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HRSC on MarsExpress

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MEX-HRSC To Planetary Science Archive Interface Control Document (EAICD)

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Release ……………………………………………………………………………………………………

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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 a 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 (PSA).

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 Mars Express from the spacecraft 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 further on.

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, June 1, 1999, Version 3.3, 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 1, J. Diaz del Rio, ESA RSSD Planetary Missions Division, SOP-RSSD-TN-010, 20-September-2004.
8. MarsExpress - HRSC Level-1 Product Description, T. Roatsch, HRSC-DLR-TN-4200-004, Issue 001, 10-November-2000.
9. MarsExpress - HRSC Level-2 Product Description, T. Roatsch, HRSC-DLR-TN-4200-006, Issue 001, 10-November-2000.
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-4100-001/4D, 24-July-2002

12. The VICAR Image Processing System, http://www-mipl.jpl.nasa.gov/external/vicar.html
13. Navigation and Ancillary Information Facility (NAIF), http://pds-naif.jpl.nasa.gov/
14. Roatsch, T., Oberst, J., Acton, C., Zender, J.: SPICE Usage on the Mars Express Orbiter. XXVI. General Assembly of the European Geophysical Society, Nice, France, March 25-30, 2001, European Geophysical Society, (2001)
15. Zender, J., Bachman, N., Semenov, B., Acton, C., Roatsch, T.: Implementation Concept for Exchanging Ancillary Spacecraft Data for ESA's Mission to Mars, Mars Express. XXVI. General Assembly of the European Geophysical Society, Nice, France, March 25-30, 2001, European Geophysical Society, (2001)
16. Planetary Science Archive PVV User Manual, J. Zender and D. Heather, SOP-RSSD-UM-004, Issue 1, 06-November-2003
17. Mars Express Agreement on the Long-term Preservation of HRSC Camera Data, ME-EST-TN-11420, Issue 1.09 May 2003

1.6 Relationships to Other Interfaces

This document is in close relationship to

- Mars Express - HRSC Data Products Naming Convention [5]
- MarsExpress - HRSC Level-2 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	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 Investigator
PSA	Planetary Science Archive
PVV	Planetary Data Science Volume Verifier
SRC	Super Resolution Camera
VICAR	Video Image Communication and Retrieval

1.8 Contact Names and Addresses

Archive generation software	Klaus-Dieter Matz, DLR
Archive distribution	Thomas Roatsch, DLR
Levels 1 generation software cognizant engineer	Thomas Roatsch, DLR
Map projection and generation	Frank Scholten, DLR
Calibration software and procedures	Klaus-Dieter Matz, DLR
Operations	Reñe Pischel, DLR
VICAR software cognizant Engineer	Robert G. Deen, JPL
PDS Central Node MEX Data Engineer	Betty Sword, JPL
PDS Imaging Node contact	Rafael Alanis, JPL

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 push-broom 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 photo-geologic studies. The spatial resolution from the nominal periapsis altitude of 250 km will be 10 m px -1, with an image swath of 53 km, for the HRSC and 2.3 m px -1 for the SRC. During the mission's 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 d 15 m px-1. More than 70% of the surface can be observed at a spatial resolution of 30 m px -1, while more than 1% will be imaged at better than 2.5 m px -1. The HRSC will thus close the gap between the medium to low resolution 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 instrument and its operation can be found in [4] and [11].

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 CODMAC Level 2 (see Section 2.2.1)
- radiometric calibration of the data
- calculate footprints of every image file and get CODMAC Level 3 (see Section 2.2.1)

The formats of the CODMAC data levels 2 and 3 are described in [8] and [9], respectively (note that internally, the HRSC team define the processing levels differently to CODMAC; see Section 2.2.1).

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.

The cognizant persons for the specific task are listed in chapter 1.8. Please, address all questions and comments through the Data Processing Manager (thomas.roatsch@dlr.de).

