DLR

Institut für Planetenforschung

HRSC on MarsExpress

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# MEX-HRSC To Planetary Science Archive Interface Control Document for Phobos Data (EAICD)

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# Table Of Contents

# 1 INTRODUCTION

## 1.1 Purpose and Scope

The purpose of this EAICD (Experimenter to (Science) Archive Interface Control Document) is two fold. First it provides users of the HRSC instrument with detailed description of the product and a description of how it was generated, including data sources and destinations. Secondly, it is the official interface between the HRSC team and the Planetary Science Archive.

## 1.2 Archiving Authorities

The Planetary Data System Standard is used as archiving standard by

- NASA for U.S. planetary missions, implemented by PDS
- ESA for European planetary missions, implemented by the Research and Scientific Support Department (RSSD) of ESA

**ESA's Planetary Science Archive (PSA)**

ESA implements an online science archive, the PSA,

- to support and ease data ingestion
- to offer additional services to the scientific user community and science operations teams as e.g.
  - search queries that allow searches across instruments, missions and scientific disciplines
  - several data delivery options as
    - direct download of data products, linked files and data sets
    - ftp download of data products, linked files and data sets

The PSA aims for online ingestion of logical archive volumes and will offer the creation of physical archive volumes on request.

## 1.3 Contents

This document describes the data flow of the HRSC instrument on MarsExpress from the s/c until the insertion into the PSA for ESA. It includes information on how data were processed, formatted, labeled and uniquely identified. The document discusses general naming schemes for data volumes, data sets, data and label files. Standards used to generate the product are explained. Software that may be used to access the product is explained furtheron.

The design of the data set structure and the data product is given. Examples of these are given in the appendix.

## 1.4 Intended Readership

The staff of the archiving authority (Planetary Science Archive, ESA, RSSD, design team) and any potential user of the HRSC data.

## 1.5 Applicable Documents

1. Planetary Data System Preparation Workbook, February 1, 1995, Version 3.1, JPL, D-7669, Part1
2. Planetary Data System Standards Reference, August 1, 2003, Version 3.6, JPL, D-7669, Part 2
3. MarsExpress Archive Generation, Validation and Transfer Plan, J. Zender, , ESA-MEX-TN-4009, Rev. 1.0, 21-Jun-2001
4. HRSC: the High Resolution Stereo Camera of Mars Express, . G. Neukum1, R. Jaumann and the HRSC Co-Investigator and Experiment Team, ESA SP-1240, 2004.
5. Mars Express - HRSC Data Products Naming Convention, T. Roatsch, HRSC-DLR-TN-4200-001, Issue 005, 6-August-2003.
6. PDS Standards Reference , http://pds.jpl.nasa.gov/documents/sr/index.html
7. Planetary Science Data Archive Technical Note – Geometry and Position Information, Issue 3, Revision 4, J. Diaz del Rio, ESA RSSD Planetary Missions Division, SOP-RSSD-TN-010, 09-November-2004.
8. MarsExpress - HRSC Level-1 Product Description, T. Roatsch, HRSC-DLR-TN-4200-004, Issue 001, 10-November-2000.
9. MarsExpress - HRSC Level-3 Product Description, T. Roatsch, HRSC-DLR-TN-4200-007, Issue 001, 14-August-2002.
10. MarsExpress – HRSC VICAR Label Description Document, T. Roatsch, HRSC-DLR-TN-4200-002, Issue 004, 24-August-2004.
11. Flight User Manual for HRSC on MarsExpress, R. Pischel, HRSC-DLR-MA-4100-001/5, 10-December-2004
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16. Planetary Science Archive PVV User Manual, D. Heather, A. Venet, J, Vazquez, SOP-RSSD-UM-004, Issue 2.6, 21-October-2004
17. Mars Express Agreement on the Long-term Preservation of HRSC Camera Data, ME-EST-TN-11420, Issue 1.09 May 2003
18. Planetary Science Archive Experiment Data Release Concept Technical Proposal, J. Zender, SOP-RSSD-TN-015 Issue 1.14 22 October 2004
19. Willner, K., Oberst, J., Hussmann, H., Giese, B., Hoffmann, H., Matz, K.-D., Roatsch, T., Duxbury, T., 2010. Phobos control point network, rotation, and shape. Earth and Planetary Science Letters 294, 541-546.
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21. Wählisch, M., Willner, K., Oberst, J., Matz, K.-D., Scholten, F., Roatsch, T., Hoffmann, H., Semm, S., Neukum, G., 2010. A new topographic image atlas of Phobos. Earth and Planetary Science Letters 294, 547-553.
22. Wählisch, M., Stooke, P.J., Karachevtseva, I.P., Kirk, R., Oberst, J., Willner, K., Nadejdina, I.A., Zubarev, A.E., Konopikhin, A.A., Shingareva, K.B., 2014. Phobos and Deimos cartography. Planetary and Space Science 102, 60-73.
23. Archinal, B.A., A'Hearn, M.F., Bowell, E., Conrad, A., Consolmagno, G.J., Courtin, R., Fukushima, T., Hestroffer, D., Hilton, J.L., Krasinsky, G.A., Neumann, G., Oberst, J., Seidelmann, P.K., Stooke, P., Tholen, D.J., Thomas, P.C., Williams, I.P., 2010. Report of the IAU Working Group on Cartographic Coordinates and Rotational Elements: 2009. Celestial Mechanics and Dynamical Astronomy 109, 101-135.

## 1.6 Relationships to Other Interfaces

This document is in close relationship to

- Mars Express - HRSC Data Products Naming Convention [5]
- MarsExpress - HRSC Level-3 Product Description [9]
- MarsExpress – HRSC VICAR Label Description Document [10]

The contents of these documents is summarized in this document for easier use.

## 1.7 Acronyms and Abbreviations

| | |
|---|---|
| CoI | Co-Investigator |
| DLR | Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center) |
| ESOC | European Space Operation Center |
| ESTEC | European Space Research and Technology Center |
| FUB | Free University of Berlin |
| HRSC | High Resolution Stereo Scanner |
| JPL | NASA Jet Propulsion Laboratory |

| | |
|---|---|
| PI | Principal Investigaror |
| PSA | Planetary Science Archive |
| PVV | PSA Volume Verifier |
| SRC | Super Resolution Camera |
| VICAR | Video Image Communication and Retrieval |
| XVD | VICAR Display program for X environment |

## 1.8 Contact Names and Addresses

| | |
|---|---|
| Archive generation software | Klaus-Dieter Matz, DLR |
| Archive distribution | Thomas Roatsch, DLR |
| Map projection and generation | Marita Wählisch, DLR |
| Calibration software and procedures | Klaus-Dieter Matz, DLR |
| DTM Generation | Konrad Willner, DLR |
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# 2 Overview of Instrument Design, Data Handling Process and Product Generation

