, minimum, center, reference, and standard-parallel latitudes. This can differ from the type of latitude that is equally sampled in certain database projections (see PROJECTION_LATITUDE_TYPE), though use of different values for the two keywords is not recommended. The IAU definition for direction of positive longitude should be adopted: for objects with prograde rotation, a positive longitude direction of west is used in conjunction with PLANETOGRAPHIC latitudes, whereas for objects with retrograde rotation positive east longitude is used with PLANETOGRAPHIC latitudes. By IAU convention east longitude may be used with PLANETOCENTRIC latitude for any body. The keyword COORDINATE_SYSTEM_NAME describes these IAU-approved combinations of latitude and longitude definitions. The keywords KEYWORD_LATITUDE_TYPE and POSITIVE_LONGITUDE_DIRECTION separately specify the definitions for latitude and longitude and hence may be used to describe not only the IAU-approved combinations but also non-IAU-approved combinations as needed. Adherence to the IAU standard is recommended by the PDS.
CENTER_LATITUDE	The center_latitude element provides a reference latitude of the map projection. The map_scale (or map_resolution) is typically defined at the center_latitude and center_longitude of the map projection.
CENTER_LONGITUDE	The center_longitude element provides a reference longitude for certain map projections. For example, in an Orthographic projection, the center_longitude along with the center_latitude defines the point or tangency between the sphere of the planet and the plane of the projection. The map_scale (or map_resolution) is typically defined at the center_latitude and center_longitude. In unprojected images, center_longitude represents the longitude at the center of the image frame.
LINE_FIRST_PIXEL	The line_first_pixel element provides the line (row) index for the first pixel that was physically recorded at the beginning of the image array. Note: In the PDS, for a fuller explanation on the use of this data element in the Image Map Projection Object, please refer to the PDS Standards Reference.

LINE_LAST_PIXEL	The line_last_pixel element provides the line (rows) index for the last pixel that was physically recorded at the end of the image array. Note: In the PDS, for a fuller explanation on the use of this data element in the Image Map Projection Object, please refer to the PDS Standards Reference.
SAMPLE_FIRST_PIXEL	The sample_first_pixel element provides the sample (column) index for the first pixel that was physically recorded at the beginning of the image array. Note: In the PDS, for a fuller explanation on the use of this data element in the Image Map Projection Object, please refer to the PDS Standards Reference.
SAMPLE_LAST_PIXEL	The line_last_pixel element provides the sample (column) index for the last pixel that was physically recorded at the end of the image array. Note: In the PDS, for a fuller explanation on the use of this data element in the Image Map Projection Object, please refer to the PDS Standards Reference.
MAP_PROJECTION_ROTATION	The map_projection_rotation element provides the clockwise rotation, in degrees, of the line and sample coordinates with respect to the map projection origin (line_projection_offset, line_projection_offset) This parameter is used to indicate where 'up' is in the projection. For example, in a polar stereographic projection does the zero meridian go center to bottom, center to top, center to left, or center to right? The polar projection is defined such that the zero meridian goes center to bottom. However, by rotating the map projection, the zero meridian can go in any direction. Note: 180 degrees is at the top of the North Pole and 0 degrees is at the top of the South Pole. For example, if 0 degrees is at the top of the North Pole than the map_projection_rotation would be 180 degrees.
MAP_RESOLUTION	The map_resolution element identifies the scale of a given map. Please refer to the definition for map_scale for a more complete definition. Note: For HiRISE RDR products the map_resolution is expressed in meters/pixel.
MAP_SCALE	The map_scale element identifies the scale of a given map in pixels/degree at the center latitude and longitude of the projection.
MAXIMUM_LATITUDE	The maximum_latitude element specifies the northernmost latitude of a spatial area, such as a map, mosaic, bin, feature, or region.
MINIMUM_LATITUDE	The minimum_latitude element specifies the southernmost latitude of a spatial area, such as a map, mosaic, bin, feature, or region.
LINE_PROJECTION_OFFSET	The line_projection_offset element provides the line offset value of the map projection origin position from the line and sample 1,1 (line and sample 1,1 is considered the upper left corner of the digital array) Note: that the positive direction is to the right and down.
SAMPLE_PROJECTION_OFFSET	The sample_projection_offset element provides the sample offset value of the map projection origin position from line and sample 1,1 (line and sample