2.2.1 Data Processing Levels for archiving (CODMAC)

For archiving purposes, the HRSC team follow the so-called CODMAC definition of processing levels, which has been adopted by the NASA PDS3 and PSA archiving authorities [2, 6]. Note that this is different to the processing level definition used internally by the HRSC team [8, 9]. Within the CODMAC framework, the HRSC data are categorised as follows:

Data description	CODMAC Level
Raw data (not delivered)	2
Radiometric calibrated data	3
Map Projected data	4
DTM data	5

These values are the ones found in the DATA_SET_ID and in the product labels. The label and keyword examples provided within this document are applicable to the radiometrically calibrated data. For the Map Projected and DTM data, along with a number of other differences related to the specific products, the processing levels would be '4' and '5' respectively.

2.3 Product Generation

The starting point for the product generation are the cleaned data which are delivered by ESOC to the PI teams on CD-ROMs. Therefore, it is very important to get this data set right in time for the product generation. The following steps are the same as for the usual data product generation. The only addition is the final step of 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.

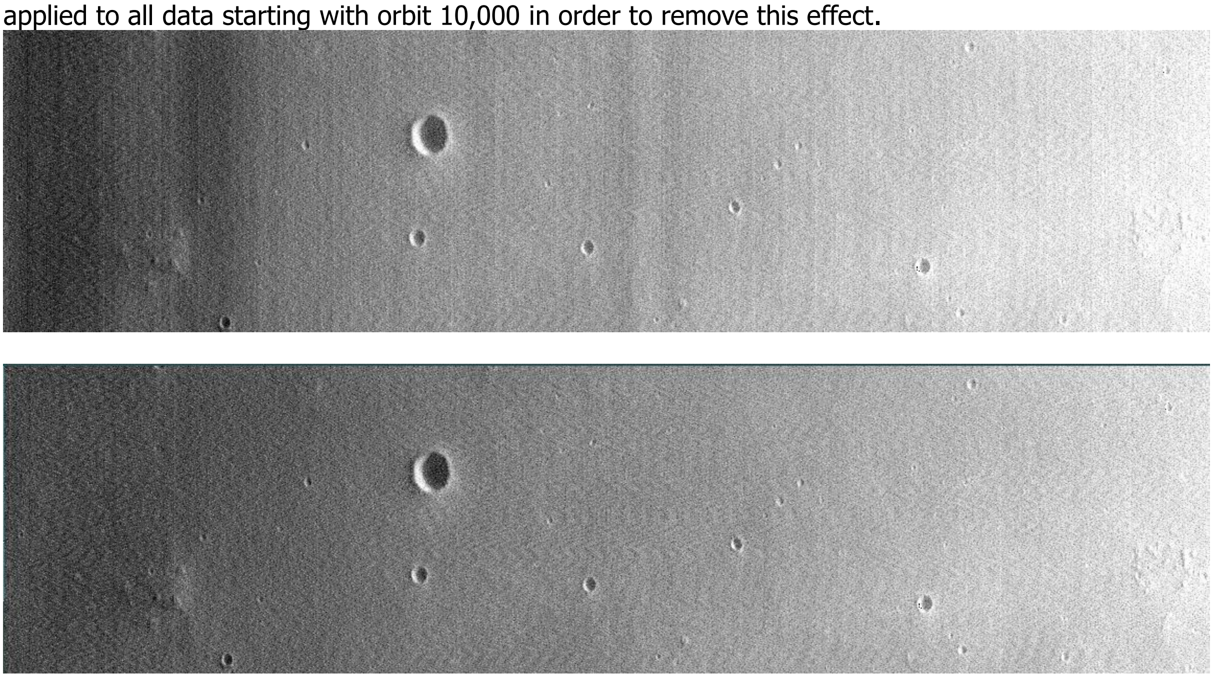
The final products will be sent to the PI and the CoIs who are in charge for the data validation. The data will be sent from DLR to PSA after successful validation and PI approval.

