Mars Express

OMEGA Experiment to Archive Interface Control Document (EAICD)

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Prepared by:

Yves Langevin
Archive Manager

Approved by:

Jean-Pierre Bibring
Principal Investigator

Approved by:

David Heather
PSA Science Archive Coordinator

Institut d'Astrophysique Spatiale
Btiment 121, Universit Paris XI, 91405 ORSAY Cedex, France
Centre National de la Recherche Scientifique

DISTRIBUTION LIST

Recipient	Organization
Jean-Pierre Bibring	Institut d'Astrophysique Spatial
Yves Langevin	Institut d'Astrophysique Spatial
Michel Berth	Institut d'Astrophysique Spatial
David Heather	SRE-OS/ESAC

CHANGE RECORD SHEET

Date	Version	Section	Changes
11/23/2004	0.6.2	all	Draft release to the PSA
11/15/2011	1.0	all	Reformatted using LaTeXto produce clean PDF, and ASCII versions.
		3.1.2	Added data set splitting information.

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1 Introduction

1.1 Purpose and Scope

The purpose of this EAICD (Experimenter to Planetary Science Archive Interface Control Document) is twofold. First it provides users of the OMEGA instrument with detailed description of the product and a description of how it was generated, including data sources and destinations. Secondly, the EAICD describes the interface to the Planetary Science Archive (PSA) of ESA and is the official document between each experimenter team and the 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 implements an online science archive, the Planetary Science Archive (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
  - 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 OMEGA instrument on Mars Express 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 data product is explained.

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 OMEGA data.

1.5 Applicable Documents

[1] Planetary Data System Data Preparation Workbook, February 17, 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] Mars Express Archive Generation, Validation and Transfer Plan, 2001 June 21, ESA-MEX-TN-4009

[4] OMEGA Flight User Manual: OME-DU-0023-118-IAS, Version 3.0

[5] Report of the IAU/IAG working group on cartographic coordinates and rotational elements of the planets and satellite: 2000, P.K. Seidelman, et al., Celestial Mechanics and Dynamical Astronomy, in Press, 2002.

[6] Planetary Science Data Archive Technical Note, Geometry and Position Information, 8 October 2004, SOP-RSSD-TN-010, Issue 3 - Revision 3

1.6 Acronyms and Abbreviations

AD	Applicable Document
APID	Application Process IDentifier
CNES	Centre National d'Etudes Spatiales
DESPA	Dpartement de Recherches Spatiales
DN	Digital Number
DDS	Data Delivery System
EAICD	Experiment Archive Interface Control Document
ESA	European Space Agency
ESOC	European Space Operation Center
ESTEC	European Space Research and Technology Center
FOV	Field of View
HK	Housekeeping
IAS	Institut d'Astrophysique Spatiale
IFOV	Instantaneous Field of View
IFSI	Istituto di Fisica dello Spazio Interplanetario
IKI	Institut Kosmitcheski Isledovanie
ISIS	Integrated Software for Imaging Spectrometers
IR	Infrared
OBT	On Board Time
MEX	Mars Express
NAIF	Navigation Ancillary Information Facility

OMEGA	Observatoire pour la Minralogie, l'Eau, les Glaces et l'Activit
PDS	Planetary Data System
PI	Principal Investigator
PSA	Planetary Science Archive
PVV	PSA Volume Verifier
RD	Reference Document
ROM	Read-Only Memory
S/C	Spacecraft
SCET	Spacecraft Elapsed Time
SWIR	Short Wavelength Infrared channel
TBC	To Be Confirmed
TBD	To Be Defined
VNIR	Visible and Near Infrared channel
WRT	With Respect To

1.7 Contact Names and Addresses

Gilles Poulleau, IAS
Overall responsibility, automatic processing
`gilles.poulleau@ias.u-psud.fr`
+33 (0) 1 69 85 86 05

Brigitte Gondet, IAS
Level 1 and 2 products, calibration
`brigitte.gondet@ias.u-psud.fr`
+33 (0) 1 69 85 86 35

Yves Langevin, IAS
Software responsibility
`yves.langevin@ias.u-psud.fr`
+33 (0) 1 69 85 86 81

Nicolas Manaud, IAS
Geometry products
`nicolas.manaud@ias.u-psud.fr`
+0033 (0) 1 69 85 86 20

Stephane Erard, IAS
Level-3 and derived products
`stephane.erard@ias.u-psud.fr`
+33 (0) 1 69 85 86 41

2 Overview of Scientific Objectives, Instrument Design, Data Handling Process and Product Generation

2.1 Scientific Objectives

The OMEGA mapping spectrometer will map the Martian surface with an IFOV of 1.2 mrad (4.1 arc minutes), and acquire for each resolved pixel the spectrum from 0.36 to 5.2 μm in 352 contiguous spectral channels (spectels).

The optical part consists in two co-aligned units, each including a telescope: a Visible Channel (VNIR) analyses the light from 0.36 to 1.07 μm, using as a detector a bi-dimensional CCD THX7863 Thomson detector in a pushbroom mode: 96 spectral lines of 128 columns, imaging at once a crosstrack line of 128 pixels large at the surface of Mars; a Near Infrared Channel, named SWIR (Short Wavelength IR Channel) disperses the light through two spectrometers from 0.93 to 2.7 μm and 2.6 to 5.2 μm, onto two linear InSb arrays (whiskbroom mode) cooled down 70K, each with a dedicated cryocooler. A scanning mirror in front of the SWIR telescope permits to acquire crosstrack swaths of 16 up to 128 pixels width, for a maximum FOV of 8.8 degrees, thus matching the VNIR FOV. SNR of 100 over the entire spectral range, for IR integration times of 5 ms per pixel, is the specification.

Combining imagery and spectrometry, OMEGA is designed to provide the mineralogical and molecular composition of the surface and atmosphere of Mars through the spectral analysis of the re-diffused solar light and surface thermal emission. OMEGA will provide a global coverage at medium resolution (1 to 5 km) of the entire surface of Mars from altitudes 1000 to 4000 km, and snapshots of selected areas, amounting to at least a few percents of the surface, with a resolution of a few hundreds meters when observed close to periapsis (300 km altitude). More specifically, with the above-mentioned spatial resolution, OMEGA should allow:

- to characterize the composition of surface materials, discriminating between the various classes of silicates, hydrated minerals, oxides and carbonates, organic frosts and ices;
- to study the time and space distribution of atmospheric CO2, CO and H2O;
- to identify the aerosols and dust particles in the atmosphere, and observe their time and space distributions
- to monitor the surface dust transportation processes.

2.2 Instrument Design

OMEGA is a mapping spectrometer working both in the visible and the infrared spectral ranges.

It is constituted of two co-aligned channels, one working in the 0.38 to 1.05 μm visible and near infrared range (VNIR channel), the other in the 0.93 to 5.1 μm short wavelength infrared range (SWIR channel). The data products constitute three-dimensional (X, Y, lambda) image-cubes, with two spatial and one spectral dimension.

The VNIR channel uses a bi-dimensional CCD detector, operated in a pushbroom mode. Its telescope acquires at once in its focal plane one cross-track line corresponding to the entire 8.8 degrees FOV, defined by an entrance slit; the second dimension of the image is provided by the motion of the S/C. Each line is spectrally dispersed along the columns of the array, the slit being imaged through a concave holographic grating.

The SWIR channel operates in the whiskbroom mode: each imaged pixel is acquired at once by an IR telescope; a scanning mirror, in front of the telescope, permits to acquire crosstrack swaths of 16 up to 128 pixels width, for a maximum FOV of 8.8 degrees, thus matching the VNIR FOV, while the S/C motion provides the second spatial dimension. The imaged pixel is focused by the telescope on a slit, followed by a collimator. The beam is then split towards two separated spectrometers, to acquire the IR spectrum of each resolved pixel onto two InSb linear arrays of 128 spectels each, from 0.93 to 2.73 μm and from 2.55 to 5.1 μm respectively. Each array is cooled down 70 K by a dedicated cryocooler, while the entire spectrometer is cooled down 190 K by a conductive link to a passive radiator. The typical IR integration time, defined by the S/C ground track velocity and the spatial sampling chosen, is 5 msec. The corresponding VNIR integration times are 100 to 800 ms, depending on the swath width, thus the altitude. With such integration times, SNR ¿ 100, over the entire spectral range, is the specification.

OMEGA is made of two distinct units:

- a Camera unit (OMEGA-C) with the VNIR and SWIR spectrographs, their associated electrical devices, and one electronics assembly for the control of the camera. All units are integrated onto a common base plate; its mass is 23.8 kg.
- a Main Electronics module (OMEGA-ME), for the data processing and the general management of the instrument; its mass is 5.1 kg.

VNIR spectrograph VNIR is made of two optical subsystems: a focusing telescope with its focal plane on a slit, and a spectrometer, that spreads the slit image in the spectral dimension. It provides image data in the spectral range 0.38 to 1.05 μm achieving a maximum spatial sampling of 0.4 mrad and a maximum spectral sampling of 50 Angstrom. A refractive telescope focuses the image on a slit placed on the Rowland circle of an aberration corrected concave holographic grating mirror. This element reflects and disperses the light on a CCD detector tangent to the Rowland circle. The detector used is the TH7863 frame transfer CCD produced by Thomson. The chosen grating mirror can create a flat image onto the focal plane. This property allows to match very well the flat detector matrix to the grating, without other optical components. A CCD frame is then composed of N rows each containing an image of the slit at a given wavelength, and M columns each containing the spectrum of a point along the slit. The bi-dimensional image of the surface is obtained by the pushbroom technique, in which the spacecraft movement along its orbit performs a scan of the slit across the planetary surface. The electrical signal from the detector is amplified and then digitized by a fast 12 bit A/D converter; after conversion, all data are processed within the OMEGA-ME.

In order to decrease the detector noise, VNIR is cooled down 190 K by conduction to the SWIR mechanical unit. The choice of refractive over reflective optics was made because of the large (8.8 degrees) field of view requirement. The telescope has a 6 elements objective similar to that of a modern commercial photographic camera. The shape of the elements and the types of optical glass were chosen to obtain the best chromatic aberration corrections over the entire spectral range. The last element serves as a field lens, which matches the entire objective with the grating to avoid light losses. To avoid stress in the lenses at the working temperature, the two doublets are not cemented. The two glasses, FK54 and fused silica, have very different expansion coefficients of 8 and 0.55 x 10^{-6} / K at room temperature. The entrance aperture of 15.6 mm is defined by a diaphragm between the two doublets. An aberration corrected concave holographic grating is placed 142.7 mm from the entrance slit (which is in the focal plane of the telescope). The grating is tilted to form the spectrum at an angle of roughly 6 degrees from the optical axis. This angle does not allow CCD insertion near the entrance without beam obscuration; therefore, a folding mirror deflects the beam toward the side of the assembly, where the CCD can be mounted with ample clearance.