	1,1 is considered the upper left corner of the digital array). Note: that the positive direction is to the right and down.
EASTERNMOST_LONGITUDE	The following definitions describe easternmost longitude for the body-fixed, rotating coordinate systems: For Planetocentric coordinates and for Planetographic coordinates in which longitude increases toward the east, the easternmost (rightmost) longitude of a spatial area (e.g., a map, mosaic, bin, feature or region) is the maximum numerical value of longitude unless it crosses the Prime Meridian.
WESTERNMOST_LONGITUDE	The following definitions describe westernmost longitude for the body-fixed, rotating coordinate systems: For Planetocentric coordinates and for Planetographic coordinates in which longitude increases toward the east, the westernmost (leftmost) longitude of a spatial area (e.g., a map, mosaic, bin, feature or region) is the minimum numerical value of longitude unless it crosses the Prime Meridian.
VIEWING_PARAMETERS	**Group within label**
NORTH_AZIMUTH	The north_azimuth element provides the value of the angle between the line from the center of an image to the north pole and a horizontal reference line (in the image plane) extending from the image center to the middle right edge of the image. The values of this angle increase in a clockwise direction. This angle is relative to the RDR product described by the label.

Appendix C – Orthoimage PDS Label Definitions

Table B – Definitions of keywords used in the HiRISE Orthoimage Labels	
Keyword	Definition
PDS_VERSION_ID	The version number of the PDS standards documents that is valid when the data product is created. PDS3 is used for HiRISE Products.
Identification Information	Group within label
DATA_SET_ID	MRO-M-HIRSE-5-DTM-V1.0 The data_set_id element is a unique alphanumeric identifier for a data set or a data product. The data_set_id value for a given data set or product is constructed according to flight project naming conventions. In most cases the data_set_id is an abbreviation of the data_set_name.
DATA_SET_NAME	MRO MARS HIGH RESOLUTION IMAGE SCIENCE EXPERIMENT DTM V1.0 – Digital terrain models derived from HiRISE stereo pairs, and the orthoimages created from each image in the stereo pair. The data_set_name element provides the full name given to a data set or a data product. The data_set_name typically identifies the instrument that acquired the data, the target of that instrument, and the processing level of the data.
PRODUCER_INSTITUTION_NAME	UNIVERSITY OF ARIZONA The producer_institution_name element identifies university, research center, NASA center or other institution associated with the production of a data set. This would generally be an institution associated with the element producer_full_name.
PRODUCER_ID	UA The producer_id element provides a short name or acronym for the producer or producing team/group of a dataset
PRODUCER_FULL_NAME	The producer_full_name element provides the full_name of the individual mainly responsible for the production of a data set.
PRODUCT_ID	The product_id data element represents a permanent, unique identifier assigned to a data product by its producer. Note: In the PDS, the value assigned to product_id must be unique within its data set. Additional note: The product_id can describe the lowest-level data object that has a PDS label.
PRODUCT_VERSION_ID	The product_version_id element identifies the version of an individual product within a data set. Note: This is not the same as the data set version that is an element of the data_set_id value.
INSTRUMENT_HOST_NAME	MARS RECONNAISSANCE ORBITER The instrument_host_name element provides the full name of the host on which an instrument is based. This host can be either a spacecraft or an earth base.

INSTRUMENT_HOST_ID	MRO The instrument_host_id element provides a unique identifier for the host where an instrument is located. This host can be either a spacecraft or an earth base.
INSTRUMENT_NAME	HIGH RESOLUTION IMAGING SCIENCE EXPERIMENT The instrument_name element provides the full name of an instrument.
INSTRUMENT_ID	HIRISE The instrument_id element provides an abbreviated name or acronym that identifies an instrument.
TARGET_NAME	MARS, SKY, CAL, MOON The target_name element identifies a target. The target may be a planet, satellite, ring, region, feature, asteroid or comet.
SOURCE_PRODUCT_ID	The source_product_id data element identifies a product used as input to create a new product.
RATIONALE_DESC	The rationale_desc element describes the rationale for performing a particular observation.
IMAGE_MAP_PROJECTION	**Object within label**
^DATA_SET_MAP_PROJECTION	The data_set_map_projection object is one of two distinct objects that define the map projection used in creating the digital images in a PDS data set. The name of other associated object that completes the definition is called IMAGE_MAP_PROJECTION. The map projection information resides in these two objects, essentially to reduce data redundancy and at the same time allow the inclusion of elements needed to process the data at the image level. Static information applicable to the complete data set resides in the DATA_SET_MAP_PROJECTION object, while dynamic information that is applicable to the individual images reside in the IMAGE_MAP_PROJECTION object. The DATA_SET_MAP_PROJECTION object is to be included in an Archive Quality Data Product Label, and used to load the map projection catalog data into a PDS Catalog.
MAP_PROJECTION_TYPE	EQUIRECTANGLAR, POLAR STEROGRAPHIC The map_projection_type element identifies the type of projection characteristic of a given map.
PROJECTION_LATITUDE_TYPE	PLANETOCENTRIC For some map projections, identifies the type of latitude that is sampled in equal increments by successive image lines. These projections are sometimes known informally as 'database projections' because their simplicity and global applicability for storing data for an entire planet are of greater interest than their formal cartographic properties. The EQUIRECTANGULAR and SIMPLE CYLINDRICAL projections can exist with projection latitude types of PLANETOGRAPHIC or PLANETOCENTRIC projection) and do not require this keyword.