2.4 Changes in data set version 4

2.4.1 Radiometric calibration

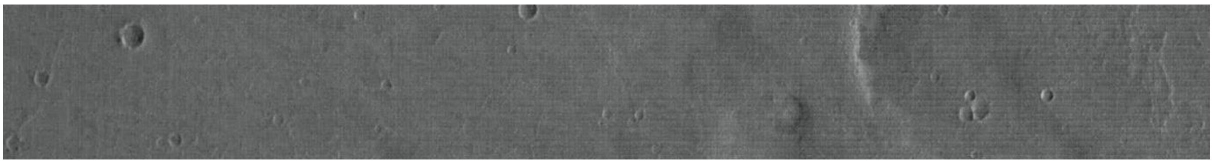
The radiometrically calibrated HRSC data have been continuously investigated by the HRSC team. The team noted three problems in the data which could be improved by changes of the calibration software:

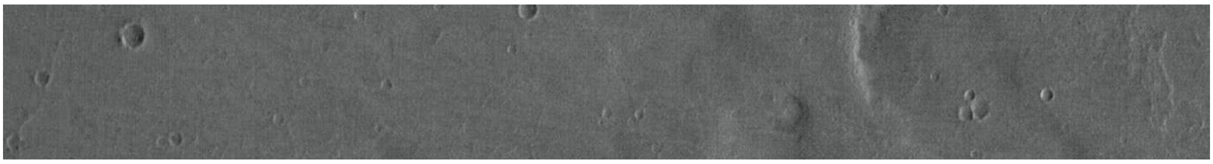
- The team noted a degradation of the filters (especially the blue filter) caused by increasing age. This was observed as a darker part at the start of the line. New in-flight dark currents were calculated and applied to all data starting with orbit 10,000 in order to remove this effect.



Blue sensor image from orbit 21,986 before (top) and after (bottom) correction

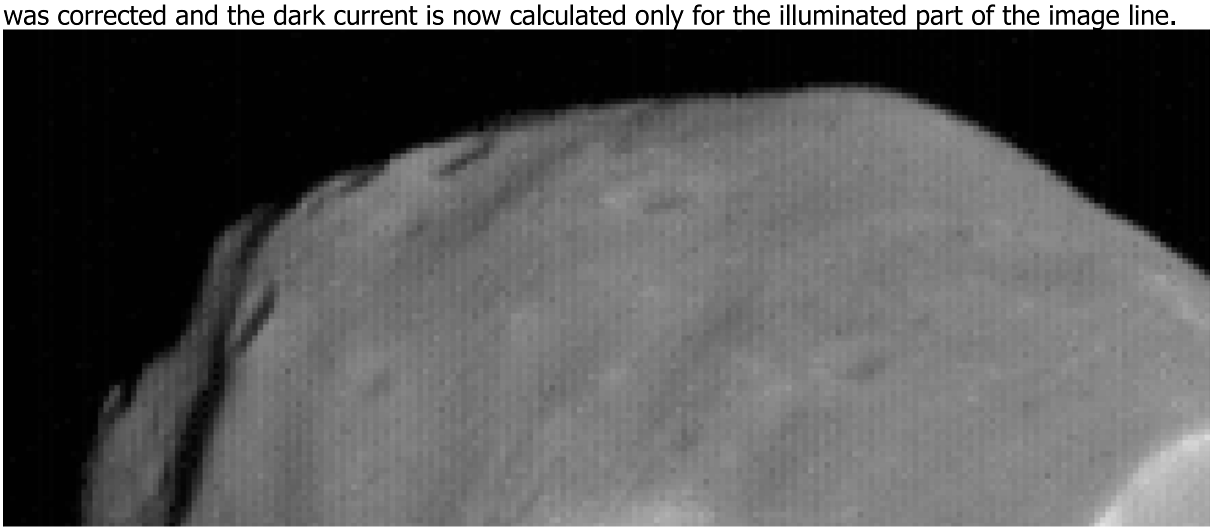
- The team noted artefacts in the data which were caused by interferences between sensors with different macropixel formats. The software was updated to identify potentially problematic data by checking the planning database for the commanded macropixels and then to apply the necessary correction offsets.