The zero order spectrum, at 4.5 degrees from the folded optical axis (lying in the y-z plane) is directed into a light trap to prevent degradation of the image. The first order spectrum ranges in angle from 6 degrees at $\lambda = 0.35\mu$m to 10 degrees for $\lambda = 1.05\mu$m. The second and higher order spectra can, in principle, also degrade the data. Its contribution depends both on the grating efficiency, and the spectral distribution of the incident radiation. For this reason, a dedicated filter is mounted, in front of the detector. The concave, spherical, holographic grating in a Rowland mounting - where the entrance slit and the spectrum are on radii of curvature of the grating - makes the spectrometer compact, light, and simple. In fact, no collimator or camera lens is required and the spectrometer has only one element. Moreover, the focal plane image can be flat, to match the planar CCD sensors. Since the concave holographic grating is obtained by recording a perfect optical pattern with groove spacing absolutely constant, it has no ghosts. Stray light has also a much lower level than the best ruled gratings. Therefore, concave holographic gratings generally have a much higher signal to noise ratio than classically ruled gratings.

The optical performances have been computed by ray tracing. In the focal plane the spot diagram is about the pixel size (23x23 microns). For off-axis propagation (4.4 degrees off-axis), the total spot size is about 2 pixels in the sagittal direction. More precisely, on axis and at 0.7 μm, 98.8 % of the energy falls within a 23x23 micron pixel; at 4.4 degrees off-axis and lambda = 0.4 μm, 74 % of the energy falls within a CCD element. When the light propagates off-axis, the spot size is smaller for the shorter wavelengths.

The Pattern Generator (PG) determines the CCD integration time, and generates the timing signals necessary to transfer an image from the light sensitive area to the masked zone and then to the output shift register of the CCD. The output of the CCD is then amplified and converted by a fast 12-bit A/D converter under control of the PG. The timing of the instrument imposes a relatively high frequency for CCD operation. In fact, depending on the distance from the planet and hence on the spacecraft speed, the time TR between consecutive frames can be chosen as: 100, 200, 400 or 800 ms. During the TR period the integration, readout and data transmission processes must occur. To save time, integration and transmission of the previous frame are overlapped. Because the maximum data value, which can be transmitted during TR, is limited to 12288 bytes, it is not possible to read the total frame of 384x288 pixels, corresponding to 110592 bytes. We are forced to read only a sub-frame, or to reduce the number of pixels by summing them on chip. The combination of different scientific requirements, integration times and hardware limitations led us to the definition of

40 operation modes, which can be selected through commands sent to the spacecraft, ranging from the nominal (spatial x spectral) mode (128x96 with summation of 3x3 pixels), to the high spectral resolution mode (64x144), too the high speed mode (16x96) Summation along columns and rows will decrease the spatial and spectral resolution, but increases signal-to-noise ratio considerably. The implementation of mode 16x74 is the most critical due to the short time available to complete all the operations (TR = 100 ms). For this reason the Pattern Generator provides two values for the pixel readout frequency: $f_{slow} = 500$ kHz when the pixel voltage has to be digitized and $f_{fast} = 4$ MHz when the pixel is simply read from the CCD output register without any digital conversion.

SWIR Spectrograph The IR channel is constituted of a telescope and its fore-optics, a beam splitter and two spectrometers, each with its detector array actively cooled. The telescope is a Cassegrain type one with a 200 mm focal length, a f/4 aperture, leading to a 1.2 mrad (4.1 arcmin) IFOV, and a 15 arcmin free field of view (including the positioning tolerances). The distance between the primary and the secondary mirrors is 51 mm; that between the secondary mirror and the image plane is 82 mm. In front of the telescope, a fore-optics system has the primary goal of providing a cross-track scanning of the IFOV. It includes two mirrors, a moving and a fixed one. The total scanning angle is ± 4.4 degrees (FOV = 128 IFOV), and is adjusted to the OMEGA viewing direction. The control of the scanning mechanism is performed by a dedicated FPGA-based electronic sub-system.

Focused by the telescope on an entrance slit, through a shutter, the beam is first collimated, then separated, by a dichroic filter with its cut-off wavelength at 2.7 μm towards two spectrometers, operating in the following spectral ranges: 0.93 to 2.73 μm and 2.55 to 5.1 μm. Each spectrometer includes a blazed grating working at its first order, and an optical reflective system, then a field mirror and a refractive refocusing system which gives a large aperture on the detection block (f/1.6): it images the spectrum onto a 128 elements InSb linear array, cooled down a temperature of < 80 K, and multiplexed by a charge transfer device. Sets of filters are implemented in front of the detector to reject the contribution of other orders from the grating. The InSb photodiodes have been manufactured by SAT. The dimension of each photosensitive element is 90 micron x 120 microns, with a pitch of 120 micron. All elements of the focal planes are hybridized on a ceramic with two electric circuit layers to connect the elements together. The ceramic is glued on a titanium base plate and covered with a titanium closure, which includes the filters.

An internal calibration source is implemented, to control potential shifts of the overall spectrometer transmission, and to calibrate the relative response of each pixel. It is made of a tungsten lamp, operated as a black body, which can be power, heated at different temperatures. The calibration beam is reflected towards the spectrometer by diffusion on the backside of the entrance slit.

SWIR requires an accurate thermal control, at three levels:

- the IR detectors must be cooled down a temperature of < 80 K, controlled with an accuracy better than 0.1K. This is done by connecting them (copper heat link) to two cryocoolers, one for each array: they consist in Inframetrics 13000 series integral Stirling cycle coolers. Their guaranteed lifetimes are > 2500 hours. They are controlled by a dedicated electronics

- the spectrometer must be cooled down to 190 K, in order both to allow the detectors to reach their required operational temperature (< 80 K), and to minimize the thermal background. This is achieved by conductive coupling (heat pipes) to a "low temperature" radiator, provided by the S/C;
- the electronics and the cryocoolers heads must be coupled (copper links) to a "high temperature" (280 K) radiator to dissipate their energy.

OMEGA-ME Unit The OMEGA main electronics is designed to power and control the instrument, to acquire and compress all scientific data on line, and to interface with the S/C telecommand/telemetry system. The entire system is cold redundant. Within OMEGA-ME, the Command and Data Processing Unit (CDPU) has the following tasks:

- acquisition of all scientific data from VNIR and SWIR;
- formatting for real time data compression
- wavelet based data compression, followed by formatting of processed data
- reception and formatting of HK data
- forward all data to the S/C telemetry system

The CDPU is based on a TSC21020 Temic processor, and integrated, together with a 6Mbyte SRAM, into a 3D packaged highly miniaturized cube, inherited from a IVA/Rosetta development.
Institut d'Astrophysique Spatiale is responsible for data preparation and distribution to CoI's. The relevant contact information is provided in section **??** page **??**.
The following table describes the OMEGA data processing level:

Processing Level	Definition
1A	Raw data that have been separated by instrument and sorted by orbit number. It contains science and housekeeping data.
1B	PDS formatted data, including decompressed science data, housekeeping, and geometry data. The science data are still uncalibrated.
2	Calibrated science data resulting from the data reduction done by the OMEGA software provided the dataset.
3	High level derived product such as mineralogical maps

Table 1: Data Level Definition

IAS recovers two types of information relevant to OMEGA data:

- All packets with an OMEGA APID (pull from ESOC dds to IAS)
- SPICE kernels (pull from ESTEC navigation database to IAS).

They are automatically processed into OMEGA data products, using the following procedure.

1. Every 12 hours, the IAS gateway server checks the arrival of new OMEGA packets on the DDS server at ESOC. Science packets are sorted by orbit number (4 digits) by comparing the generation time of the packet and the sequence of apocenter times. The corresponding file, `ORBNNNN.dds`, constitutes the level-1A data product (archived at ESOC for six months and at IAS permanently). The HK packets are also sorted by orbit number, constituting a file `HKNNNN.dds`. If during such a search a new packet is found which belongs to an orbit with an already existing `ORBNNNN.dds` or `HKNNNN.dds` file, the file is reopened and the packet is inserted at the ranking corresponding to increasing APID's. Only the last packet with a given APID is kept. If there is no file associated with the orbit of the packet, a corresponding `ORBNNNN.dds` is opened. At the end of the check procedure, all opened files are closed.

2. Once the checking procedure is complete, the server automatically reprocesses all level-1A data files, which have been created or modified. It sorts out the high rate telemetry packets, then decompresses the data and produces a series of preliminary PDS data cubes. Each data cube corresponds to the interval between the start and end of an observation (with a given set of observation parameters). There can be several observations for one orbit. The corresponding cubes are named `ORBNNNN_0.QUB`, `ORBNNNN_1.QUB`, . . . , `ORBNNNN_9.QUB`, then `ORBNNNN_A.QUB`, then `B`, `C`, and so on if there are more than 10 cubes for an orbit.

3. After all the relevant level-A files have been processed, the server processes each new preliminary cube by determining the geometric information relevant for each of the three channels, each scan and each pixel, and using the latest relevant kernel received from ESTEC. This generates an auxiliary geometry file, `ORBNNNN_X.PRE`. Part of the overall geometric information (e.g. minimum and maximum latitude, westernmost and easternmost longitude) is included in the label of the preliminary data cube, generating a final level-1B data cube `ORBNNNN_X.QUB`. The format of level-1B PDS files and associated auxiliary PDS files is given in section 5.2.

4. Every 24 hours, the kernel directory in ESTEC is checked. If a new kernel is available, it is retrieved by the server. All auxiliary geometry cubes with dates, which are covered by the new kernel, are then reprocessed so as to take into account this new positioning and/or pointing information. The corresponding level-1B data cubes are updated accordingly.

5. After 30 days, it is considered that the navigation information will not be updated for a given orbit. Every 24 hours, each auxiliary geometry cube for which the orbit is older than 30 days is copied into a geometry cube, `ORBNNNN_X.NAV`, which is therefore expected to provide the most accurate information on the observation geometry.

To each science level-1B PDS file is associated a geometry PDS file containing information on the projection of the looking directions on the surface of Mars. The format of level-1B PDS files and associated geometry PDS files is given in section 4.1. The level-1B cubes will be used by the OMEGA team and they will be archived at the ESA's Planetary Science Archive (PSA) for long term preservation.