A_AXIS_RADIUS	nnnn.nn <KM>
	The a_axis_radius element provides the value of the semimajor axis of the ellipsoid that defines the approximate shape of a target body. 'A' is usually in the equatorial plane.
	NOTE: The EQUIRECTANGULAR projection is based on the formula for a sphere. To eliminate confusion in the IMAGE_MAP_PROJECTION object we have set all three radii, A_AXIS_RADIUS, B_AXIS_RADIUS, and C_AXIS_RADIUS to the same number. The value recorded in the three radii is the local radius at the center latitude on the Mars ellipsoid. That is, equatorial radius of 3396.190000 km and polar radius of 3376.200000 kilometers. Using the local radius of the ellipsoid implies that the MAP_SCALE and MAP_RESOLUTION are true at the center latitude.
B_AXIS_RADIUS	nnnn.nn <KM>
	The b_axis_radius element provides the value of the intermediate axis of the ellipsoid that defines the approximate shape of a target body. 'B' is usually in the equatorial plane.
C_AXIS_RADIUS	nnnn.nn <KM>
	The c_axis_radius element provides the value of the semiminor axis of the ellipsoid that defines the approximate shape of a target body. 'C' is normal to the plane defined by 'A' and 'B'.
COORDINATE_SYSTEM_NAME	PLANETOCENTRIC
	The coordinate_system_name element provides the full name of the coordinate system to which the state vectors are referenced. PDS has currently defined body-fixed rotating coordinate systems.
	The Planetocentric system has an origin at the center of mass of the body. The planetocentric latitude is the angle between the equatorial plane and a vector connecting the point of interest and the origin of the coordinate system. Latitudes are defined to be positive in the northern hemisphere of the body, where north is in the direction of Earth's angular momentum vector, i.e., pointing toward the hemisphere north of the solar system invariant plane. Longitudes increase toward the east making the Planetocentric system right-handed.
	The Planetographic system has an origin at the center of mass of the body. The planetographic latitude is the angle between the equatorial plane and a vector through the point of interest, where the vector is normal to a biaxial ellipsoid reference surface. Planetographic longitude is defined to increase with time to an observer fixed in space above the object of interest. Thus, for prograde rotators (rotating counter clockwise as seen from a fixed observer located in the hemisphere to the north of the solar system invariant plane), planetographic longitude increases toward the west. For a retrograde rotator, planetographic longitude increases toward the east. Note: If this data element is not present in the PDS Image Map Projection Object (for pre-V3.1 PDS Standards), the default coordinate system is assumed to body-fixed rotating Planetographic.