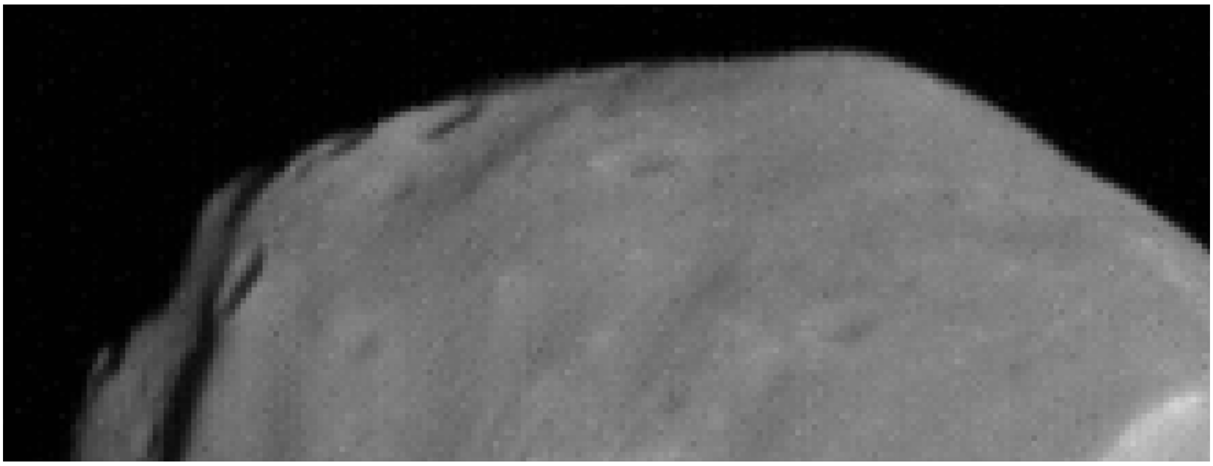




Nadir sensor image from orbit 1,096 before (top) and after (bottom) correction

- The dark current correction was modeled for the whole image line. This caused some errors when major parts of the image line were looking to the dark sky (Phobos, Deimos, limb images, etc.). This was corrected and the dark current is now calculated only for the illuminated part of the image line.





Phobos (blue sensor) image in orbit 22,131 before (top) and after (bottom) correction

2.4.2 Footprint calculation

The footprint calculation software calculates the surface intersection points for a few thousand line of sight vectors at the image borders. Only 100 important points (i.e. significant changes of the footprint) are stored in the image label, which in some cases did not include the four corners of the field of view. These four corner points (upper left, upper right, lower left, lower right) are now always stored in the PDS label. Entries in the GEO_MARS index file are not affected by this change because they already contained the corners.

2.4.3 Data set organization

The volume is now split in one dataset per mission extension to make downloads of the data more convenient for the user. The index files are now also smaller but a user has now to check each index file for non-time related queries.

3 ARCHIVE FORMAT AND CONTENT

3.1 Format and Conventions

3.1.1 Deliveries and Archive Volume Format

The HRSC data will be delivered to PSA every 6 months. Every delivery contains the data taken during a period of 6 months. The delivery will be performed only via file transfer, no storage media like CD or DVD will be used. The data will be split into a couple of sub-datasets to avoid file transfer problems with huge files. All sub-datasets will have a size < 10 GByte. The sub-datasets will also be compressed (using bzip2) to minimize the file transfer time.

The following file naming scheme combining country and instrument name (as suggested by PSA) will be used for the sub-dataset names:

DE_DLR_PF_MEXHRSC

All sub-datasets 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 cfvj and the extension bz2 will be added to the filename.

3.1.2 Data Set ID Formation

All HRSC will be delivered in one dataset per mission extension. The DATA_SET_ID has the following values:

MEX-M-HRSC/SRC-3-RDR-V4.0

MEX-M-HRSC/SRC-3-RDR-EXT1-V4.0

MEX-M-HRSC/SRC-3-RDR-EXT2-V4.0

…

These names follow the standard PDS rules and contain the mission name, the instrument name, describes the level of processing (RDR for the radiometric data), the mission extension, and the version number. The separation of data sets by mission extension phase was a major change to the original single data set format, and was implemented for V4.0 of the HRSC deliveries.