## 2.1 Instrument Design Overview

The High Resolution Stereo Camera (HRSC), originally developed for the Russian-led Mars-96 mission, was selected as part of the Orbiter payload for ESA s Mars Express mission. The HRSC is a pushbroom scanning instrument with nine CCD line detectors mounted in parallel in the focal plane. Its unique feature is the ability to obtain near-simultaneous imaging data of a specific site at high resolution, with along-track triple stereo, four colours and five different phase angles, thus avoiding any time-dependent variations of the observational conditions. An additional Super-Resolution Channel (SRC) - a framing device - will yield nested images in the meter-resolution range for detailed photogeologic studies. The spatial resolution from the nominal periapsis altitude of 250 km will be 10 m/pixel, with an image swath of 53 km, for the HRSC and 2.3 m/pixel for the SRC. During the missions nominal operational lifetime of 1 martian year (2 Earth years) and assuming an average HRSC data transfer share of 40%, it will be possible to cover at least 50% of the martian surface at a spatial resolution of 15 m/pixel. More than 70% of the surface can be observed at a spatial resolution of 30 m/pixel, while more than 1% will be imaged at better than 2.5 m/pixel. The HRSC will thus close the gap between the medium- to lowresolution coverage and the very high-resolution images of the Mars Observer Camera on the Mars Global Surveyor mission and the in situ observations and measurements by landers. The HRSC will make a major contribution to the study of martian geosciences, with special emphasis on the evolution of the surface in general, the evolution of volcanism, and the role of water throughout martian history. The instrument will obtain images containing morphologic and topographic information at high spatial and vertical resolution, allowing the improvement of the cartographic base down to scales of 1:50 000. The experiment will also address atmospheric phenomena and atmosphere-surface interactions, and will provide urgently needed support for current and future lander missions as well as for exobiological studies. The goals of HRSC on Mars Express will not be met by any other planned mission or instrument.

Further information about the insturment and its operation can be found in [4] and [11].

To achieve its goals with respect to Mars science the MEX spacecraft is in highly elliptical polar orbit about Mars. The orbit ellipse reaches beyond the low orbit of the Martian moon Phobos resulting in regular close flybys and the opportunity to observe this natural satellite globally with the HRSC and the SRC.

Thanks to a favorable orbit constellation of Mars Express the HRSC is able to observe the Martian Moon Phobos at close range ( below 2000km) regularly. This has led to an almost global image coverage of this small natural satellite and enabled scientist to derive digital terrain models (DTM) on a global scale for Phobos. Related data products and map projected image maps are released with this archiving effort.

## 2.2 Data Handling Process

All HRSC data are processed at DLR in Berlin, Germany.

The data processing consists of the following steps:

- transfer of data from ESOC to DLR
- remove all transmission headers to get the original camera data
- sort camera data by sensor and combine them with the housekeeping data
- decompress the data to get Level 1
- radiometric calibration of the data
- calculate footprints of every image file and get Level 2
- improvement of orbit and attittude data [19, 20]
- generation of Digital terrain Models and Orthorectification of image data [19, 20, 21, 22]

All data processing steps are performed in the VICAR environment [12], a software package developed and maintained by JPL and used for the data processing of many planetary missions.

DLR developed specific VICAR modules for every processing step. All Phobos map products to be delivered use west longitude.

The cognizitant persons for the specific task are listed in chapter 1.8. Please, adress all questions and comments through the CoI Dr. Konrad Willner (konrad.willner@dlr.de).

## 2.3 Product Generation

The data products of the HRSC Level-4 processing for Phobos are 16 Bit ortho-rectified images (also orthoimage) for the Nadir and the 4 color channels, 8 Bit for the Level-5 orthoimage mosaics and 16 Bit for the Level-5 DTMs, all delivered in PDS format including a second label section in MIPL VICAR file format. The map scales of the individual ortho-rectified images (in km/ pixel) depend on the ground resolution of the respective image. The map scale for all Level 5 ortho-rectfied mosaics is ~0.012 km/ pixel or 16 pixel/ degree. The map scale for the global Level 5 DTM is 0.1 km/ pixel or 1.94 pixel/ degree and 0.15 km/ pixel or 1.29 pixel/ degree for the DTM tiles. The principal geometric reference for both planimetry and height is a sphere of radius r=11.1 km as defined by the IAU [23]. The digital number value of the DTM grids represents the elevation in meter of that particular grid with respect to the geometric reference.

DTM generation [19, 20] is based on multi-image matching using pyramid-based least-squares correlation after pre-processing. 3D Point determination by least-squares forward intersection is followed by DTM grid interpolation (distance weighted averaging within a local interpolation radius). The overall process involves automatic procedures in combination with standardized quality checks. DTM generation uses adjusted orbit and pointing data that are referenced to a common global control point network [19]. The north pole is represented in a mosaic from -20° polewards, the south pole is represented in a mosaic from +20° polewards, both projected in polar Stereographic projection. Two DTMs represent the equatorial part of Phobos, both having a latitudal extent from −60° to 60° and a longitudal extend of 180°. The DTMs of the equatorial region are provided in Mercator projection. Phobos' leading hemisphere is centered at 0° latitude, 90° western longitude. Phobos’ trailing hemisphere is centered at 0° latitude, 270° western longitude.

The DTM and the adjusted orientation data are finally applied for orthoimage production. Since Level-4 orthoimages are based on an individual Level-4 DTM, they are available exclusively for areas covered by the DTM. All individual orthoimages are projected twice in Orthographic and Equidistant projections centered at the latitude and western longitude of the image center. The global ortho-image mosaic is derived from 10 HRSC images and in Simple Cylindrical projection centered at 0° latitude and 0° longitude west. The poles are represented by an image mosaic from ±55° polewards, projected in polar Stereographic projection. The equatorial part of Phobos is provided as two mosaics, both having a latitudal extent from −57° to 57°, and each with a longitudal extend of 180°. The mosaics of the equatorial region are provided in Mercator projection and like the DTM data centered at 0° latitude, 90° western longitude and at 0° latitude, 270° western longitude.
The final step is the conversion from the VICAR format to PDS format and the generation of the complete data sets. This step is also performed at DLR in Berlin. The final products will be provided to PSA after PI approval.

# 3 ARCHIVE FORMAT AND CONTENT

## 3.1 Format and Conventions

### 3.1.1 Deliveries and Archive Volume Format

The HRSC Phobos data products will be delivered to PSA as new referenced data products are available. The delivery will be performed only via file transfer, no storage media like CD or DVD will be used. The Planetary

Science Archive of ESA implemented the “Release” concept [18]: data is delivered as units (releases), which can be updated (revision). Two specific data elements are included to handle the release concept:
RELEASE_ID
REVISION_ID
RELEASE_ID defines the release number and REVISION_ID defines the revision number.
The data will be split in a couple of different releases to avoid file transfer problems with very huge files..The releases will also be compressed (using bzip2) to minimize the file transfer time.

Every release will be packed to one single file (only for the file transfer from DLR to PSA) using the UNIX tar command with the following options: tar cfv. The following file naming scheme (including release and revision number) will be used for the file transfer ot the releases:

HRSC_Prel001rev000.tar.bz2

### 3.1.2 Data Set ID Formation

All HRSC data belong to one data set. Therefore, the DATA_SET_ID for all data is constant and has the following value:

MEX-MSA-HRSC-5-REFDR-PHOBOS-MAPS-V1.0

This name follows the standard PDS rules and contains the mission name, target name, the instrument name, describes the level of processing (RDR and the version number. The DATA_SET_ID must be changed whenever it will become necessary to deliver different versions.

Proposed DATA_SET_NAME

"MARS EXPRESS MARS SATELLITE HRSC REFDR PHOBOS MAPS V1.0"

### 3.1.3 Data Directory Naming Convention

The Phobos data are sorted by the type of data in the DATA directory, each sub-directory will have the name of the different data product: image, mosaic, dtm.

### 3.1.4 Filenaming Convention

The file naming convention is described in detail in [5].