During the proprietary period, a data reduction tool in IDL is made available to all coI's to read the level-1B data set and to convert it into a data set corrected for the photometric function, hence in physical units ($W/m^2/steradian/\mu$). This data set is relevant for regions of the spectrum dominated by thermal emission (typically above 4 μm). Another data set is provided in I/F, dividing by the solar spectrum, which is relevant for the region of the spectrum dominated by diffused sunlight (typically below 3 μm). These two data cubes have the same dimensions as the corresponding level-1B cube. Eventually, The spectral information will be co-registered to the looking direction of the 65th spectel of the "IR C" channel of the OMEGA experiment. These processing tools are built on the best knowledge available on the instrument from ground calibration, self-consistency checks and comparison with other experiments (e.g. MOLA for altimetry data, THEMIS for spectral data). The OMEGA user is made aware that this understanding will evolve with the learning curve on the actual behaviour of OMEGA around Mars. The signal/noise obtained by OMEGA can exceed 1000 over part of the wavelength range, not taking into account the along-track summing by a factor of 1 to 4 which can be performed on-board when 128 scans are implemented. No ground calibration can provide that level of confidence, in particular for visible-near IR imaging spectrometry. As an example, for this type of experiments, an absolute photometric calibration level of 10 % is considered an ambitious goal, which can only be achieved after careful cross-comparison of actual data with the results of ground calibration and that of other experiments. Linearity or cross-talk at a level of a few percent has been observed to depend strongly on the stimulus during ground calibration.

The Planetary Data Center at IAS will also maintain an archive of the OMEGA products. Level-1B, geometry files and various software tools will be distributed to co-Is during the operational phase, Example derived products (level-3 files) will also be produced and distributed at IAS as examples of the science which can be done with OMEGA. They will also be provided to the archive when available in a PDS compliant format.

2.3 Overview of Data Products

2.3.1 Pre-Flight Data Products

No ground calibration information will be made available. The OMEGA team will provide and update relevant information so that the processing pipeline is up to date with the current understanding of the characteristics of OMEGA.

2.3.2 Sub-System Tests

The only relevant sub-system test for this purpose will be performed if an anomaly is observed in the data packets. A fixed test data set can be generated by a specific command so as to check the integrity of the downlink chain, in any of the possible observation modes of OMEGA. The processing pipeline will generate a level 1B file with a fixed data pattern, which will have exactly the same format as a real observation with the same parameters.

2.3.3 Instrument Calibrations

Calibration files (at IAS and PSA)

Spectral Table giving for each channel (96 or144 visible, 256 IR) the exact spectral position

Geometric Table giving for each pixel along a line (128 elements) the angular viewing direction

Radiometric Transfer functions for each of the three channels, covering (0.35-5.2 μm)

The current version of the photometric function, the wavelength scale and the solar spectrum at OMEGA wavelengths, are provided together with the OMEGA data reduction software.

2.3.4 Other Files written during Calibration

A series of observations of rocks and powders has been performed during calibration. This data set will be made available through a direct collaboration with the PI team.

2.3.5 In-Flight Data Products

Raw data (at ESOC, PSA and IAS)
ESOC and PSA will archive all data downlinked by MEX, sorted by APID.
IAS will archive the packets relevant to OMEGA in dds format.

Experiment Data Records (at IAS and PSA)
Level-1B Science data product: `ORBNNNN_X.QUB`
One file, in PDS format, for each observation, including decompressed science data (level-1B), and all omega acquired HK.

Derived Data Records (at IAS and PSA)
Level-1B Geometry data product: `ORBNNNN_X.NAV`
One file, in PDS format, for each session, including all S/C derived geometrical information. A given file applies to a level-1B science data file and to the corresponding level-2 science data file.

Reduced Data (at IAS, with selected subsets at PSA)
Level-3 Science data product
Example results when available.

2.3.6 Software

Pipeline processing software

MAKE_PDS tool is used to generate science level-1B data products. It will not be distributed neither at IAS nor PSA.

GEOMEG is an IDL library designed to generate the OMEGA geometry data products. This software will be archived at PSA. The tool is a SPICE-based software using the MEX kernels data set as ancillary data (see 2.4.9 for details), and the MGS MOLA Mission Experiment Gridded Data Records as global topographic maps. The main GEOMEG functionalities are:

- searching/loading required kernels

- computing geometry information at times of pixels signal acquisition
- formatting data in PDS format
- updating science data product label

Data reduction software The archive will include the software tools to reduce level 1B PDS cubes, but not the reduced data cubes, as these may evolve rapidly during the mission. The software tools will be included in the SOFTWARE directory as ZIP files indicating the version number. A new version will be provided as a release when warranted by deeper level knowledge of instrument behaviour. It contains a readme file, which indicates the changes since the last version (in particular in terms of photometric function and geometric calibration) and the confidence level, i.e. the magnitude of the variations in terms of spectral features, which are considered reliable by the PI team. These are expected to improve until the end of the mission.

After the proprietary period, the same information (level-1B and processing tool to level-2) will be made available to the wide scientific community. The wide scientific community will be made aware that this "best-effort" level-2 processing tools may be superseded by later versions as the understanding of the instrument behaviour around Mars continues to improve. The users are strongly advised to take into account the confidence levels in the readme file encoded in the software package when publishing scientific results. The basic software tools (and its required input files, all in IDL) will be archived as part of the data volumes provided by IAS. A library written in C with the same capabilities will be provided in the software package so as to provide access to users, which cannot use IDL due to funding limitations.

2.3.7 Documentation

The main document provided in the DOCUMENT subdirectory is the EAICD itself, which contains all the relevant information on the content of the level-1B science PDS cube and the corresponding geometry cube. The OMEGA Flight User Manual will also be provided as WORD and PDF document. Additional information is provided as small ASCII text file pointed by the data product label. Please refer to the section 3.4.5 page 25 describing the DOCUMENT directory content.

2.3.8 Derived and other Data Products

All derived data (level-3) will be distributed in PDS format at IAS when ready, including:

- Spectral cubes providing radiance spectra of the whole surface, derived from data merging of low-resolution observations. The tiling scheme is TBD, but will be as consistent as possible with other experiment products (TES...).
- Cubes of modelled surface spectra, consisting in data spectrally merged with first order correction for thermal emission, atmospheric absorption and scattering, and surface

photometric effects. These spectra will provide an estimate of surface normal albedo between 0.35 and 5.2 μm.

- Spectral units maps, as derived from data analysis, together with corresponding type spectra.
- Mineralogical maps deriving from data analyses. These maps will represent mineralogical fractions and estimated grain size in the observed regions.
- Seasonal maps (clouds, dust storms, etc...).
- Data derived from limb observations (gas and dust profiles, etc...).

Representative level-3 products (maps) will be delivered to ESA for public outreach purpose.

2.3.9 Ancillary Data Usage

As mentioned in section 2.3.6, we use SPICE kernels to generate the geometry data products. SPICE kernels are ancillary data files, which hold all the relevant information required to produce OMEGA observation geometry calculation. MEX-specific kernels are either converted from ESOC auxiliary data: orbit attitude, and time correlation files, or designed by the NAIF team. The following table described the kernels used by GEOMEG. This software also uses global topographic maps of Mars provided by the MOLA Mission Experiment Gridded Data Records (MEGDRs) at resolutions of 64, and 128 pixels per degree. See `http://pds-geosciences.wustl.edu/missions/mgs/megdr.html` for further details.

Type	File Name	Description
SPK	`ORMM__YYMMDDhhmmss_xxxxx.BSP`	This file contains a Mars Express predict ephemeris after orbit insertion covering the time span starting at the date `YYMMDDhhmmss`.
CK	`ATNM_PYYMMDDhhmmss_xxxxx.BC`	Contains Mars Express predicted attitude information covering the time span starting at the date `YYMMDDhhmmss`
SCLK	`MEX_yymmdd_STEP.TSC`	This file is a SPICE spacecraft clock (SCLK) kernel containing information required for MEX spacecraft on-board clock to UTC conversion. This file provides the same time information that the Time Correlation packets released via DDS.
FK	`MEX_Vxx.TF`	File containing the complete set of frame definitions for the Mars Express Spacecraft (MEX) including definitions for the MEX science instrument frames. This kernel also contains NAIF ID/name mapping for the MEX instruments.
IK	`MEX_OMEGA_Vxx.TI`	File containing OMEGA detectors geometry: scanning mirror motion, pixel field of view and optical distortion parameters
SPK	`DE405S.BSP`	Contains ephemeris data for planet barycenters, and for the sun, earth and moon mass centers. Spans the entire MEX mission.
SPK	`MAR033_2000-2025.BSP`	Contains ephemeris data for Phobos and Deimos. Spans the entire MEX mission.
LSK	`NAIF0007.TLS`	File specifying the relationship between the Barycentric Dynamical Time (TDB, also called ephemeris time) and Coordinated Universal Time (UTC) up to the last modification in the leapseconds.
PCK	`MARS_IAU2000_V0.TPC`	File containing the radii and orientation constants for Mars and its natural satellites.

Table 2: SPICE kernels used in Data Processing.
`x` tokens indicate the version number of the kernel file

3 Archive Format and Content

3.1 Format and Conventions

3.1.1 Deliveries and Archive Volume Format

The OMEGA data is delivered according to the *release concept* procedure, i.e. there is a single data set and data volume. A new release is provided for each complete set of 100 orbits. The name of the data volume is: `OMEGA-FR-CNES-CNRS-MEXOMG-0001`

3.1.2 Data Set ID Formation

The OMEGA data set ID is formed according to the scheme:
`<mission>-<target>-<experiment>-<level>-<type>-<name>[-<ext>]-<version>`. For example: `MEX-M-OMEGA-2-EDR-FLIGHT-V1.0` **To do** (1)

3.1.3 Data Set Directory Structure

The following figure shows the OMEGA data set directory structure:

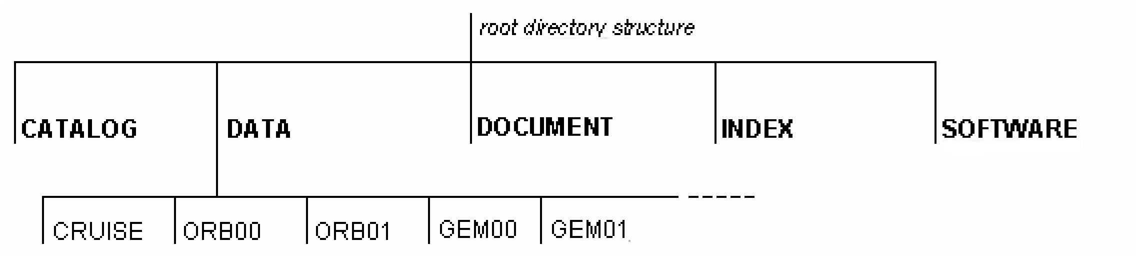

Figure 1: Data Set Directory Structure

3.1.4 File Naming Convention

The table 3 page 21 describes the naming convention used for files within the data directory:

3.2 Standards Used in Data Product Generation

3.2.1 PDS Standards

The PDS standard for the cubes is that of PDS version 3.6 as described in the document [2] (JPL D-7669 part 2)

Data product	Level	File name
Science data	1B	`ORBnnnn_x.QUB`
	1B	`CRUISEyymmdd_x.QUB`
Geometry data	1B	`ORBnnnn_x.NAV`

where `nnnn` is a four-digit number representing the orbit number at the observation time, where `x` is a one-digit character in HEX format (0 to 9, then A to F), and `yymmdd` represents the time of observation during the cruise phase. Each pair of QUB and NAV files corresponds to a data set obtained by OMEGA with the same observation parameters.