Note that the processing level will be different for the Map Projected and DTM data, which will be '4-REFDR' and '5-DDR' respectively, e.g.:

MEX-M-HRSC-4-REFDR-MAPPROJECT-EXT1-V4.0

MEX-M-HRSC-5-DDR-DTM-EXT1-V4.0

3.1.3 Data Directory Naming Convention

The HRSC data are sorted by orbit in the DATA directory, each sub-directory will have the name
oooo
where oooo is the number of the orbit in which the data were taken.

3.1.4 Filenaming Convention

The file naming convention is described in detail in [5]. The image files in the DATA directories follow this convention:
HOOOO_MMM_DD3IMG

where

OOOO	4 digit orbit number
MMM	number of the image in this orbit
DD	sensor name (can be ND, S1, S2, P1, P2, BL, GR, IR, RE, SR)

The '3' indicates the CODMAC level of processing which is archived in PSA/PDS (see Section 2.2.1).

Please, note that all line sensor data which were taken together will get the same number.

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 int he 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.

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:

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

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

The second process is to check that the image data contained in the data volumes are correct. This will be done by visual inspection by the PI and three CoIs. Specific tools for automated checks may be developed by the teams in charge for this step.

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 identifier 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
INST.CAT
INSTHOST.CAT
MISSION.CAT
PERSON.CAT
REF.CAT
SOFT.CAT

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, geoindex.lbl and geoindex.tab

The Index Directory also contains the Geometric Index File as defined in [7].
These geometric index files currently do not exist for Phobos and Deimos data. The reason is that it is not possible to calculate the information based on the current SPICE kernels. Both orbit and pointing information must be improved, ESTEC is investigating this problem.

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 sub-directories for every orbit which belongs to the data set, the directory name is the four digits orbit number. The browse images are generated from the original data using the following steps:

- reducing the size both in line and sample direction by a factor of 8
- conversion to unsigned 8 bit data
- conversion to raw data
- conversion to jpeg using the UNIX program cjpeg with the highest compression quality (100)

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.
Please, note that huge images (number of lines > 240,00) are reduced by a higher factor to avoid browse images with a number of lines > 30,000 which cannot be displayed by some image display programs (like Adobe Photoshop).

3.4.3.6 Geometry Directory

There is no Geometry Directory, all external geometry information (orbit data, attitude data, etc.) can be found in the Mars Express SPICE data set. The SPICE data are released as separate data sets and are necessary for the generation of higher data levels.
SPICE kernels will not be available as separate release at the time of the first HRSC data release, unfortunately. The user of the HRSC data has to get the SPICE kernels from the ftp server at ESTEC
ftp://ssols01.esac.esa.int/pub//data/SPICE/MEX/kernels/
or from the ftp mirror at NAIF
ftp://naif.jpl.nasa.gov/pub/naif/MEX/kernels/

3.4.3.7 Software Directory

There is no software directory. The user can download the VICAR Open Source software from https://www-mipl.jpl.nasa.gov/vicar_open.html.

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 Experimenter 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 ESA SP-1240
- 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
- HRSC_MINIVICAR.LBL	the label for the MINIVICAR documentation
- HRSC_MINIVICAR.TXT	the Text file describing the how to install and run MINIVICAR
- VICAR2.LBL	the Label for the description of the VICAR labels
- VICAR2.TXT	Text file describing the VICAR label.

3.4.3.11 Extras Directory

There is no Extras Directory.

3.4.3.12 Data Directory

The Data Directory contains sub-directories for every orbit which is part of the data set, the directory names are the four digits orbit number. The content of these sub-directories is described in 3.4.8.

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 all data which were taken in Mars orbit from Mars and its satellites Phobos and Deimos.

The data are delivered at three different processing levels (Section 2.2.1): radiometrically calibrated (CODMAC level 3), map projected (CODMAC level 4) and DTM (CODMAC level 5). There are currently no plans for the HRSC team to archive the uncalibrated data in the PSA, as agreed in [17].