**Directory DATA/DTM:**

The DTM files in the DATA sub directory dtm have the following naming convention:

HRSC_DTM_DT5_ZZZ_XXN_YYYW.IMG
HRSC_DTM_DT5_ZZZ_XXN_YYYW.JP2

HRSC_DTM_DT5_ZZZ_XXN_YYYW.LBL

Where

| | |
|---|---|
| HRSC | 4 digit camera name (HRSC) |
| DTM | indicates that this is a dtm |
| DT | indicates that the height values are refererenced to a sphere |
| The '5' indicates | the level of processing which is archived in PSA/PDS |
| ZZZ | 4 digit indicating the type of projection<br>(EQU = EQUIDISTANT<br>MER = MERCATOR<br>STE = STEREOGRAPHIC) |
| XXN/ XXS | 2 digit center latitude of the dtm content following by N/S (north or south) |
| YYYW | 3 digit center longitude of the dtm content following by W (west) |

e. g.
HRSC_DTM_DT5_EQU_00N_000W.IMG
HRSC_DTM_DT5_MER_00N_090W.IMG
HRSC_DTM_DT5_MER_00N_270W.IMG
HRSC_DTM_DT5_STE_90N_000W.IMG
HRSC_DTM_DT5_STE_90S_000W.IMG

**Directory DATA/IMAGE:**

The image files in the DATA sub directory image follow this convention with an additional suffix:

HOOOO_MMMM_DD4_ZZZ_XXN_YYYW.IMG
HOOOO_MMMM_DD4_ZZZ_XXN_YYYW.JP2
HOOOO_MMMM_DD4_ZZZ_XXN_YYYW.LBL

Where

| | |
|---|---|
| H | being the identifyer for the instrument, HRSC |
| OOOO | 4 digit orbit number |
| MMMM | 4 digit number of the image in this orbit |
| DD | sensor name (can be ND, BL, GR, IR, RE) |
| The '4' indicates | the level of processing which is archived in PSA/PDS |
| ZZZ | 4 digit indicating the type of projection<br>(EQU = EQUIDISTANT<br>ORT = ORTHOGRAPHIC). |
| XXN/ XXS | 2 digit center latitude of the image content followed by N/S (north or south) |
| YYYW | 3 digit center longitude of the image content followed by W (west) |

Please, note that all line sensor data which were taken together will get the same OOOO_MMMM number. The same image in 2 different projections has the same name except the ZZZ digits e. g.:

H7937_0000_S14_EQU_20N_190W.IMG
H7937_0000_S14_ORT_20N_190W.IMG

All *.JP2 files are the JPEG2000 compressed version (with GeoTIFF label) of the respective *.IMG files while the *.LBL files are the lable files for the JPEG2000 compressed versions of the data delivery.

**<u>Directory DATA/MOSAIC:</u>**

The mosaic files in the DATA sub directory mosaic have the following naming convention:

HHHH_MOS_DD5_ZZZ_XXN_YYYW.IMG
HHHH_MOS_DD5_ZZZ_XXN_YYYW.JP2
HHHH_MOS_DD5_ZZZ_XXN_YYYW.LBL

Where

| | |
|---|---|
| HHHH | 4 digit camera name (HRSC or SRC_) |
| MOS | indicates that this is a mosaic |
| DD | sensor name (can be ND, BL, GR, IR, RE, SR) |
| The '5' indicates the level of processing which is archived in PSA/PDS | |
| ZZZ | 4 digit indicating the type of projection<br>(EQU = EQUIDISTANT<br>MER = MERCATOR<br>STE = STEREOGRAPHIC). |
| XXN/ XXS | 2 digit center latitude of the mosaic content following by N/S (north or south) |
| YYYW | 3 digit center longitude of the mosaic content following by W (west) |

e. g.
HRSC_MOS_ND5_MER_00N_090W.IMG
HRSC_MOS_ND5_MER_00N_270W.IMG
HRSC_MOS_ND5_EQU_00N_000W.IMG
HRSC_MOS_ND5_STE_90N_000W.IMG
HRSC_MOS_ND5_STE_90S_000W.IMG

**<u>Directory EXTRAS:</u>**

This directory contains additional data products and description file:

- EXTRINFO.TXT
  A description of the contents of this directory.

- PHOBOS_CONTROLNET_A1.DAT
  This file contains the object point coordinates of the control point network.

- PHOBOS_CONTROLNET_A1.LBL
  A PDS detached label that describes PHOBOS_CONTROLNET_A1.TAB.

The byte-by-byte description of PHOBOS_CONTROLNET_A1.DAT is in the table below:

| Byte | Format | Unit | Label | Explanation |
|---|---|---|---|---|
| | | | | |
| 1 - 4 | I4 | --- | Point | Pointnumber |
| 6 - 15 | F10.3 | m | X | X-coordinate of the point |
| 17 - 26 | F10.3 | m | Y | Y-coordinate of the point |
| 28 - 37 | F10.3 | m | Z | Z-coordinate of the point |
| 39 - 48 | F10.3 | m | sigma_X | One sigma error of X |
| 50 - 59 | F10.3 | m | sigma_Y | One sigma error of Y |
| 61 - 70 | F10.3 | m | sigma_Z | One sigma error of Z |

## 3.2 Standards Used in Data Product Generation

### 3.2.1 PDS Standards

All data apply to version 3.6 of the PDS Standards Reference, please see [1], [6] for details.

### 3.2.2 Time Standards

All time information in the data follows the SPICE time standards. Please, see [13], [14], and [15] for details. Within the data products themselves, the time standard used is ET (Ephemeris Time), which is a double precision number of seconds. The starting point for this time is the J2000 epoch. This epoch is Greenwich noon on January 1, 2000 Barycentric Dynamical Time. This ephemeris time is calculated from the Spacecraft Onboard Time using the appropriate SPICE routines and the time correlation packages which are provided by ESTEC as a SPICE Clock Kernel. Outside of the products themselves, there are a few instances inthe HRSC data sets where time flags are provided. The main time values are provided in the data product labels, which provide a start and stop time for the measurement, and a corresponding clock count from the spacecraft. Below, the standards used to define these values are described.

#### 3.2.2.1 START_TIME and STOP_TIME Formation

The PDS formation rule for dates and time in UTC is:

YYYY-MM-DDThh:mm:ss.fff

| | |
|---|---|
| YYYY | year (0000-9999) |
| MM | month (01-12) |
| DD | day of month (01-31) |

| | |
|---|---|
| T | date/time separator |
| hh | hour (00-23) |
| mm | minute (00-59) |
| ss | second (00-59) |
| fff | fractions of second (000-999) (restricted to 3 digits) |

This standard is followed for all START_TIME and STOP_TIME values in the products included in the HRSC data sets.

#### 3.2.2.2 SPACECRAFT_CLOCK_START_COUNT and SPACECRAFT_CLOCK_STOP_COUNT

The SPACECRAFT_CLOCK_START_COUNT and SPACECRAFT_CLOCK_STOP_COUNT values represent the on-board time counters (OBT) of the spacecraft and instrument computers. This OBT counter is given in the headers of the experiment telemetry source packets. It contains the data acquisition start time as 32-bit of unit seconds followed by 16-bit of fractional seconds. The time resolution of the fractional part is 2^-16 = 1.52×10^-5 seconds. Thus, the OBT is represented as a decimal real number in floating-point notation with 5 digits after the decimal point.
A reset of the spacecraft clock is represented by an integer number followed by a slash, e.g. "1/" or "2/".