Table 3: Data File Naming Convention

3.2.2 Time Standards

Three time standards are used in the OMEGA data products:**To do** (2)

- UT: year, month, day, hour, minute, second, millisecond
- SCET: seconds and fractions of seconds since January 1st 1970, 00:00:00
- On-Board time: seconds and fractions of seconds since last switch-on of the spacecraft (nominally after launch)

The On-Board time is the only time available to the instrument during operation. It is reset each time a "time" TC is received by OMEGA. OMEGA uses a timer to update this time between two successive times TC. The on-board time at generation is written by OMEGA within each generated data packet

For each packet, The SCET is generated by the spacecraft from the on-board time in the packet, according to its time synchronization information

The UT time is generated by the DDS ground segment system from the SCET time when it encapsulates the packets so as to generate level-1A files

3.2.3 Cartographic Standards

Inertial Reference Frame The Earth Mean Equator and Equinox of Julian Date 2451545.0 (referred to as the J2000 system) is standard inertial frame.

Mars Body-Fixed Frame Body fixed frames are reference frames that do not move with respect to surface features of an object. The Mars Body-Fixed frame center is the center of mass of Mars. The spin axis of Mars defines the z-axis, whereas the prime meridian provides the direction of the x-axis that lies on the equatorial plane. The y-axis completes the right-handed frame. Values used to model the orientation of the north pole (including precession), and the prime meridian as a function of time, are those recommended by the International Astronomical Union and adopted by the Mars Express project.

Coordinates System We use the planetocentric coordinates system that consists of longitude measured positive eastward and planetocentric latitude, defined as the angle between the equatorial plane and a line from the center of mass of Mars to given point. This system is right-handed and identical to spherical polar coordinates as commonly defined. Longitudes range from 0 to 360 degrees, and latitudes range from -90 to 90 degrees. Please refer to document [5] for further information on IAU 2000 standards.

Reference Surface Two standards are used to model the surface of Mars. The first one is the digital terrain model (DTM) based on MOLA data, which defines Mars radius as a function of planetocentric latitude and longitude in the Mars-Body fixed frame. The second one is the triaxial ellipsoid centered on the planetocentric system origin that fits best the MOLA data. Note that the reference ellipsoid is used only the reference surface for defining map projections, whereas detailed topographic model (DTM) is used for accurate projection of remote-sensed data.

Cartographic constants used for OMEGA data mapping can be found in the document [5]. Data acquired on Phobos will use Simonelli's model (TBC with T. Duxbury and ESA). OMEGA cartographic products will use a simple cylindrical projection, and possibly polar projections for regions located above 60 in latitude (TBC), so as to facilitate changes in data projections and comparison with other data sets.

3.2.4 Other Applicable Standards

N/A

3.3 Data Validation

The individual packet validation is performed by ESOC, which rejects non-compliant packets. All valid OMEGA packets containing science data (type 20, subtype 13) are integrated into the level-1A files to be processed into a set of PDS level-1B data products.

OMEGA data is structured into sub-slices of 64 pixels by 64 spectels (48 spectels, 64 spectels or 80 spectels for the visible channel), each corresponding to an integer number of packets (1 in most compression modes, 2 for non compressed formats). A consistency check is performed during the decompression of the data stream. If the number of words required for decompression is different from the number of available data words, one considers that a SEU has occurred and the corresponding sub-slice values are set to 0.

The OMEGA team members validate conversion of level-1B products into level-2 products interactively during the proprietary period. At the end of the proprietary period, a set of software products will be released, so as to provide the tools to generate level-2 products from the level 1B products in the database. It is expected that the understanding of the instrument behaviour will improve during the next few years, as was the case for other experiments of this type. These software products will be therefore be updated whenever a new release is deemed necessary. Similarly, the calibration data may be updated if the characteristics of the instrument in terms of spectral, spatial or radiometric performances change with time.

The datasets will be validated through the PVV tool, and a peer review. The main purpose of PVV, distributed by ESA, is to provide the instrument archive team with a tool that allows it to check and verify their datasets before sending them to the PSA. It also shall be taken into account that this same tool will be used in the PSA before ingestion as an additional security step, to prevent whomever from accidentally or intentionally ingesting a wrong or corrupted dataset. It might happen too that some part of the dataset is lost during the transmission process, so the tool should prevent somehow for this inconvenience.

3.4 Data Set Directories Content

3.4.1 Root Directory

Files in the Root Directory include an overview of the archive, a description of the volume for the PDS Catalog, and a list of errata or comments about the archive. The following files are contained in the Root Directory.

File Name	Description
`AAREADME.TXT`	Volume content and format information
`ERRATA.TXT`	A cumulative listing of comments and updates concerning all archive volumes published to date
`VOLDESC.CAT`	A description of the contents of this volume in a PDS format readable by both humans and computers

Table 4: Data Set Root Directory Content

3.4.2 Catalog Directory

The files in the Catalog Directory provide a top-level understanding of the mission, spacecraft, instruments, and data sets. The files in this directory are coordinated with the PSA team, who is responsible for loading them into the PDS catalog. The following files are found in the Catalog Directory.

File Name	Description
`CATINFO.TXT`	A description of the contents of this directory
`DATASET.CAT`	Data set information for the PDS catalog
`INSTHOST.CAT`	Instrument host (spacecraft) information for the PDS catalog
`INST.CAT`	Instrument information for the PDS catalog
`MISSION.CAT`	Mission information for the PDS catalog
`SOFTWARE.CAT`	Software information for the PDS catalog
`RELEASE.CAT`	For each data set, there is one release catalog file which defines, through release objects, a data products delivery to the PSA

Table 5: Data Set Catalog Directory Content

3.4.3 Index Directory

Files in the Index Directory are provided to help the user locate products on this archive volume and on previously released volumes in the archive. The following files are contained in the Index Directory.

File Name	Description
`INDXINFO.TXT`	A description of the contents of this directory
`INDEX.TAB`	A table listing all data products on this volume
`INDEX.LBL`	A PDS detached label that describes INDEX.TAB
`GEO_MARS.TAB`	Geometry Index Table providing geometry and position information about the data product listed in INDEX.TAB
`OMEGA_INDEX.LBL`	Geometry Index label for `GEO_MARS.TAB`
`OMEGA_INDEX.TAB`	Additional Index Table providing information about OMEGA at the time of observation, plus other geometrical parameters
`OMEGA_INDEX.LBL`	Index Label for `OMEGA_INDEX.TAB`

Table 6: Data Set Index Directory Content

Please refer to document [6] for further information on geometry index, and refer to index label files themselves to have a complete description of the index table parameters.

3.4.4 Software Directory

The Software directory contains software for extracting data from the data product files, and for data reduction. The main tools for using OMEGA data are described in the document: `softNN_readme.txt` encoded in the SOFTNN.ZIP file. It will unzip as a subdirectory (`/SOFTNN`) so as to maintain the history of the changes in the reduction process. A path file (`omega_path`), included in `SOFTNN.ZIP` needs to be edited to the specific user environment so as to provide the proper path to the OMEGA data directory, where the user stores the science data cubes and the OMEGA geometry directory, where the user stores the geometry cubes The readomega.pro routine reads an omega data cube, creating IDL arrays idat (raw data), jdat (I/F) and kdat (radiance). The readomega tool also reads the companion geometry cube, providing information on the location of the IFOV of each pixel on Mars (or Phobos, when relevant) as derived from the SPICE kernels provided by the project. Input files to readomega.pro are also included in `SOFTNN.ZIP`, providing the current version of the photometric function, the wavelength scale and the solar spectrum at OMEGA wavelengths, which is used to derive I/F values from radiance values. The following files are contained in the Software Directory:

File Name	Description
SOFTINFO.TXT	A description of the contents of this directory
SOFT01.ZIP	A ZIP file containing all needed files for OMEGA data reduction for the first release (first public delivery)
SOFT01.LBL	The label for this file
ZIPINFO.TXT	This file provides an overview of the ZIP file format
SOFT02.ZIP	A ZIP file with the second version of the OMEGA reduction
SOFT02.LBL	The label for this file
...	...

Table 7: Data Set Software Directory Content

3.4.5 Document Directory

The Document Directory contains documentation to help the user understand and use the archive data. The following files are contained in the Document Directory.

3.4.6 Data Directory

The Data directory contains the science and geometry data product, both at level-1B. Science data files are sorted into subdirectories by groups of 100 orbits according to the following scheme:

```
DATA
  |
  ‘- ORBnn
```

where `nn` are the first two digits of the stating orbit number. Data obtained before arrival at Mars (EV and IC mission phases) are stored in the CRUISE sub-directory according to the following scheme:

```
DATA
  |
  ’-- CRUISE
```

Geometry data files are sorted into subdirectories by groups of 100 orbits according to a similar scheme:

```
DATA
  |
  ‘-- GEMnn
```

where `nn` are the first two digits of the stating orbit number. Example: the `ORB12` subdirectory contains all the data files corresponding to orbits from 1200 and 1299. There are no geometry data products for cruise data.