These data can be used both for cross-instrument calibration (e.g. with the spectrometer OMEGA) or with instruments from other missions (e.g. from NASAs MER lander mission).

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, Galileo). 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

3.4.7 Documentation

The contents of the document directory is described in 3.4.3.10.

3.4.8 Derived and other Data Products

There are currently no plans to deliver any further derived / other data products. 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 accommodate 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 signed 16-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.
All data are stored as Most Significant Byte first ("big-endian", as used by e.g. Sun computers and Java)

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 without path		string	
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-RDR-V1.0
DETECTOR_ID	Identifies which of the ten CCD detectors was used for this particular image.		string	MEX_HRSC_S2, MEX_HRSC_RED, MEX_HRSC_P2, MEX_HRSC_BLUE, MEX_HRSC_NADIR, MEX_HRSC_GREEN, MEX_HRSC_P1, MEX_HRSC_IR, MEX_HRSC_S1, MEX_HRSC_SRC,MEX_HRSC_10, MEX_HRSC_11
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_SCANNER
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 CODMAC processing level of a data set (Section 2.2.1); parameter must be updated after each processing step according to the program specification.		int	3
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	
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 computed 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 used during test and cruise)	time	string	

SPACECRAFT_ORIENTATION	The spacecraft orientation element provides the orientation of a spacecraft in orbit or cruise in 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	{(0,1,0), (0,-1,0)}
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	MARS, PHOBOS, DEIMOS, SKY
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 HKD doc.) for sensor P1, IR, S1; temp_fpm in hrhk23, SRC first level is 2	Celsius	real	

FOCAL_PLANE_TEMPERA-TURE	TEMPERATURE OPTICS in Dornier HKD document, HRSC only, temp_co in hrhk23	Celsius	real	
INST_CMPRS_NAME	Flag indicating whether space-craft on-board compression has been bypassed, in which case, the received data were uncom-pressed; HRSC: config. byte 1/2, bit 2 = 1 ==> BYPASS_FLAG = "YES"		string	NONE,"DIGITAL COSINE TRANSFORMATION"
INST_CMPRS_QUALITY	The compression index parame-ter 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 ma-trix 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 Dorn-ier HKD document, temp_fee in hrhk23, SRC first level is 2	Celsius	real	
LENS_TEMPERATURE	TEMPERATURE OPTICAL BENCH in Dornier HKD docu-ment, HRSC only, temp_ob in hrhk23	Celsius	real	
MACROPIXEL_SIZE	Macropixel format		int	1,2,4,8
MISSING_FRAMES	The MISSING_FRAMES ele-ment is the total number of frames that are missing from a file (Cf. ERROR_FRAMES and OVERFLOW_FRAMES). Note: for MARS EXPRESS, a frame, which is also called a "row", is eight lines of data.		int	
PIXEL_SUBSAMPLING_FLAG	The PIXEL_SUBSAM-PLING_FLAG element indicates whether this product is the result of subsampling of the data, HRSC only.		string	Y,N
SAMPLE_FIRST_PIXEL	Position of the first pixel on the CCD line that contributes to the first VICAR macropixel (may still be dark or dummy pixels for level 1 images); config bytes 3,4; bits 0-12; note: FIRST_PIXEL = start_pixel_number + 1		int	
SIGNAL_CHAIN_ID	The SIGNAL_CHAIN_ID ele-ment identifies the signal chain (electronic signal path) number selected for charge-coupled de-vice (CCD) output.		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 (CCD+Optics).	nm	real	
CENTER_FILTER_WAVE-LENGTH	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/ste-radian	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/ste-radian	real	
REFLECTANCE_SCALING_FAC-TOR	The reflectance_scaling_factor element identifies the conversion factor from DN to reflectance.		real	