Example:
SPACECRAFT_CLOCK_START_COUNT = "1/21983325.39258"

### 3.2.3 Reference Systems

The reference systems used for orbit, attitude, and target body follow the SPICE standards and are defined in the different SPICE kernels. Please, see [3], [13], [14], and [15] for details.

All latitudes and longitudes are given in degrees, latitudes are planetocentric. All Phobos map products to be delivered use west longitude.

The level 4 image products will be projected onto a SPHERE in above mentioned projections (sphere formulae with planetocentric latitude) using mean radius of Phobos (11.1 km) [20, 22, 23]:

We used this reference for the generation of the mosaics – files containing '_MOS_' in the filename and the digital terrain models – files containing '_DTM_' in the filename [20, 22].

### 3.2.4 Other Applicable Standards

No other standards are used.

## 3.3 Data Validation

The validation of these volumes is divided into two processes:

The first process is to check that the volumes are technically correct:

- Insure that the volume is complete, and has correct structure as defined in this document.
- Insure that dynamically generated file, such as index and catalog files are correct and complete.
- Insure that structure of each generated volume is PDS compliant

These steps will be performed using PVV, the PSA Volume Verification Tool developed by ESTEC [16].

All data are validated during their scientific use by the HRSC CoI-Team before the delivery to PSA. There is no special validation before the delivery.

## 3.4 Content

#### 3.4.1 Volume Set

There are no volume sets since the data will be delivered electronically. It is not planned to generate archives on any medium (like CD-ROM or DVD).

#### 3.4.2 Data Set

The data set name is defined in chapter 3.1.2.

#### 3.4.3 Directories

##### 3.4.3.1 Root Directory

The Root Directory contains the following standard PDS files:
AAREADME.TXT
VOLDESC.CAT

##### 3.4.3.2 Calibration Directory

There is no calibration directory, the data are already radiometrically calibrated.

##### 3.4.3.3 CATALOG Directory

The Catalog Directory contains the following standard PDS files:
CATINFO.TXT
DATASET.CAT
DSMAP.CAT
INST.CAT
INSTHOST.CAT
MISSION.CAT
PERSON.CAT

REF.CAT
RELEASE.CAT
SOFT.CAT

This directory also contains the file RELEASE.CAT as described in [18]. This file isnecessary to use the release concept developed by PSA.

**3.4.3.4 INDEX Directory**

**3.4.3.4.1 Dataset Index File, INDEX.LBL and INDEX.TAB**

The INDEX Directory contains the required PDS index files which are generated by PVV [16].

**3.4.3.4.2 Geometric Index File, GEO_PHOBOS.LBL and GEO_PHOBOS.TAB**

The Index Directory also contains the Geometric Index File as defined in [7].

**3.4.3.4.3 other Index Files**

The data set also contains browse index files which are generated using PVV [16].

**3.4.3.5 BROWSE Directory and Browse Files**

The browse directory has 3 sub-directories DTM, IMAGE and MOSAIC. The browse images are generated from the origial data using the following steps:

- reducing the size both in line and sample direction
- conversion to unsigned 8 bit data
- conversion to raw data
- conversion to jpeg using the UNIX program nconvert

The filenames of the browse files are the same as the original image files, the extension is changed from IMG for the image files to JPG for the browse files.
The browse directory also contains a PDS labels for every browse image.

**3.4.3.6 Geometry Directory**

There is no Geometry Directory, all geometry information was already used during the generation of the data included in this delivery.

**3.4.3.7 Software Directory**

There is no Software Directory.

**3.4.3.8 Gazetter Directory**

There is no Gazetter Directory.

#### 3.4.3.9 Label Directory

There is no Label directory.

#### 3.4.3.10 DOCUMENT Directory

This directory contains the documentation for the HRSC data sets.
The content is:

| | |
|---|---|
| - DOCINFO.TXT | the standard PDS info file. |
| - HRSC_EAICD.LBL | the label for the Experimenter to Archive ICD |
| - HRSC_EAICD.PDF | the Adobe PDF file of the xperimenter to Archive ICD |
| - HRSC_EAICD.TXT | the Text file of the experimenter to Archive ICD |
| - HRSC_ESA_SP.LBL | the label for the HRSC Instrument Description published in the ESASP1240 |
| - HRSC_ESA_SP.PDF | the Adobe PDF file of the ESA SP-1240 |
| - HRSC_LABEL.LBL | the label for the HRSC VICAR and PDS label table |
| - HRSC_LABEL.PDF | the Adobe PDF file of the HRSC VICAR and PDS label table |
| - HRSC_LABEL_HEADER.LBL | the label for the HRSC VICAR and PDS label description |
| - HRSC_LABEL_HEADER.PDF | the Adobe PDF file of the HRSC VICAR and PDS label description |
| - VICAR2.LBL | Label for VICAR2.TXT |
| - VICAR2.TXT | Description of the VICAR image label |
| - JP2INFO.TXT | description of the JPEG2000 compression |
| - JP2INFO.LBL | the label for JP2INFO.TXT |

#### 3.4.3.11 EXTRAS Directory

The directory contains data of the control network dervied by least-squares bundle–block adjustment of SRC image data and a label file describing the table [19, 20].

#### 3.4.3.12 DATA Directory

The Data Directory contains three sub-directories for each type of data delivered : IMAGE, MOSAIC, DTM. The delivery contains level-4 data for the nadir sensor and the four color sensors directory IMAGE [21, 22]. It also contains mosaics – level-5 data – [21, 22] (directory MOSAIC) and Digital Terrain Models (DTMs) in the directory DTM [19,20].

### 3.4.4 Other Data Products

No Pre-Flight Data Products, Sub-System test data, and instrument calibration data will be delivered to PSA/PDS.

### 3.4.5 In-Flight Data Products

The HRSC data archive contains data which were taken in Mars orbit from Phobos with a sufficient data quality.

The data are radiometrically and geometrically calibrated and map projected, the HRSC team calls them level-4 data.

The HRSC team defined back in the early 1990s a simple numbering scheme for the different processing level which is unfortunately not the same as the more complicated CODMAC scheme used by PDS. Please, see below a short comparison for easy reference.

| | | |
|---|---|---|
| HRSC Level1: | raw data, labeled, uncompressed | CODMAC 1a |
| HRSC Level2: | radiometrically calibrated | CODMAC 3 |
| HRSC Level3: | map projected on the MOLA DTM | CODMAC 5 |
| HRSC Level4: | HRSC-DTMs, map projection on these DTMS also | CODMAC 5 |
| HRSC Level5: | HRSC- image mosaics, global DTM and DTM tiles also | CODMAC 5 |

### 3.4.6 Software

The HRSC processing software was developed in the VICAR environment [12]. VICAR was developed by NASA/JPL and was used for the processing of camera data from many planetary missions (e.g. Viking, Galeileo). The data processing team at DLR in Berlin developed specific modules to process the HRSC data.

These modules perform the following steps:

- remove all telemetry headers from the data
- sort the data by sensor and combine the image data with the housekeeping data
- decompression of the data
- radiometric calibration of the data
- calculation of the footprints for every image
- improvement of orbit and attittude data [19,20]
- generation of Digital terrain Models and Orthorectification of image data [21,22]

### 3.4.7 Documentation

The contents of the documentation directory is described in 3.4.3.10.

### 3.4.8 Derived and other Data Products

There are currently no plans to deliver derived data products other than the once included within this release. Other data products are included in the Extras folder. Also, no data based on the cooperation with other Mars Express teams will be delivered.