File Name	Description
DOCINFO.TXT	A description of the contents of this directory
EAICD_OMEGA.DOC	The OMEGA Experiment Archive Interface Control Document (this document) as a MS Word document
EAICD_OMEGA.ASC	The OMEGA Experiment Archive Interface Control Document (this document) as text.
EAICD_OMEGA.PDF	The OMEGA Experiment Archive Interface Control Document (this document) as a PDF file.
EAICD_OMEGA.LBL	A PDS detached label describing all EAICD related documents and figures.
EAICD_FIG1.PNG	PNG Figure 1 for the ASCII version
EAICD_FIG2.PNG	PNG Figure 2 for the ASCII version
EAICD_FIG3.PNG	PNG Figure 3 for the ASCII version
EAICD_FIG4.PNG	PNG Figure 4 for the ASCII version
EAICD_FIG5.PNG	PNG Figure 5 for the ASCII version
OMEGA_FUM.DOC	The OMEGA Flight User Manual as MS Word document
OMEGA_FUM.PDF	The OMEGA Flight User Manual as PDF document
OMEGA_FUM.LBL	A PDS detached label describing FUM related documents
GEOCUBE_DESC.TXT	Description of the geometry data cubes content
GEOCUBE_DESC.LBL	Label file for GEOCUBE_DESC.TXT
MEX_ORIENTATION_DESC.TXT	Description of the Mars Express spacecraft orientation
MEX_ORIENTATION_DESC.LBL	Label file for MEX_ORIENTATION_DESC.TXT
OMEGA_CALIBRATION_DESC.TXT	Description of the OMEGA calibration parameters
OMEGA_CALIBRATION_DESC.LBL	Label file for OMEGA_CALIBRATION_DESC.TXT
OMEGA_DESC.TXT	Description of the OMEGA instrument
OMEGA_DESC.LBL	Label file for OMEGA_DESC.TXT

Table 8: Data Set Document Directory Content

Science and geometry data files are named according to the Table 3 page 21.

4 Detailed Interface Specifications

4.1 Data Product Design

A series of PDS files starting from level-1B is generated for each sub-session of OMEGA, i.e. a series of scans performed in the same operational mode (IR mode, VIS mode, spatial summing) as described in section 2.2. These PDS files contain all the scientific data and geometry data produced by OMEGA. The PDS label is always included in the file

4.1.1 Science Level-1B Data Product

The EDR data files contain the DN numbers from the experiment as PDS files in the QUBE format. An example PDS label for a 1B OMEGA data file is given in annex B.

File Characteristics Data Elements PDS data product labels contain data element information that describes important attributes of the physical structure of a data product file. The PDS file characteristic data elements are:

```
RECORD_TYPE
RECORD_BYTES
FILE_RECORDS
LABEL_RECORDS
FILE_NAME
```

The `RECORD_TYPE` data element identifies the record characteristics of the data product file. Physical records are always fixed-length. The `RECORD_BYTES` data element identifies the number of bytes in each physical record in the data product file. Records length is always equal to 512 bytes. The `FILE_RECORDS` data element identifies the number of physical records in the file. The `LABEL_RECORDS` data element identifies the number of physical records that make up the PDS product label. The `FILE_NAME` data element identifies the name of the geometry file.

The Planetary Science Archive of ESA implements the "Release concept": 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.

Data Object Pointers Identification Data Elements The label refers to a single data object, which is a QUBE. The data object starts in the next physical record after the PDS product label area. The data object pointer takes the following form:

```
^QUBE = nnn
```

where nnn represents the starting record number within the geometry file (first record is numbered 1).

Data Identification Elements The following data identification elements provide additional information about the data product.

```
DATA_SET_ID                     = "MEX-M-OMEGA-2-EDR-FLIGHT-V1.0"
PRODUCT_ID                      = "ORB0018_1_DATA"
PRODUCT_TYPE                    = EDR
PRODUCT_CREATION_TIME           = 2004-03-24T12:33:18.000
PRODUCER_INSTITUTION_NAME       = IAS
PI_PDS_USER_ID                  = BIBRING
SPACECRAFT_NAME                 = "MARS EXPRESS"
MISSION_PHASE_NAME              = "MC PHASE 1"
INSTRUMENT_ID                   = OMEGA
INSTRUMENT_TYPE                 = "IMAGING SPECTROMETER"
^INSTRUMENT_DESC                = "OMEGA_DESC.TXT"
^INSTRUMENT_CALIBRATION_DESC    = "OMEGA_CALIBRATION_DESC.TXT"

DATA_QUALITY_ID                 = 3
DATA_QUALITY_DESC               = " from 0 to 3 depending on
                            missing lines and compression errors"

MISSING_SCAN_LINES              = 0
CHANNEL_ID                      = (IRC,IRL,VIS)
SOFTWARE_VERSION_ID             = "OMEGA 4.5"
TARGET_NAME                     = MARS
```

EDR stands for Experiment Data Records. The PRODUCT_CREATION_TIME element provides the time at which the geometry data product has been generated.

The MISSION_PHASE_NAME indicates in which phase of the mission the data was acquired. Mission phases are: EV, IC (cruise phase), and then MC PHASE 1 to N (Mars orbit).

Two files are referred to in the DOCUMENT directory: OMEGA_DESC.TXT and OMEGA_CALIBRATION_DESC.TXT which contain information on the instrument and on the ground calibration respectively.

The TARGET_NAME element provides the target of the observation. It can be MARS, PHOBOS, or DEIMOS.

Descriptive Data Elements In addition to the data identification elements, we included descriptive data elements that provide an overview of the observation geometry and some information on the data product generation process.

```
ORBIT_NUMBER
```

The ORBIT_NUMBER element is the number of the Mars Express orbit around Mars at observation time.

```
MAXIMUM_LATITUDE
MINIMUM_LATITUDE
EASTERNMOST_LONGITUDE
WESTERNMOST_LONGITUDE
```

The `MAXIMUM_LATITUDE` element specifies the northernmost latitude of the spatial area covered by the observation. The `MINIMUM_LATITUDE` element specifies the southernmost latitude of the spatial area covered by the observation. The `EASTERNMOST_LONGITUDE` element provides the maximum numerical value of planetocentric longitude of the spatial area covered by the observation, unless it crosses the prime meridian. The `WESTERNMOST_LONGITUDE` element provides the minimum numerical value of planetocentric longitude of the spatial area covered by the observation, unless it crosses the prime meridian. Angles are expressed in degrees.

```
SLANT_DISTANCE
```

The `SLANT_DISTANCE` element provides a measure of the distance, in kilometers, from the spacecraft to the center of the observation along the line of sight.

```
SOLAR_LONGITUDE
SOLAR_DISTANCE
SUB_SOLAR_LONGITUDE
SUB_SOLAR_LATITUDE
```

The `SOLAR_LONGITUDE` element provides the areocentric longitude of the Sun that is a measure of season on Mars, in degrees. The `SOLAR_DISTANCE` element provides the value of the distance from the center of the observation to the apparent position of the Sun, in kilometer. The `SUB_SOLAR_LONGITUDE` and the `SUB_SOLAR_LATITUDE` elements provide respectively the longitude and the latitude of the sub-solar point at observation time. The sub-solar point is defined as the intersection point between the apparent position vector of the Sun in the Mars-fixed rotating frame, and the reference surface of Mars.

The following data elements contain information on the operating mode of OMEGA

```
COMMAND_NAME = "OMEGA_NOMINAL"
COMMAND_DESC = "00838383,00303030,04600900,050000EF,
     06001549,07708721,08000000,0900006F,0AEED804"
```

This indicates the series of hexadecimal commands, which were sent to OMEGA for this particular data set. They control the operational modes

```
INSTRUMENT_MODE_ID  = ( 06,06,09)
EXPOSURE_DURATION   = (5.0,5.0, 50.0) <MS>
DOWNTRACK_SUMMING   = 1
```

`INSTRUMENT_MODE_ID` indicates the operating mode for each of the 3 channels of OMEGA (IRC, IRL, VIS). The mode is always the same for IRC and IRL, from 0 to 10. The VIS operating mode can range from 0 to 41. **To do** (3)

```
INST_CMPRS_NAME = "WAVELET"
INST_CMPRS_RATE = 3.00
```

`INST_CMPRS_NAME` indicates which of the 3 types of compression was used for the data: `NONE`, `REVERSIBLE` or `WAVELET`. In the "WAVELET" compression mode, `INST_CMPRS_RATE` indicates the requested compression rate in bits per data. It is set as 12 for "NONE" and as 5 for "REVERSIBLE

```
OFFSET          = 0.0
SCALING_FACTOR  = 0.983
```

To do (4)

Fixed parameters. The `SCALING_FACTOR` indicates the IFOV ratio between the VIS and IR channels

```
START_TIME                     = 2004-01-14T00:19:12.032
STOP_TIME                      = 2004-01-14T00:23:03.059
SPACECRAFT_CLOCK_START_COUNT   = "22054009.23265"
SPACECRAFT_CLOCK_STOP_COUNT    = "22054240.00630"
```

To do (5)

Data Object Definitions The data object is a QUBE that does not fulfill ISIS standards. The binary data is constituted of a cube, 7 side planes in the X direction and 1 side plane in the Y direction. The data cube is coded as 16 bits signed integers (`LSB_SIGNED_INTEGER`). All side-planes are coded as 32 signed bits integers (`LSB_SIGNED_INTEGER`)

Among the keywords mentionned above, only `CORE_ITEMS` can take different values:

- The first dimension, named `SAMPLE`, refers to the length of scan. It can be 16, 32, 64, or 128 pixels. It gives the first spatial dimension.
- The second dimension, named `BAND`, refers to the number of spectral elements in each spectrum. It can be either 352 (nominal) or 400 (high VIS spectral resolution)
- The third dimension, named `LINE`, refers to the rank of the scan. It is the second spatial dimension.

The side plane added to the X dimension contains either 352 or 400 values for each scan, depending on the visible mode. The first 256 values correspond to the dark current for the IR channels. The next 8 values correspond to dark currents of shielded spectels (2 at each end of the C and L IR channels). The next 88 or 136 values are given a constant value corresponding to the offset applied to the visible channel, which takes into account the operating temperature of the VIS CCD.

7 side planes are added to the Y dimension. For each scan, each of the seven side-lines has a dimension corresponding to the length of the scan (16, 32, 64 or 128). All information is included in the first 16 data, which correspond to the minimum length of these lines. The other data are set to 0.