4.5 Example PDS Product Label

```
PDS_VERSION_ID                          = PDS3
/* FILE DATA ELEMENTS */
RECORD_TYPE                                   = FIXED_LENGTH
RECORD_BYTES                                  = 10420
FILE_RECORDS                                  = 251387
LABEL_RECORDS                                 = 2
/* POINTERS TO DATA OBJECTS */
^IMAGE_HEADER                                 = 3
^IMAGE                                              = 4
/* IDENTIFICATION DATA ELEMENTS */
FILE_NAME                                           = "H0024_0000_ND3.IMG"
DATA_SET_ID                             = "MEX-M-HRSC/SRC-3-RDR0010-V4.0"
DETECTOR_ID                                   = MEX_HRSC_NADIR
EVENT_TYPE                        = "MARS-LOCAL-CARTOGRAPHY-Im-Lc-Tc"
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                      = MC_Phase_1
PROCESSING_LEVEL_ID                     = 3
PRODUCT_CREATION_TIME             = 2004-11-24T19:53:14.000Z
PRODUCT_ID                                    = "H0024_0000_ND2.IMG"
/* TIME DATA ELEMENTS */
SPACECRAFT_CLOCK_START_COUNT      = "1/0022332827.31245"
SPACECRAFT_CLOCK_STOP_COUNT       = "1/0022333524.07540"
START_TIME                                    = 2004-01-16T11:35:55.639Z
STOP_TIME                                     = 2004-01-16T11:52:36.574Z
/* ORBITAL DATA ELEMENTS */
ASCENDING_NODE_LONGITUDE           = 228.47
```

```
MAXIMUM_RESOLUTION                        = 11.7 <m/pixel>
FOOTPRINT_POINT_LATITUDE                  = (-51.592,-51.3204,-51.3182,-
50.2127,
                                                        -49.1343,-
47.0532,-45.0716,-44.1141,
                                                  -43.1777,-42.2627,-
40.4919,-38.7932,
                                                        -37.1618,-
34.0794,-31.9082,-30.5201,
                                                        -29.8429,-
29.1757,-27.2292,-26.5962,
                                                        -25.9749,-
25.3606,-24.7522,-22.3965,
                                                        -21.8232,-
21.2573,-20.691,-20.1401,
                                                        -18.502,-
17.9641,-17.4256,-16.345,
                                                        -15.8032,-
15.2604,-13.6279,-13.0823,
                                                        -12.5358,-
11.9887,-10.3444,-9.79539,
                                                        -9.24578,-
8.69579,-7.59391,-7.04251,
                                                        -6.4911,-
5.38784,-4.28411,-3.73212,
                                                        -3.18019,-
2.07651,-1.52482,-0.973341,
      0.679678,3.42738,4.52295,5.61604,
      7.79353,9.41786,12.1229,12.1305,12.1303
      ,11.5946,11.0577,10.5197,9.98082,
      9.44085,8.89994,6.18221,-3.71932,
                                                        -5.92888,-
6.48098,-7.03285,-7.58452,
```

```
                                                  -8.13596,-
8.68704,-9.78828,-10.3382,
                                                  -11.4364,-
11.9848,-12.5326,-13.0799,
                                                  -13.6262,-
15.2612,-15.8047,-16.3473,
                                                  -16.8891,-
17.9697,-18.5084,-19.0461,
                                                  -21.8354,-
22.9913,-23.5757,-26.6196,
                                                  -28.5455,-
29.2072,-34.1319,-34.8845,
                                                  -45.2103,-
48.2611,-51.592)
FOOTPRINT_POINT_LONGITUDE          = (175.791,171.024,171.001,171.293,
      171.557,172.005,172.39,172.557,172.701,