# 4. DETAILED INTERFACE SPECIFICATIONS

## 4.1. Data Product Structure

The data structure consists of an ASCII PDS label, followed by an embedded ASCII VICAR label, followed by a n x m block of binary image data. Inherent to the VICAR label is the possibility of an ASCII EOL label being appended after the binary data in order to handle label modifications. This EOL label is simply a continuation field for the main VICAR label, when there is no more space for expansion before the image data.

## 4.2 Label and Header Descriptions

### 4.2.1 PDS Label

HRSC data have an attached PDS label. A PDS label is object-oriented and describes the objects in the data file. The PDS label contains keywords for product identification. The label also contains descriptive information needed to interpret or process the data in the file.

PDS labels are written in Object Description Language (ODL [1]. PDS label statements have the form of "keyword = value". Each label statement is terminated with a carriage return character (ASCII 13) and a line feed character (ASCII 10) sequence to allow the label to be read by many operating systems. Pointer statements with the following format are used to indicate the location of data objects in the file:

^object = location

where the carat character (^, also called a pointer) is followed by the name of the specific data object. The location is the 1-based starting record number for the data object within the file.

### 4.2.2 PDS Image Object

An IMAGE object is a two-dimensional array of values, all of the same type, each of which is referred to as a *sample*. IMAGE objects are normally processed with special display tools to produce a visual representation of the samples by assigning brightness levels or display colors to the values. An IMAGE consists of a series of lines, each containing the same number of samples.

The required IMAGE keywords define the parameters for simple IMAGE objects:

- LINES is the number of lines in the image.
- LINE_SAMPLES is the number of samples in each line.
- SAMPLE_BITS is the number of bits in each individual sample.
- SAMPLE_TYPE defines the sample data type.

The IMAGE object has a number of keywords relating to image statistics. These keywords will be present in all data, the statistics keywords are:

- MEAN
- MEDIAN
- MAXIMUM
- MINIMUM
- STANDARD_DEVIATION

Many variations on the basic IMAGE object are possible with the addition of optional keywords and/or objects. The "^IMAGE" keyword identifies the start of the image data and will skip over the VICAR label.

#### 4.2.3 Keyword Length Limits

All PDS keywords are limited to 30 characters in length (Section 12.7.3 in PDS Standards Reference). Therefore, software that reads HRSC PDS labels must be able to ingest keywords up to 30 characters in length.

#### 4.2.4 Data Type Restrictions

In order to accomodate VICAR dual-labeled files, 16-bit data must be stored as signed data. Unsigned 16-bit data is not supported.

#### 4.2.5 Interpretation of N/A, UNK, and NULL

During the completion of data product labels or catalog files, one or more values may not be available for some set of required data elements. In this case PDS provides the symbolic literals "N/A", "UNK", and "NULL", each of which is appropriate under different circumstances.

- "N/A" ("Not Applicable") indicates that the values within the domain of this data element are not applicable in this instance.

- "UNK" ("Unknown") indicates that the value for the data element is not known and never will be.

- "NULL" is used to flag values that are *temporarily* unknown. It indicates that the data preparer recognizes that a specific value should be applied, but that the true value was not readily available. "NULL" is a placeholder

#### 4.2.6 VICAR Label

For all data products, an embedded VICAR label follows the PDS label and is pointed to by the PDS pointer "^IMAGE_HEADER". The VICAR label is also organized in an ASCII, "keyword = value" format, although there are only spaces between keywords (no carriage return/line feeds as in PDS). The information in the VICAR label is an exact copy of the information in the PDS label as defined in the next section.

#### 4.2.7 VICAR Format

The reader is referred to the VICAR File Format document for details of the format, which is available at the URL "http://www-mipl.jpl.nasa.gov/vicar/vic_file_fmt.html". The following text is an excerpt which describes the basic structure:

> A VICAR file consists of two major parts: the labels, which describe what the file is, and the image area, which contains the actual image. The labels are potentially split into two parts, one at the beginning of the file, and one at the end. Normally, only the labels at the front of the file will be present. However, of the EOL keyword in the system label (described below) is equal to 1, then the EOL labels (End Of file Labels) are present. This happens if the labels expand beyond the space allocated for them. The VICAR file is treated as a series of fixed-length records, of size RECSIZE (see below). The image area always starts at a record boundary, so there may be unused space at the end of the label, before the actual image data starts.
>
> The label consists of a sequence of "keyword=value" pairs that describe the image, and is made up entirely of ASCII characters. Each keyword-value pair is separated by spaces. Keywords are strings, up to 32 characters in length, and consist of uppercase characters, underscores ("_"), and numbers (but should start with a letter). Values may be integer, real, or strings, and may be multiple (e.g. an array of 5 integers, but types cannot be mixed in a single value). Spaces may appear on either side of the equals character (=), but are not normally present. The first keyword is always LBLSIZE, which specifies the size of the label area in bytes. LBLSIZE is always a multiple of RECSIZE, even if the labels don't fill up the record. If the labels end before LBLSIZE is reached (the normal case), then a 0 byte terminates the label string. If the labels are exactly LBLSIZE bytes long, a null terminator is not necessarily present. The size of the label string is determined by the occurrence of the first 0 byte, or LBLSIZE bytes, whichever is smaller. If the system keyword EOL has the value 1, then End-Of-file Labels exist at the end of the image area (see above). The EOL labels, if present, start with another LBLSIZE keyword, which is treated exactly the same as the main LBLSIZE keyword. The length of the EOL labels is the smaller of the length to the first 0 byte or the EOL's LBLSIZE. Note that the main LBLSIZE does not include the size of the EOL labels. In order to read in the full label string, simply read in the EOL labels, strip off the LBLSIZE keyword, and append the rest to the end of the main label string.

## 4.3 Binary Data Storage Conventions

HRSC data are stored as binary data. The data are stored in 8-bit integers. The PDS and VICAR labels are stored as ASCII text.
The ordering of bits and bytes is only significant for pixel data; all other labeling information is in ASCII.

## 4.4 PDS keyword table

The same keywords are used for all data. These keywords are described in the following table:

| | | | | |
|---|---|---|---|---|
| FILE_NAME | usual default name of the output file; this entry allows the user to check for accidental renaming of files, filename | | string | |

| | | | | |
|---|---|---|---|---|
| | without path | | | |
| DATA_SET_ID | The data_set_id element is a unique alphanumeric identifier for a data set or a data product. | | string | MEX-M-HRSC-3- REFDR-DTM-V1.0 |
| DETECTOR_ID | identifies which of the ten CCD detectors was used for this particular image. | | string | MEX_HRSC_RED, MEX_HRSC_BLUE, MEX_HRSC_NADIR, MEX_HRSC_GREEN, MEX_HRSC_IR |
| EVENT_TYPE | identifies the classification of an event, HRSC specific, to be defined by HRSC planning group | | string | |
| INSTRUMENT_HOST_ID | The instrument_host_id element provides a unique identifier for the host where an instrument is located. | | string | MEX |
| INSTRUMENT_HOST_ NAME | full name of the spacecraft | | string | MARS_EXPRESS |
| INSTRUMENT_ID | The instrument_id element provides an abbreviated name or acronym which identifies an instrument. | | string | HRSC |
| INSTRUMENT_NAME | full name of an instrument | | string | HIGH_RESOLUTION_STEREO_CAMER A |
| MISSION_NAME | full name of mission | | string | MARS_EXPRESS |
| MISSION_PHASE_NAME | The mission_phase_name element provides the commonly-used identifier of a mission phase. | | string | |
| PROCESSING_LEVEL_ID | identifies the processing level of a data set; parameter must be updated after each processing step according to the program specification , DLR-Levels | | int | 4, 5 |
| PRODUCT_CREATION_ TIME | The product_creation_time element defines the UTC system format time when a product was created. | | string | |
| PRODUCT_ID | The product_id data element represents a permanent, unique identifier assigned to a data product by its producer. | | string | |
| RELEASE_ID | Number of the data release | | int | |
| REVISION_ID | Number of the revision in a rlease | | int | |
| SPACECRAFT_CLOCK_ START_COUNT | provides the value of the spacecraft clock at the beginning of a time period of interest. This is the same for all line sensors and SRC images during one imaging sequence. | | string | |
| SPACECRAFT_CLOCK_ STOP_COUNT | provides the value of the spacecraft clock at the end of a time period of interest. This is the same for all line sensors and SRC images during one imaging sequence. | | string | |