Keyword	Definition	Typical value
AXES	Dimension of the qube	3
AXIS_NAME	Names of axes	(SAMPLE,BAND,LINE)
CORE_ITEMS	Core dimensions of axes	(64,352,648)
CORE_ITEM_BYTES	Core element size	2
CORE_ITEM_TYPE	Core element type	LSB_SIGNED_INTEGER
CORE_BASE	Base value item scaling*	0.0
CORE_MULTIPLIER	Multiplier for core item scaling*	1.0
SUFFIX_BYTES	Storage allocation for suffix elements	4
SUFFIX_ITEMS	Suffix dimensions of axes	(1,7,0)
CORE_VALID_MINIMUM	Minimum valid core value	"NULL"
CORE_NULL	Special value indicating 'invalid' data	"NULL"
CORE_LOW_REPR_SATURATION	Special value indicating representation saturation at low end**	-32768
CORE_LOW_INSTR_SATURATION	Special value indicating instrument saturation at low end**	-32768
CORE_HIGH_REPR_SATURATION	Special value indicating representation saturation at high end**	32767
CORE_HIGH_INSTR_SATURATION	Special value indicating instrument saturation at high end**	32767
CORE_NAME	Name of value stored in core	RAW_DATA_NUMBER
CORE_UNIT	Unit of core values	DIMENSIONLESS

* true value = base + multiplier * stored value ** These keywords are required but not applicable in the case of the geometry data qube

Table 9: Science Data Qube Keywords Definition

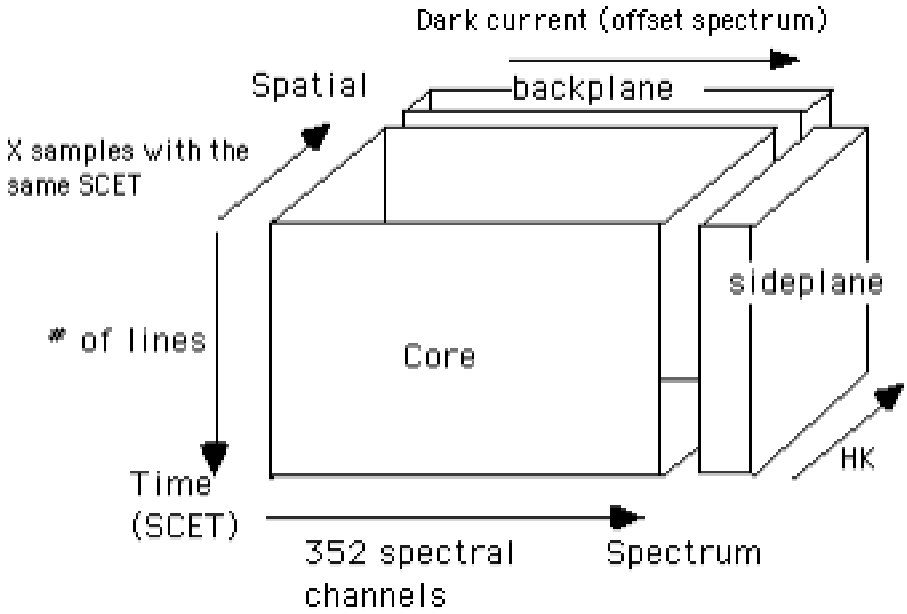

Figure 2: Conceptual view of the Science Data Qube

All analog values are expressed as a 32 bits signed integer:

- temperatures are expressed as multiples of 0.001 °C
- voltages are expressed as multiples of 0.001 V
- currents are expressed as multiples of 0.001 A

1st side plane scanning mirror position (in Data Numbers coming out of the scanner monitoring device)

2nd side plane information on the time at the beginning of the scan, in the following order:

- UT time: 7 values (year, month, day, hour, minute, second, millisecond)
- On-Board time: 2 values (seconds, milliseconds)
- SCET time: 4 values (2 for seconds, 2 for microseconds)

3rd side plane selected temperatures

- Temperature detector block C (SOA 5)
- Temperature detector block L (SOA 6)
- Temperature spectro C1 (SOA 1)
- Temperature spectro C2 (SOA 2)
- Temperature spectro L1 (SOA 3)

- Temperature spectro L2 (SOA 4)
- Temperature slit (SOA 8)
- Temperature detector C (SES 6, raw data)
- Temperature detector L (SES 14, raw data)

4th side plane electronics and cooler temperatures

- Temperature spectro structure (SOA 9)
- Temperature 190 K interface (SOA 10)
- Temperature detector L (HR) (SOA 11)
- Temperature SEP module (SEP 1)
- Temperature electronics 1 (SEA 3)
- Temperature electronics 2 (SEA 4)
- Temperature calibration source (SOA 7)
- Temperature 280 K (PF 1)
- Temperature SKA motor C (SKA 1)
- Temperature SKA motor L (SKA 2)
- Temperature SKC C (SKC 1)
- Temperature SKC L (SKC 2)
- Temperature SES C (SES 5)
- Temperature SES L (SES 13)
- Temperature SES (SES 17)

5th side plane scanner, voltages, currents, status

- Temperature FOA (FEA 1)
- Temperature FEA (FEA 2)
- +12 V FEA (SEP 2)
- Voltage + 5V PF (SEA 5)
- Voltage +15V PF (SEA 6)
- Voltage -15V PF (SEA 7)
- Status on-off (SEA 9)
- Voltage motor C (SKA 3)
- Current motor C (SKA 4)
- Voltage motor L (SKA 5)

- Current motor L (SKA 6)
- Voltage setting C (SKA 7)
- Voltage setting L (SKA 8)
- Status (SEA 10)
- Current (calibration source) (SEA 1)
- Voltage (calibration source) (SEA 2)

6th side plane SES voltages

- VGL1 C (SES 1)
- PHIP LB C (SES 2)
- Polarization diode C (SES 3)
- Video offset C (SES 4)
- 24 Volts C (SES 7)
- constant offset C (SES 8)
- VGL1 L (SES 9
- PHIP LB L (SES 10)
- Polarization diode L (SES 11)
- Video offset L (SES 12)
- 24 Volts L (SES 15)
- constant offset (SES 16)

7th side plane VEA subsystem (visible channel)

- Setting 15 volts (VEA 2)
- Setting -15 volts (VEA 3)
- Setting 5 volts (VEA 1)
- Setting -5 volts (VEA 4)
- Temperature CCD (VEA 7)
- Temperature optics (VEA 6)
- Temperature electronics VEA (VEA 5
- Current (calibration source) (VEA 8)
- Status calibration + test (VEA 10)
- Operation mode (VEA 11)
- Frame number (VEA 12)

- Command Echo 1 (VEA 13)
- Command Echo 2 (VEA 14)
- Number of transmitted blocks (VEA 15)
- Number of spectral elements (VEA 16)

4.1.2 Geometry Level-1B Data Product

A geometry data product is equal to a single data file, which has the PDS format. It contains the observation geometry of each pixel for each of the three OMEGA detectors.The data product label is attached at the beginning of the data product file. The following subsections describe in details the content of this label and the data object it is referring to. An example label for a geometry data product is provided in annex C.

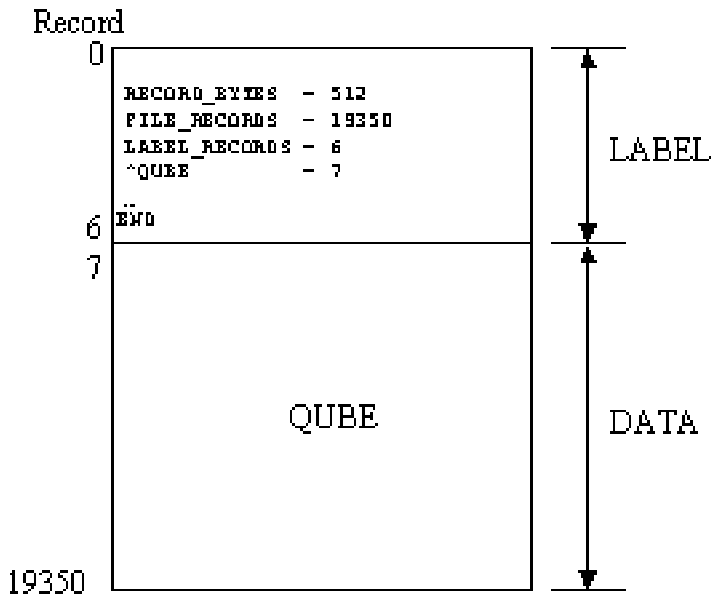

Figure 3: View of a geometry data product

File Characteristics Data Elements PDS data product labels contain data element information that describes important attributes of the physical structure of a data product file. The PDS file characteristic data elements are:

```
RECORD_TYPE
RECORD_BYTES
FILE_RECORDS
LABEL_RECORDS
FILE_NAME
```

The RECORD_TYPE data element identifies the record characteristics of the data product file. Physical records are always fixed-length. The RECORD_BYTES data element identifies the number of bytes in each physical record in the data product file. Records length is always equal to 512 bytes. The FILE_RECORDS data element identifies the number of physical records in the file. The LABEL_RECORDS data element identifies the number of physical records that make up the PDS product label. The FILE_NAME data element identifies the name of the geometry file.

The Planetary Science Archive of ESA implements the "Release" concept: 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.

Data Object Pointers Identification Data Elements The label refers to a single data object, which is a QUBE. The data object starts in the next physical record after the PDS product label area. The data object pointer takes the following form:

```
^QUBE = nnn
```

where nnn represents the starting record number within the geometry file (first record is numbered 1).

Data Identification Elements The following data identification elements provide additional information about the data product.

```
DATA_SET_ID                   = "MEX-M-OMEGA-2-EDR-FLIGHT-V1.0"
PRODUCT_ID                    = "ORB0018_1_GEOM"
PRODUCT_TYPE                  = EDR
PRODUCT_CREATION_TIME         = 2004-09-29T08:46:38.098
PRODUCER_INSTITUTION_NAME     = IAS
PI_PDS_USER_ID                = BIBRING
SPACECRAFT_NAME               = "MARS EXPRESS"
MISSION_PHASE_NAME            = "MC PHASE 1"
INSTRUMENT_ID                 = OMEGA
TARGET_TYPE                   = PLANET
TARGET_NAME                   = MARS
START_TIME                    = 2004-01-14T00:19:12.032
STOP_TIME                     = 2004-01-14T00:23:03.059
SPACECRAFT_CLOCK_START_COUNT  = "22054009.23265"
SPACECRAFT_CLOCK_STOP_COUNT   = "22054240.00630"
```

EDR stands for Experiment Data Records. The PRODUCT_CREATION_TIME element provides the time at which the geometry data product has been generated. The TARGET_NAME element provides the target of the observation. It can be MARS, PHOBOS, or DEIMOS.