      172.843,173.092,173.309,173.491,173.8,
      173.991,174.097,174.144,174.195,174.321
      ,174.357,174.389,174.422,174.449,
      174.566,174.588,174.613,174.635,174.656
      ,174.702,174.713,174.736,174.764,
      174.772,174.775,174.811,174.827,174.834
      ,174.839,174.883,174.904,174.916,
      174.931,174.913,174.901,174.901,174.909
      ,174.914,174.912,174.914,174.915,
      174.913,174.913,174.907,174.888,174.878
```

```
      ,174.866,174.836,174.809,174.756,
      176.143,176.149,176.143,176.139,176.138
      ,176.133,176.13,176.127,176.115,176.094
      ,176.094,176.093,176.09,176.089,176.089
      ,176.088,176.092,176.091,176.084,
      176.083,176.082,176.087,176.081,176.077
      ,176.08,176.081,176.084,176.085,176.082
      ,176.081,176.072,176.067,176.063,
      176.051,176.048,176.042,176.014,176.006
      ,175.906,175.858,175.791)
ORBIT_NUMBER                                  = 24
ORBITAL_ECCENTRICITY                    = 0.667
ORBITAL_INCLINATION                     = 86.66
ORBITAL_SEMIMAJOR_AXIS                  = 11020.2
PERIAPSIS_ALTITUDE                      = 274.22
PERIAPSIS_ARGUMENT_ANGLE          = 355.69
PERIAPSIS_TIME                                = 2004-01-16T11:48:35.000Z
SPACECRAFT_ORIENTATION                  = (0.0,1.0,0.0)
^MEX_ORIENTATION_DESC                   = "MEX_ORIENTATION_DESC.TXT"
SPACECRAFT_POINTING_MODE          = ACROSSTRACK
^MEX_POINTING_DESC                      = "MEX_POINTING_DESC.TXT"
RIGHT_ASCENSION                         = -1e+32
DECLINATION                                   = -1e+32
OFFSET_ANGLE                                  = 2.04
SPACECRAFT_SOLAR_DISTANCE         = 2.23543e+08
```

```
TARGET_NAME                             = MARS
/* CAMERA DATA ELEMENTS */
DETECTOR_TEMPERATURE                    = 18.3705 <degC>
FOCAL_PLANE_TEMPERATURE                 = 9.8067 <degC>
INST_CMPRS_NAME                         = "DISCRETE COSINE TRANSFORMATION
(DCT)"
INST_CMPRS_RATIO                        = 7.43431
INST_CMPRS_QUALITY                      = 0
INST_CMPRS_QUANTZ_TBL_ID                = 0
INSTRUMENT_TEMPERATURE                  = 11.4379 <degC>
LENS_TEMPERATURE                        = 10.0106 <degC>
MACROPIXEL_SIZE                         = 1
MISSING_FRAMES                          = 0
PIXEL_SUBSAMPLING_FLAG                  = N
SAMPLE_FIRST_PIXEL                      = 80
SIGNAL_CHAIN_ID                         = 0
/* RADIOMETRIC DATA ELEMENTS */
BANDWIDTH                               = 177.0 <nm>
CENTER_FILTER_WAVELENGTH                = 677.5 <nm>
RADIANCE_OFFSET                         = 0.0 <W*m**-2*sr**-1>
RADIANCE_SCALING_FACTOR                 = 0.0695439 <W*m**-2*sr**-1>
REFLECTANCE_SCALING_FACTOR              = 0.00184611
/* DATA OBJECT DEFINITIONS */
OBJECT                                  = IMAGE
  INTERCHANGE_FORMAT                    = BINARY
  LINES                                 = 251384
  LINE_PREFIX_BYTES                     = 68
  LINE_SAMPLES                          = 5176
  SAMPLE_TYPE                           = MSB_INTEGER
  SAMPLE_BITS                           = 16
  BANDS                                 = 1
  BAND_STORAGE_TYPE                     = BAND_SEQUENTIAL
```

```
  MAXIMUM                    = 209
  MEAN                       = 127.59
  MINIMUM                    = 62
  STANDARD_DEVIATION         = 23.3313
END_OBJECT                   = IMAGE
/* IMAGE HEADER DATA ELEMENTS */
OBJECT                       = IMAGE_HEADER
 HEADER_TYPE                 = VICAR2
 INTERCHANGE_FORMAT          = ASCII
 BYTES                       = 10420
 ^DESCRIPTION                = "VICAR2.TXT"
END_OBJECT                   = IMAGE_HEADER
END
```