| | | | | |
|---|---|---|---|---|
| START_TIME | date and time of recording of the first image line in UTC format "YYYY-MM-DDTHH:MM:SS.MMMZ" (corresponds to the ephemeris time prefix entry of that line ) | | string | |
| STOP_TIME | date and time of recording of the last image line in UTC format "YYYY-MM-DDTHH:MM:SS.MMMZ" (corresponds to the ephemeris time prefix entry of that line ) | | string | |
| ASCENDING_NODE_ LONGITUDE | value of the angle of the xy-plane of the J2000 coordinate system to the ascending node computed from the spacecraft's position- and velocity vector at periapsis (not to be used during test and cruise) | deg | real | |
| MAXIMUM_RESOLUTION | highest resolution in an image | m/pixel | real | |
| FOOTPRINT_POINT_ LATITUDE | The footprint_point_latitude element provides the latitude of a point within an array of points along the border of a footprint, described as a polygon, outlining an imaged area on the planet's surface. Latitude values are planetocentric. | deg | real (100) | |
| FOOTPRINT_POINT_ LONGITUDE | The footprint_point_longitude element provides the longitude of a point within an array of points along the border of a footprint, described as a polygon, outlining an imaged area on the planet's surface. Longitude values are planetocentric. | deg | real (100) | |
| ORBIT_NUMBER | number of the orbital revolution of the s/c around the target body (not to be used during test and cruise) | | int | |
| ORBITAL_ECCENTRICITY | value of orbit eccentricity computed from the spacecraft's position- and velocity vector at periapsis (not to be used during test and cruise) | | real | |
| ORBITAL_INCLINATION | value of the angle of inclination with respect to the xy-plane computed from the spacecraft's position- and velocity vector at periapsis | | real | |
| ORBITAL_SEMIMAJOR_ AXIS | value of orbit semi-major axis cumputed from spacecraft 's position - and velocity vector at periapsis (not to be used during test and cruise) | km | real | |
| PERIAPSIS_ALTITUDE | The PERIAPSIS_ALTITUDE element provides the distance between the spacecraft and the target body at periapsis. Periapsis is the closest approach point of the spacecraft to the target body in its orbit around the target body. | km | real | |
| PERIAPSIS_ARGUMENT_ ANGLE | angle in the xy-plane of the J2000 coordinate system from the ascending node to periapsis (not to be used during test and cruise) | deg | real | |

| | | | | |
|---|---|---|---|---|
| PERIAPSIS_TIME | The PERIAPSIS_TIME element is the time, in UTC format "YYYY-MM-DDThh:mm:ss[.fff]Z", when the spacecraft passes through periapsis. Periapsis is the closest approach point of the spacecraft to the target body in its orbit around the target body. (not to be | time | string | |
| SPACECRAFT_ ORIENTATION | The spacecraft orientation element provides the orientation of a spacecraft in orbit or cruise with respect to a given frame. E.g. a non-spinning spacecraft might be flown in +Y or -Y direction in respect to the spacecraft mechanical build frame. This element shall be used in combination with the keyword spacecraft_orientation_desc that describes the convention used to describe the spacecraft orientation. The spacecraft orientation shall be given as a 3-tuple, one value for the x,y and z axes | | real | N/A for level 4 and level 5 data |
| SPACECRAFT_POINTING_ MODE | The spacecraft pointing element provides information on the pointing mode of the spacecraft. The definition of the modes and the standard values are given in the s/c pointing mode description element, that shall always accompany the keyword | | string | {"NADIR", "ALONGTRACK", "ACROSSTRACK", "TRACKING" |
| RIGHT_ASCENSION | The right_ascension element provides the right ascension value. Right_ascension is defined as the arc of the celestial equator between the vernal equinox and the point where the hour circle through the given body intersects the Earth's mean equator (reckoned eastward). | degree | real | |
| DECLINATION | The declination element provides the value of an angle, corresponding to latitude, used to fix position on the celestial sphere. Declination is measured positive north and negative south of the celestial equator, and is defined relative to a specified reference period or epoch. | degree | real | |
| OFFSET_ANGLE | offset from nadir looking during ACROSS_TRACKING or ALONG_TRACKING | degrees | real | |
| SPACECRAFT_SOLAR_ DISTANCE | the spacecraft's distance to the Sun measured from its position vector at periapsis (not to be used during test and cruise) | km | real | |
| TARGET_NAME | name of the target body | | string | PHOBOS |
| DETECTOR_ TEMPERATURE | TEMPERATURE SPL_F (Dornier HKD doc.) for sensor P2,RE,S2, TEMPERATURE SPL_N (Dornier HKD doc.) for sensor BL,ND,GR, TEMPERATURE SPL_A (Dornier | Celsius | real | |

| | | | | |
|---|---|---|---|---|
| | HKD doc.) for sensor P1,IR,S1; , temp_fpm in hrhk23, SRC first level is 2 | | | |
| FOCAL_PLANE_ TEMPERATURE | TEMPERATURE OPTICS in Dornier HKD document, HRSC only, temp_co in hrhk23 | Celsius | real | |
| INST_CMPRS_NAME | flag indicating whether spacecraft on-board compression has been bypassed, in which case, the received data were uncompressed; HRSC: config. byte 1/2, bit 2 = 1 ==> BYPASS_FLAG = "YES" | | string | NONE,"DIGITAL COSINE TRANSFORMATION" |
| INST_CMPRS_QUALITY | The compression index parameter in the table of scale factors (TABF). It is in the range from 0 to 15. A higher value means more compression | | int | 0,1,2,3,4,5,...,15 |
| INST_CMPRS_QUANTZ_ TBL_ID | Number of the quantization matrix in the PMEM file, TB*2 + Malgo | | int | 0,1,2,3 |
| INST_CMPRS_RATIO | mean compression rate for the entire image data represented in the file, this number is =1 for data collected in the bypass mode. | | real | |
| INSTRUMENT_ TEMPERATURE | TEMPERATURE FEE in Dornier HKD document, temp_fee in hrhk23, SRC first level is 2 | Celsius | real | |
| LENS_TEMPERATURE | TEMPERATURE OPTICAL BENCH in Dornier HKD document, HRSC only, temp_ob in hrhk23 | Celsius | real | |
| MACROPIXEL_SIZE | macropixel format | | int | 1,2,4,8 |
| MISSING_FRAMES | The MISSING_FRAMES element is the total number of frames that are missing from a file. (Cf. ERROR_FRAMES and OVERFLOW_FRAMES).<br>Note: For MARS EXPRESS, a frame, which is also called a "row", is eight lines of data. Each line, in turn, is composed of a s | | int | |
| PIXEL_SUBSAMPLING_ FLAG | The PIXEL_SUBSAMPLING_FLAG element indicates whether this product is the result of subsampling of the data, HRSC only. | | string | Y,N |
| SIGNAL_CHAIN_ID | The SIGNAL_CHAIN_ID element identifies the signal chain (electronic signal path) number selected for charge-coupled device (CCD) output.<br>Note: For MARS EXPRESS the High-Resolution Stereo Colour Imager (HRSC) is composed of 10 channels, each consisting of | | int | 0,1,2,3 |
| BANDWIDTH | The bandwidth element provides a measure of the spectral width of a filter or channel. For a root-mean-square detector this is the effective bandwidth of the filter i.e., the full width having a flat response over the bandwidth and zero response elsewhere. For HRSC this value is for the whole sensor | nm | real | |