POSITIVE_LONGITUDE_DIRECTION	EAST The positive_longitude_direction element identifies the direction of longitude (e.g. EAST, WEST) for a planet. The IAU definition for direction of positive longitude is adopted. Typically, for planets with prograde rotations, positive longitude direction is to the WEST. For planets with retrograde rotations, positive longitude direction is to the EAST.
KEYWORD_LATITUDE_TYPE	PLANETOCENTRIC Identifies the type of latitude (planetographic or planetocentric) used in the labels, e.g., for the maximum, minimum, center, reference, and standard-parallel latitudes. This can differ from the type of latitude that is equally sampled in certain database projections (see PROJECTION_LATITUDE_TYPE), though use of different values for the two keywords is not recommended. The IAU definition for direction of positive longitude should be adopted: for objects with prograde rotation, a positive longitude direction of west is used in conjunction with PLANETOGRAPHIC latitudes, whereas for objects with retrograde rotation positive east longitude is used with PLANETOGRAPHIC latitudes. By IAU convention east longitude may be used with PLANETOCENTRIC latitude for any body. The keyword COORDINATE_SYSTEM_NAME describes these IAU-approved combinations of latitude and longitude definitions. The keywords KEYWORD_LATITUDE_TYPE and POSITIVE_LONGITUDE_DIRECTION separately specify the definitions for latitude and longitude and hence may be used to describe not only the IAU-approved combinations but also non-IAU-approved combinations as needed. Adherence to the IAU standard is recommended by the PDS.
CENTER_LATITUDE	The center_latitude element provides a reference latitude of the map projection. The map_scale (or map_resolution) is typically defined at the center_latitude and center_longitude of the map projection.
CENTER_LONGITUDE	The center_longitude element provides a reference longitude for certain map projections. For example, in an Orthographic projection, the center_longitude along with the center_latitude defines the point or tangency between the sphere of the planet and the plane of the projection. The map_scale (or map_resolution) is typically defined at the center_latitude and center_longitude. In unprojected images, center_longitude represents the longitude at the center of the image frame.
LINE_FIRST_PIXEL	The line_first_pixel element provides the line (row) index for the first pixel that was physically recorded at the beginning of the image array. Note: In the PDS, for a fuller explanation on the use of this data element in the Image Map Projection Object, please refer to the PDS Standards Reference.
LINE_LAST_PIXEL	The line_last_pixel element provides the line (rows) index for the last pixel that was physically recorded at the end of the image array. Note: In the PDS, for a fuller explanation on the use of

	this data element in the Image Map Projection Object, please refer to the PDS Standards Reference.
SAMPLE_FIRST_PIXEL	The sample_first_pixel element provides the sample (column) index for the first pixel that was physically recorded at the beginning of the image array. Note: In the PDS, for a fuller explanation on the use of this data element in the Image Map Projection Object, please refer to the PDS Standards Reference.
SAMPLE_LAST_PIXEL	The line_last_pixel element provides the sample (column) index for the last pixel that was physically recorded at the end of the image array. Note: In the PDS, for a fuller explanation on the use of this data element in the Image Map Projection Object, please refer to the PDS Standards Reference.
MAP_PROJECTION_ROTATION	The map_projection_rotation element provides the clockwise rotation, in degrees, of the line and sample coordinates with respect to the map projection origin (line_projection_offset, line_projection_offset) This parameter is used to indicate where 'up' is in the projection. For example, in a polar stereographic projection does the zero meridian go center to bottom, center to top, center to left, or center to right? The polar projection is defined such that the zero meridian goes center to bottom. However, by rotating the map projection, the zero meridian can go in any direction. Note: 180 degrees is at the top of the North Pole and 0 degrees is at the top of the South Pole. For example, if 0 degrees is at the top of the North Pole than the map_projection_rotation would be 180 degrees.
MAP_RESOLUTION	The map_resolution element identifies the scale of a given map. Please refer to the definition for map_scale for a more complete definition. Note: For HiRISE RDR products the map_resolution is expressed in meters/pixel.
MAP_SCALE	The map_scale element identifies the scale of a given map in pixels/degree at the center latitude and longitude of the projection.
MAXIMUM_LATITUDE	The maximum_latitude element specifies the northernmost latitude of a spatial area, such as a map, mosaic, bin, feature, or region.
MINIMUM_LATITUDE	The minimum_latitude element specifies the southernmost latitude of a spatial area, such as a map, mosaic, bin, feature, or region.
LINE_PROJECTION_OFFSET	The line_projection_offset element provides the line offset value of the map projection origin position from the line and sample 1,1 (line and sample 1,1 is considered the upper left corner of the digital array) Note: that the positive direction is to the right and down.
SAMPLE_PROJECTION_OFFSET	The sample_projection_offset element provides the sample offset value of the map projection origin position from line and sample 1,1 (line and sample 1,1 is considered the upper left corner of the digital array). Note: that the positive direction is to the right and down.