Descriptive Data Elements In addition to the data identification elements, we included descriptive data elements that provide an overview of the observation geometry and some information on the data product generation process.

```
ORBIT_NUMBER
SPACECRAFT_POINTING_MODE
SPACECRAFT_ORIENTATION
```

The `ORBIT_NUMBER` element is the number of the Mars Express orbit around Mars at observation time. The `SPACECRAFT_POINTING_MODE` element indicates the spacecraft-pointing mode during the observation. It can be `NADIR`, `ALONGTRACK`, `ACROSSTRACK`, or `INERT`. These values result from an analysis of orbit and attitude data at observation time. Let the +Zb axis be the pointing direction of the spacecraft. We assume a nadir-pointing mode when the +Zb axis is continuously pointing to the center of Mars. We assume the spacecraft is along-track pointing when the +Zb axis is lying on the s/c orbit plane and is separated from the vector pointing to the center of Mars by a constant offset angle. The across-track pointing is defined as follows: the +Zb axis is continuously lying on the plane perpendicular to s/c orbit plane and passing by the center of Mars and the spacecraft position. In other words, the +Zb axis is rotated about the spacecraft velocity vector by a constant offset angle. This angle is provided within the label by mean of the following keyword:

```
MEX: OFFSET_ANGLE
```

In the last case, the spacecraft is 3-axes pointing or inertial pointing. This means that the spacecraft orientation is fixed with respect to stars background. If so, pointing coordinates in J2000 frame are provided by mean of the two following keywords:

```
RIGHT_ASCENSION
DECLINATION
```

The `SPACECRAFT_ORIENTATION` element indicates whether the +Yb axis is oriented towards the spacecraft velocity vector, (0,1,0), or in the opposite direction, (0,-1,0). See appendix 5 to get further information on the spacecraft frame.

```
MAXIMUM_LATITUDE
MINIMUM_LATITUDE
EASTERNMOST_LONGITUDE
WESTERNMOST_LONGITUDE
```

The `MAXIMUM_LATITUDE` element specifies the northernmost latitude of the spatial area covered by the observation. The `MINIMUM_LATITUDE` element specifies the southernmost latitude of the spatial area covered by the observation. The `EASTERNMOST_LONGITUDE` element provides the maximum numerical value of planetocentric longitude of the spatial area covered by the observation, unless it crosses the prime meridian. The `WESTERNMOST_LONGITUDE` element provides the minimum numerical value of planetocentric longitude of the spatial area covered by the observation, unless it crosses the prime meridian. Angles are expressed in degrees.

```
SLANT_DISTANCE
```

The `SLANT_DISTANCE` element provides a measure of the distance, in kilometers, from the spacecraft to the center of the observation along the line of sight.

```
SOLAR_LONGITUDE
SOLAR_DISTANCE
SUB_SOLAR_LONGITUDE
SUB_SOLAR_LATITUDE
```

The `SOLAR_LONGITUDE` element provides the areocentric longitude of the Sun that is a measure of season on Mars, in degrees.
The `SOLAR_DISTANCE` element provides the value of the distance from the center of the observation to the apparent position of the Sun, in kilometer. The `SUB_SOLAR_LONGITUDE` and the `SUB_SOLAR_LATITUDE` elements provide respectively the longitude and the latitude of the sub-solar point at observation time. The sub-solar point is defined as the intersection point between the apparent position vector of the Sun in the Mars-fixed rotating frame, and the reference surface of Mars.

```
^DATA_DESC = "GEOCUBE_DESC.TXT"
```

The `DATA_DESC` pointer provides the name of the file describing the content of the geometry data qube.

```
DATA_QUALITY_ID
SOFTWARE_NAME
SPICE_FILE_NAME
```

The `DATA_QUALITY_ID` element is always `"NULL"`. The `SOFTWARE_NAME` element indicates the name and the version number of the software that has been used to generate the geometry data product. The `SPICE_FILE_NAME` element provides the list of all the SPICE kernels required and used to generate the geometry data product of concern.

Data Object Definitions The data object is a QUBE that does not fulfill ISIS standards. Unlike science level-1B data qubes, geometry qubes do not hold suffix areas, but have the same core structure. This core is a three-dimensional array with two spatial dimensions, and one dimension used to store the observation geometry parameters. The qube's structure and attributes are described by the following keywords:

Among the keywords mentionned above, only `CORE_ITEMS` can take different values:

- The first dimension, named `SAMPLE`, refers to the length of scan. It can be 16, 32, 64, or 128 pixels. It gives the first spatial dimension.
- The second dimension, named `BAND`, actually refers to the 51 parameters describing the geometry of the observation of concern.
- The third dimension, named `LINE`, refers to the rank of the scan. It is the second spatial dimension.

The first and third dimensions are the same as that of the corresponding science level-1B data cube. From geometry planes, one value of the corresponding parameter is associated to each of the spectra in the science level-1B data cubes. There is an exception to this: the second plane is used to store information on time at the beginning of the IR scan.

Keyword	Definition	Typical value
AXES	Dimension of the qube	3
AXIS_NAME	Names of axes	(SAMPLE,BAND,LINE)
CORE_ITEMS	Core dimensions of axes	(128,51,648)
CORE_ITEM_BYTES	Core element size	4
CORE_ITEM_TYPE	Core element type	LSB_SIGNED_INTEGER
CORE_BASE	Base value item scaling*	0.0
CORE_MULTIPLIER	Multiplier for core item scaling*	1.0
SUFFIX_BYTES	Storage allocation for suffix elements	4
SUFFIX_ITEMS	Suffix dimensions of axes	(0,0,0)
CORE_VALID_MINIMUM	Minimum valid core value	"NULL"
CORE_NULL	Special value indicating 'invalid' data	"NULL"
CORE_LOW_REPR_SATURATION	Special value indicating representation saturation at low end**	-2147483648
CORE_LOW_INSTR_SATURATION	Special value indicating instrument saturation at low end**	-2147483648
CORE_HIGH_REPR_SATURATION	Special value indicating representation saturation at high end**	2147483648
CORE_HIGH_INSTR_SATURATION	Special value indicating instrument saturation at high end**	2147483648
CORE_NAME	Name of value stored in core	RAW_DATA_NUMBER
CORE_UNIT	Unit of core values	DIMENSIONLESS

* true value = base + multiplier * stored value ** These keywords are required but not applicable in the case of the geometry data qube

Table 10: Geometry Qube Keywords Definition

The following table lists the parameters contained within the data cube, which describes the geometry of an OMEGA observation:

	#	Parameter	Unit
	1	IR scan mirror position	DIMENSIONLESS
	2	time at the beginning of the IR scan	See note 1
SWIR-C	3	incidence angle w.r.t the outward normal to the reference ellipsoid	0.0001 <DEG>
	4	emergence angle w.r.t the outward normal to the reference ellipsoid	0.0001 <DEG>
	5	incidence angle w.r.t the opposite direction of the center of Mars	0.0001 <DEG>
	6	emergence angle w.r.t the opposite direction of the center of Mars	0.0001 <DEG>
	7	longitude of the pixel footprint center point	0.0001 <DEG>
	8	latitude of the pixel footprint center point	0.0001 <DEG>
	9	incidence angle w.r.t the local normal 2	0.0001 <DEG>
	10	emergence angle w.r.t the local normal 2	0.0001 <DEG>
	11	phase angle w.r.t the local normal 2	0.0001 <DEG>
	12	slant distance from the spacecraft to pixel footprint center point	<METER>
	13	elevation of the pixel footprint center point 2	<METER>
	14-17	longitude of the 4 pixel footprint corner points	0.0001 <DEG>
	18-21	latitude of the 4 pixel footprint corner points	0.0001 <DEG>
SWIR-L	22-36	same information as plane 7-21 for SWIR-L channel	
VNIR	37-51	same information as plane 7-21 for VNIR channel	

Table 11: Geometry Data Qube Parameters Description

1. Time information format:
   - UT: year, month, day, hour, minute, second, millisecond (7 values)
   - OBT: seconds, milliseconds (2 values)
   - SCET: seconds (2 values), microseconds (2 values)
2. In the case of limb observations, incidence and emergence angles (planes number 9,10,24,25,39, and 40) are computed with respect to the opposite direction of the center of Mars instead of using local topography. Also, planes number 13, 28, and 43 are replaced with the altitude of the central tangent point above the surface of Mars, plus an offset equal to 65536.

For further information on observation geometry please refer to appendix A.

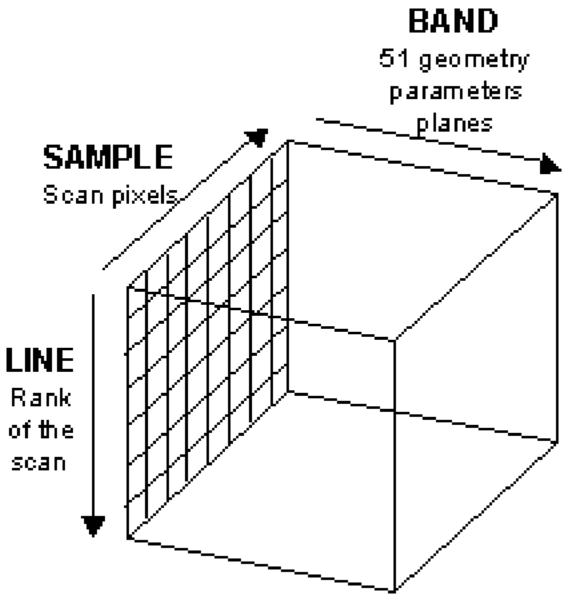

Figure 4: Conceptual view of the Geometry Data Qube

A Geometrical Parameters Definition

Pixel footprint A pixel footprint is the figure on the surface of Mars resulting from the projection (intersection) of the pixel's field of view boundary vectors onto the surface. Intersection/impact points coordinates on the surface define the pixel footprint. Indeed, although the term of pixel footprint does not make so much sense in the case of a limb observation, we use it to describe the figure on the surface defined the four boundary impact points. Note that the pixel footprint center point is the intersection point between the pixel boresight and the surface of Mars (surface observation), or the impact point built from the pixel boresight (limb observation).

Impact and tangent point An impact point is the intersection between the vector from the center of Mars to a tangent point and a reference surface. A tangent point is the closest point to the center of Mars (center of mass) lying on the pixel boresight. We use the term of tangent point only when the pixel field of view boundary vectors do not intersect the surface.