| | | | | |
|---|---|---|---|---|
| | (CCD+Optics). | | | |
| CENTER_FILTER_ WAVELENGTH | The center_filter_wavelength element provides the mid_point wavelength value between the minimum and maximum instrument filter wavelength values. For HRSC this value is for the whole sensor (CCD+Optics). | nm | real | |
| RADIANCE_OFFSET | The radiance_offset element provides the constant value by which a stored radiance is added. Note: Expressed as an equation: true_radiance_value = radiance_offset + radiance_scaling_factor * stored_radiance_value. | W/m2/ steradia n | real | |
| RADIANCE_ SCALING_FACTOR | The radiance_scaling_factor element provides the constant value by which a stored radiance is multiplied. Note: Expressed as an equation: true_radiance_value = radiance_offset + radiance_scaling_factor * st□ | W/m2/ steradia n | real | |
| REFLECTANCE_ SCALING_FACTOR | The reflectance_scaling_factor element identifies the conversion factor from DN to reflectance. | | real | |
| A_AXIS_RADIUS | 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 equitorial plane | km | | |
| B_AXIS_RADIUS | 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. | km | | |
| C_AXIS_RADIUS | 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'. | Km | | |
| CENTER_LATITUDE | The center_latitude element provides a reference latitude for certain map projections. For example, in an Orthographic projection, the center_latitude along with the center_longitude defines the point or tangency between the sphere of the planet and the plane of the projection. The map_scale (or map_resolution) is | deg | | |

| | | | | |
|---|---|---|---|---|
| | typically defined at the center_latitude and center_longitude. In unprojected images, center_latitude represents the latitude at the center of the image frame. | | | |
| 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. | deg | | |
| COORDINATE_SYSTEM_NAME | 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.<br><br>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.<br><br>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. | | | |
| COORDINATE_SYSTEM_TYPE | There are three basic types of coordinate systems: body-fixed rotating, body-fixed non-rotating and inertial. A body-fixed coordinate system is one associated with a body (e.g., planetary body or satellite). In contrast to inertial coordinate systems, a body-fixed coordinate system is centered on the body and rotates with the body (unless it is a non-rotating type). For the inertial coordinate system type, the coordinate system is fixed at some point in space. 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 be body-fixed rotating Planetographic. | | | BODY-FIXED ROTATING |
| EASTERNMOST_LONGITUDE | The following definitions describe easternmost longitude for the body-fixed, rotating coordinate systems:<br><br>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 numercial value of longitude unless it crosses the Prime Meridian.<br><br>For Planetographic coordinates in which longitude increases toward the west, the easternmost (rightmost) 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 | deg | | |

| | | | | |
|---|---|---|---|---|
| | Meridian.<br><br>For the Earth, Moon and Sun, PDS also supports the traditional use of the range (-180,180) in which case the easternmost (rightmost) longitude is the maximum numerical value of longitude unless it crosses 180. | | | |
| FIRST_STANDARD_PARALLEL | The first_standard_parallel element is used in Conic projections. If a Conic projection has a single standard parallel, then the first_standard_parallel is the point of tangency between the sphere of the planet and the cone of the projection. If there are two standard parallels (first_standard_parallel, second_standard_parallel), these parallel are the intersection lines between the sphere of the planet and the cone of the projection. The map_scale is defined at the standard parallels. | | | |
| LINE_FIRST_PIXEL | The line_first_pixel element provides the line index for the first pixel that was physically recorded at the beginning of the image array.<br>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 index for the last pixel that was physically recorded at the end of the image array.<br>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_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).<br>Note: that the positive direction is to the right and down. | | | |

| | | | | |
|---|---|---|---|---|
| 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. | deg | | |
| MAP_PROJECTION_TYPE | The map_projection_type element identifies the type of projection characteristic of a given map. Example value: ORTHOGRAPHIC. | | | SINUSOIDAL, STEREOGRAPHIC |
| 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: map_resolution and map_scale both define the scale of a map except that they are expressed in different units: map_resolution is in PIXEL/DEGREE and map_scale is in KM/PIXEL. | pix/deg | | |
| MAP_SCALE | The map_scale element identifies the scale of a given map. The scale is defined as the ratio of the actual distance between two points on the surface of the target body to the distance between the corresponding points on the map. | km/pix | | |

| | | | | |
|---|---|---|---|---|
| | The map_scale references the scale of a map at a certain reference point or line. Certain map projections vary in scale throughout the map. For example, in a Mercator projection, the map_scale refers to the scale of the map at the equator. For Conic projections, the map_scale refers to the scale at the standard parallels. For an Orthographic point, the map_scale refers to the scale at the center latitude and longitude. The relationship between map_scale and the map_resolution element is that they both define the scale of a given map, except they are expressed in different units: map_scale is in KM/PIXEL and map_resolution is in PIXEL/DEGREE. Also note that one is inversely proportional to the other and that kilometers and degrees can be related given the radius of the planet: 1 degree = (2 * RADIUS * PI) / 360 kilometers. | | | |
| MAXIMUM_LATITUDE | The maximum_latitude element specifies the northernmost latitude of a spatial area, such as a map, mosaic, bin, feature, or region | deg | | |
| MINIMUM_LATITUDE | The minimum_latitude element specifies the southernmost latitude of a spatial area, such as a map, mosaic, bin, feature, or region. | deg | | |
| POSITIVE_LONGITUDE_DIRECTION | he 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. Note: The positive_longitude_direction keyword should be used for planetographic systems, but not for | | | |