EASTERNMOST_LONGITUDE	The following definitions describe easternmost longitude for the body-fixed, rotating coordinate systems: For Planetocentric coordinates and for Planetographic coordinates in which longitude increases toward the east, the easternmost (rightmost) longitude of a spatial area (e.g., a map, mosaic, bin, feature or region) is the maximum numerical value of longitude unless it crosses the Prime Meridian.
WESTERNMOST_LONGITUDE	The following definitions describe westernmost longitude for the body-fixed, rotating coordinate systems: For Planetocentric coordinates and for Planetographic coordinates in which longitude increases toward the east, the westernmost (leftmost) longitude of a spatial area (e.g., a map, mosaic, bin, feature or region) is the minimum numerical value of longitude unless it crosses the Prime Meridian.
VIEWING_PARAMETERS	**Group within label**
NORTH_AZIMUTH	The north_azimuth element provides the value of the angle between the line from the center of an image to the north pole and a horizontal reference line (in the image plane) extending from the image center to the middle right edge of the image. The values of this angle increase in a clockwise direction. This angle is relative to the RDR product described by the label.
COMPRESSED_FILE	**Object within label**
FILE_NAME	File name of the compressed file. The file_name element provides the location independent name of a file. To promote portability across multiple platforms, PDS requires the file_name to be limited to a 27-character basename, a full stop (. period), and a 3-character extension. Valid characters include capital letters A - Z, numerals 0 - 9, and the underscore character (_).
RECORD_TYPE	UNDEFINED Designated record type of the compressed file.
ENCODING_TYPE	JP2 Encoding type of the compressed file. The JP2 designation indicates JPEG2000 standard JP2 file format.
ENCODING_TYPE_VERSION_NAME	ISO/IEC15444-1:2004 The ISO/IEC Standard version designation.
INTERCHANGE_FORMAT	BINARY The compressed file is a binary file.
UNCOMPRESSED_FILE_NAME	The name of the uncompressed file used to construct the compressed file.
REQUIRED_STORAGE_BYTES	Total number of bytes that make up the compressed file.

^DESCRIPTION	JP2INFO.TXT File containing supplemental information about the JPEG2000 file. This file can be found in the DOCUMENT directory of the PDS volume housing the RDR product.
UNCOMPRESSED_FILE	**Object within label**
FILE_NAME	File name of the source uncompressed file.
RECORD_TYPE	FIXED_LENGTH Record type of uncompressed image file
RECORD_BYTES	Number of bytes per record.
FILE_RECORDS	Number of records per file.
^IMAGE	The ^image element provides the location of the image object of the uncompressed file.
IMAGE	**Object within label**
LINES	Number of image lines (rows) in the image object.
LINE_SAMPLES	Number of samples (columns) per image line. This dimension is the fasted varying dimension of the image array.
BANDS	Number of bands.
BAND_STORAGE_TYPE	BAND_SEQUENTIAL The band_storage_type element indicates the storage sequence of lines, samples and bands in an image. The values describe, for example, how different samples are interleaved in image lines, or how samples from different bands are arranged sequentially. Example values: BAND SEQUENTIAL, SAMPLE INTERLEAVED, LINE INTERLEAVED.
SAMPLE_TYPE	MSB_UNSIGNED_INTEGER Sample or pixel type.
OFFSET	See scaling_factor keyword below.
SCALING_FACTOR	The scaling_factor and offset elements provides the constant values by which the stored pixel values are converted to I/F. Note: Expressed as an equation: true value (I/F) = offset value + (scaling factor x stored value).
SAMPLE_BITS	8 Number of bits per sample or pixel.
SAMPLE_BIT_MASK	2#11111111# The sample_bit_mask element identifies the active bits in each sample. Note: In the PDS, the domain of sample_bit_mask is dependent upon the currently described value in the sample_bits element and only applies to integer values.
SAMPLE_TYPE	MSB_UNSIGNED_INTEGER Sample or pixel type.

CORE_NULL	The core_null element identifies a special value whose presence indicates missing data.
CORE_LOW_REPR_SATURATION	The core_low_repr_saturation element identifies a special value whose presence indicates the true value cannot be represented in the chosen data type and length.
CORE_LOW_INSTR_SATURATION	The core_low_instr_saturation element identifies a special value whose presence indicates the measuring instrument was saturated at the low end.
CORE_HIGH_REPR_SATURATION	The core_high_repr_saturation element identifies a special value whose presence indicates the true value cannot be represented in the chosen data type and length.
CORE_HIGH_INSTR_SATURATION	The core_high_instr_saturation element identifies a special value whose presence indicates the measuring instrument was saturated at the high end.
CENTER_FILTER_WAVELENGTH	The center_filter_wavelength element provides the mid_point wavelength value between the minimum and maximum instrument filter wavelength values.
FILTER_NAME	RED, BLUE-GREEN, NEAR-INFRARED The filter_name element provides the commonly used name of the instrument filter through which an image or measurement was acquired or which is associated with a given instrument mode.