| | | | | |
|---|---|---|---|---|
| | planetocentric | | | |
| REFERENCE_LATITUDE | The reference_latitude element provides the new zero latitude in a rotated spherical coordinate system that was used in a given map_projection_type. | deg | | |
| REFERENCE_LONGITUDE | The reference_longitude element defines the zero longitude in a rotated spherical coordinate system that was used in a given map_projection_type. | deg | | |
| SAMPLE_FIRST_PIXEL | The sample_first_pixel element provides the sample 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 sample_last_pixel element provides the sample 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_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. | | | |
| SECOND_STANDARD_PARALLEL | Please refer to the definition for first_standard_parallel element to see how second_standard_parallel is defined. | | | |
| 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.<br><br>For Planetographic coordinates in which longitude increases toward the west (prograde rotator), the westernmost (leftmost) 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.<br><br>For the Earth, Moon and Sun, PDS also supports the traditional use of the range (-180,180) in which case the westernmost (leftmost) longitude is the minimum numerical value of longitude unless it crosses -180. | | | |
| DTM_A_AXIS_RADIUS | The DTM_A_AXIS_RADIUS element provides the value of the (+X) semi-axis length of the triaxial ellipsoid surface used as reference for DTM data. The reference surface ellipsoid is generally the best fit to the target body surface, and is centered at the body-fixed reference frame origin. The elevation provided in DTM data is the geometric height measured, typically in kilometers, along a line normal the ellipsoid surface | km | real | |
| DTM_B_AXIS_RADIUS | The DTM_B_AXIS_RADIUS element provides the value of the (+Y) semi-axis length of the triaxial ellipsoid surface used as reference for DTM data. The reference surface ellipsoid is generally the best fit to the target body surface, and is centered at the body-fixed reference frame origin. The elevation provided in DTM data is the geometric height measured, typically in kilometers, along a line normal the ellipsoid surface | km | real | |
| DTM_C_AXIS_RADIUS | The DTM_C_AXIS_RADIUS element provides the value of the (+Z) semi-axis length of the triaxial ellipsoid surface used as reference for DTM data. The reference surface ellipsoid is generally the best fit to the target body surface, and is centered at the body-fixed reference frame origin. The elevation provided in DTM data is the geometric height measured, typically in kilometers, | km | real | |

| | | | | |
|---|---|---|---|---|
| | along a line normal the ellipsoid surface | | | |
| DTM_OFFSET | The DTM_OFFSET element provides the constant value by which a stored elevation value is shifted or displaced. | m | real | |
| DTM_SCALING_FACTOR | The DTM_SCALING_FACTOR element provides the constant value by which the stored elevation is multiplied | | real | |
| DTM_MISSING_DN | The DTM_MISSING_DN element supplies the value used to indicate that no DTM data were available for a particular pixel. | | int | |
| DTM_DESC | The DTM_DESC element provides a free-form, unlimited-length character string that describes the DTM data | | string | |

## 4.5. Example PDS Product Label

```
PDS_VERSION_ID                   = PDS3

/* FILE DATA ELEMENTS */

RECORD_TYPE                      = FIXED_LENGTH
RECORD_BYTES                     = 7456
FILE_RECORDS                     = 3697
LABEL_RECORDS                    = 2

/* POINTERS TO DATA OBJECTS */

^IMAGE_HEADER                    = 3
^IMAGE                           = 4

/* IDENTIFICATION DATA ELEMENTS */

FILE_NAME                        = "H0756_0000_ND4_ORT_42N_011W.IMG"
DATA_SET_ID                      = "MEX-MSA-HRSC-5-REFDR-PHOBOS-MAPS-V1.0"
DATA_SET_NAME                    = "MARS EXPRESS MARS SATELLITE HRSC REFDR
                                     PHOBOS MAPS V1.0"
DETECTOR_ID                      = MEX_HRSC_NADIR
EVENT_TYPE                       = "PHOBOS-LIMB-CARTOGRAPHY-Im"
INSTRUMENT_HOST_ID               = MEX
INSTRUMENT_HOST_NAME             = "MARS EXPRESS"
INSTRUMENT_ID                    = HRSC
INSTRUMENT_NAME                  = "HIGH RESOLUTION STEREO CAMERA"
MISSION_NAME                     = "MARS EXPRESS"
MISSION_PHASE_NAME               = MR_Phase_2
PROCESSING_LEVEL_ID              = 4
PRODUCT_CREATION_TIME            = 2016-03-01T10:31:25.000Z
PRODUCT_ID                       = "H0756_0000_ND4_ORT_42N_011W"
```

```
RELEASE_ID                        = 0001
REVISION_ID                       = 0000

/* TIME DATA ELEMENTS */

SPACECRAFT_CLOCK_START_COUNT      = "1/0041256323.56191"
SPACECRAFT_CLOCK_STOP_COUNT       = "1/0041256413.55975"
START_TIME                        = 2004-08-22T12:05:56.070Z
STOP_TIME                         = 2004-08-22T12:06:36.071Z

/* MISCELLANEOUS */

TARGET_NAME                       = PHOBOS
MISSING_CONSTANT                  = -32768
MAXIMUM_RESOLUTION                = 0.0059 <km/pixel>

/* DATA OBJECT DEFINITIONS */

OBJECT                            = IMAGE
  INTERCHANGE_FORMAT              = BINARY
  LINES                           = 3694
  LINE_SAMPLES                    = 3728
  SAMPLE_TYPE                     = MSB_INTEGER
  SAMPLE_BITS                     = 16
  BANDS                           = 1
  BAND_STORAGE_TYPE               = BAND_SEQUENTIAL
END_OBJECT                        = IMAGE

/* MAP OBJECT DEFINITIONS */

OBJECT                            = IMAGE_MAP_PROJECTION
  ^DATA_SET_MAP_PROJECTION_CATALOG= "DSMAP.CAT"
  A_AXIS_RADIUS                   = 11.1 <km>
  B_AXIS_RADIUS                   = 11.1 <km>
  C_AXIS_RADIUS                   = 11.1 <km>
  CENTER_LATITUDE                 = 42.3719
  CENTER_LONGITUDE                = 11.418
  COORDINATE_SYSTEM_NAME          = PLANETOCENTRIC
  COORDINATE_SYSTEM_TYPE          = "BODY-FIXED ROTATING"
  EASTERNMOST_LONGITUDE           = 0.0
  FIRST_STANDARD_PARALLEL         = "N/A"
  LINE_FIRST_PIXEL                = 1
  LINE_LAST_PIXEL                 = 3694
  LINE_PROJECTION_OFFSET          = 1880.0
  MAP_PROJECTION_ROTATION         = 0
  MAP_PROJECTION_TYPE             = ORTHOGRAPHIC
  MAP_RESOLUTION                  = 32.8358548587571 <pixel/degree>
  MAP_SCALE                       = 0.0059 <km/pixel>
  MAXIMUM_LATITUDE                = 90.0
  MINIMUM_LATITUDE                = -31.6
  POSITIVE_LONGITUDE_DIRECTION    = WEST
  REFERENCE_LATITUDE              = "N/A"
```

```
  REFERENCE_LONGITUDE            = "N/A"
  SAMPLE_FIRST_PIXEL             = 1
  SAMPLE_LAST_PIXEL              = 3728
  SAMPLE_PROJECTION_OFFSET       = 1878.0
  SECOND_STANDARD_PARALLEL       = "N/A"
  WESTERNMOST_LONGITUDE          = 360.0
END_OBJECT                       = IMAGE_MAP_PROJECTION

/* DIGITAL TERRAIN MODEL DEFINITIONS */

GROUP                            = MEX:DTM
  MEX:DTM_A_AXIS_RADIUS          = -1.0E+32 <km>
  MEX:DTM_B_AXIS_RADIUS          = -1.0E+32 <km>
  MEX:DTM_C_AXIS_RADIUS          = -1.0E+32 <km>
  MEX:DTM_DESC                   = "N/A"
  MEX:DTM_MISSING_DN             = -2147483648
  MEX:DTM_OFFSET                 = -1.0E+32 <m>
  MEX:DTM_SCALING_FACTOR         = -1.0E+32 <m>
END_GROUP                        = MEX:DTM

/* IMAGE HEADER DATA ELEMENTS */

OBJECT                        = IMAGE_HEADER
 HEADER_TYPE                  = VICAR2
 INTERCHANGE_FORMAT           = ASCII
 BYTES                        = 7456
 ^DESCRIPTION                 = "VICAR2.TXT"
END_OBJECT                    = IMAGE_HEADER
END
```