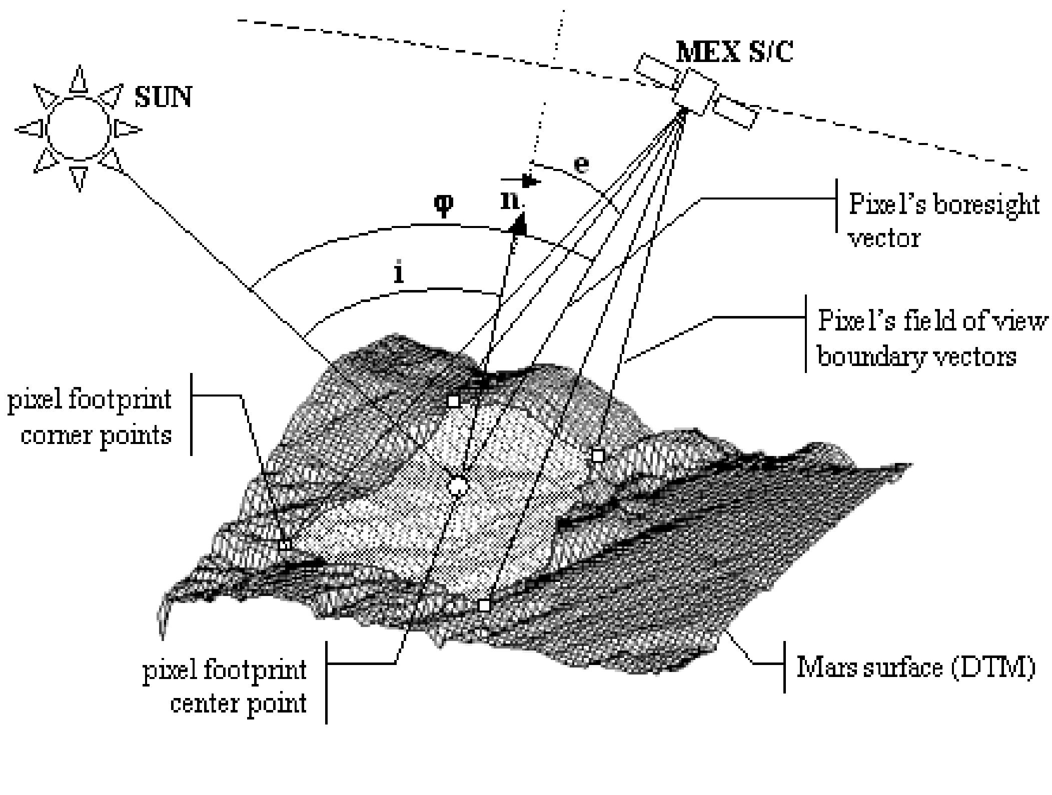

Figure 5: Overview of pixel observation geometry

Incidence angle The incidence angle (i) is the angle between the "surface" normal vector at the intercept/impact point (surface) and the vector from the intercept/impact point to the Sun.

Emergence angle Also called emission angle (e), this angle is the angle between the "surface" normal vector at the intercept/ impact point and the vector from intercept/ impact point to the spacecraft.

Phase angle The phase angle (?) is the angle between the vector from the intercept/impact point to the Sun, and the vector from the intercept/impact point to the spacecraft.

Spacecraft "mechanical/structure" frame The "mechanical/structure frame" frame (Xb, Yb, Zb), with respect to which orientation of all science instruments and spacecraft structures are defined, is called `MEX_SPACECRAFT` frame in the MEX SPICE implementation.

This frame is defined as follows:

- the payloads are located on the +Zb axis (the Main Engine being on the -Zb axis);
- the HGA is located on -Xb axis;
- the +Y axis is defined so that the (Xb,Yb,Zb) frame is right-handed.
- the origin of this frames is the launch vehicle interface point.

B Example of PDS label of an OMEGA 1B data product

```
PDS_VERSION_ID                  = 3
LABEL_REVISION_NOTE             = "2004-09-03, YL-BG-JZ"
  /* File format and length */
RECORD_TYPE                     = FIXED_LENGTH
RECORD_BYTES                    = 512
FILE_RECORDS                    = 54299
LABEL_RECORDS                   = 11
FILE_NAME                       = "ORB0018_0.QUB"
^QUBE                           = 12
DATA_SET_ID                     = "MEX-M-OMEGA-2-EDR-FLIGHT-V1.0"
RELEASE_ID                      = 0001
REVISION_ID                     = 0000
PRODUCT_ID                      = "ORB0018_0_DATA"
PRODUCT_TYPE                    = EDR
STANDARD_DATA_PRODUCT_ID        = "OMEGA DATA"
PI_PDS_USER_ID                  = BIBRING
MISSION_NAME                    = "MARS EXPRESS"
MISSION_PHASE_NAME              = "MC PHASE 1"
INSTRUMENT_NAME                 = "Observatoire Mineralogie, Eau, Glaces, Activite"
PRODUCER_INSTITUTION_NAME       = "IAS"
INSTRUMENT_ID                   = OMEGA
INSTRUMENT_TYPE                 = "IMAGING SPECTROMETER"
^INSTRUMENT_DESC                = "OMEGA_DESC.TXT"
^INSTRUMENT_CALIBRATION_DESC    = "OMEGA_CALIBRATION_DESC.TXT"

DATA_QUALITY_ID                 = 3
DATA_QUALITY_DESC               = " from 0 to 3 depending on
                                  missing lines and compression errors"

MISSING_SCAN_LINES              = 0
CHANNEL_ID                      = (IRC,IRL,VIS)
SOFTWARE_VERSION_ID             = "OMEGA 4.5"
TARGET_NAME                     = MARS
ORBIT_NUMBER                    = 18

PRODUCT_CREATION_TIME           = 2004-09-29T08:46:38.098
START_TIME                      = 2004-01-14T00:19:12.032
STOP_TIME                       = 2004-01-14T00:23:03.059
SPACECRAFT_CLOCK_START_COUNT    = "22054009.23265"
SPACECRAFT_CLOCK_STOP_COUNT     = "22054240.00630"

MAXIMUM_LATITUDE                = -54.594
MINIMUM_LATITUDE                = -65.256
EASTERNMOST_LONGITUDE           = 322.959
WESTERNMOST_LONGITUDE           = 318.126
SLANT_DISTANCE                  = 1112.726

/* set of commands */
COMMAND_NAME                    = "OMEGA_NOMINAL"
COMMAND_DESC                    = "00838383,00303030,04600900,050000EF,
```

```
    06001549,07708721,08000000,0900006F,0AEED804"

/* instrument status */
INSTRUMENT_MODE_ID              = ( 06,06,09)
EXPOSURE_DURATION               = (5.0,5.0, 50.0) <ms>
DOWNTRACK_SUMMING               = 1

INST_CMPRS_NAME                 = "WAVELET"
INST_CMPRS_RATE                 = 3.00
OFFSET                          = 0.0
SCALING_FACTOR                  = 0.983

MEX:SCAN_MODE_ID                = NOMINAL
                 /* can be "FIXED" OR "DEFAULT" */
MEX:FOCAL_PLANE_TEMPERATURE     = ( 77.6, 77.5,274.6) <K>
MEX:FOCAL_PLANE_TEMPERATURE_DESC=" temperatures of the C, L, V detectors"
MEX:SPECTROMETER_TEMPERATURE    = (182.9,181.0,191.7) <K>
MEX:SPECTROMETER_TEMPERATURE_DESC=" temperatures of the C, L, V spectrometers"
OBJECT                          = QUBE

/* ISIS cube with non-standard sideplanes */
AXES                            = 3
AXIS_NAME                       = (SAMPLE,BAND,LINE)

CORE_ITEMS                      = ( 64,352,576)
CORE_NAME                       = "RAW DATA NUMBER"
CORE_UNIT                       = "N/A"
CORE_ITEM_TYPE                  = LSB_SIGNED_INTEGER
CORE_ITEM_BYTES                 = 2
CORE_BASE                       = 0.0
CORE_MULTIPLIER                 = 1.0
CORE_VALID_MINIMUM              = "N/A"
CORE_NULL                       = "N/A"
CORE_LOW_REPR_SATURATION        = -32768
CORE_LOW_INSTR_SATURATION       = -32768
CORE_HIGH_REPR_SATURATION       = 32767
CORE_HIGH_INSTR_SATURATION      = 32767

/* suffix definitions for OMEGA */
SUFFIX_BYTES                    = 4
SUFFIX_ITEMS                    = (1,7,0) /* number of sideplanes */

SAMPLE_SUFFIX_NAME              = "DARK"
SAMPLE_SUFFIX_UNIT              = "N/A"
SAMPLE_SUFFIX_ITEM_TYPE         = LSB_SIGNED_INTEGER
SAMPLE_SUFFIX_ITEM_BYTES        = 4
SAMPLE_SUFFIX_BASE              = 0.0
SAMPLE_SUFFIX_MULTIPLIER        = 1.0
SAMPLE_SUFFIX_VALID_MINIMUM     = "N/A"
SAMPLE_SUFFIX_NULL              = "N/A"
SAMPLE_SUFFIX_LOW_REPR_SAT      = -32768
SAMPLE_SUFFIX_LOW_INSTR_SAT     = -32768
SAMPLE_SUFFIX_HIGH_REPR_SAT     = 32767
```

```
SAMPLE_SUFFIX_HIGH_INSTR_SAT   = 32767
SAMPLE_SUFFIX_NOTE             = "The sample sideplane contains the offset spectrum
       subtracted after acquisition. Visible: constant value"

BAND_SUFFIX_NAME               = "HOUSEKEEPING_PARAMETERS"
BAND_SUFFIX_UNIT               = "N/A"
BAND_SUFFIX_ITEM_TYPE          = LSB_SIGNED_INTEGER
BAND_SUFFIX_ITEM_BYTES         = 4
BAND_SUFFIX_BASE               = 0.0
BAND_SUFFIX_MULTIPLIER         = 1.0
BAND_SUFFIX_VALID_MINIMUM      = "N/A"
BAND_SUFFIX_NULL               = "N/A"
BAND_SUFFIX_LOW_REPR_SAT       = -32768
BAND_SUFFIX_LOW_INSTR_SAT      = -32768
BAND_SUFFIX_HIGH_REPR_SAT      = 32767
BAND_SUFFIX_HIGH_INSTR_SAT     = 32767
BAND_SUFFIX_NOTE               = "Housekeeping parameters and sideplane structure
                              are detailed in the OMEGA EAICD document"
^HOUSEKEEPING_DESCRIPTION      = "OMEGA_HK.TXT"

END_OBJECT                     = QUBE
END
```

C Example of PDS label of a level-1B geometry data product

```
PDS_VERSION_ID                = 3
LABEL_REVISION_NOTE           = "22-SEP-2004, N. Manaud"

/* FILE CHARACTERISTICS */
RECORD_TYPE                   = FIXED_LENGTH
RECORD_BYTES                  = 512
FILE_RECORDS                  = 14695
LABEL_RECORDS                 = 7
FILE_NAME                     = "ORB0018_0.NAV"
RELEASE_ID                    = 0001
REVISION_ID                   = 0000

/* DATA OBJECT POINTER /*
^QUBE                         = 8

/* IDENTIFICATION DATA ELEMENTS */
DATA_SET_ID                   = "MEX-M-OMEGA-2-EDR-FLIGHT-V1.0"
PRODUCT_ID                    = "ORB0018_0_GEOM"
PRODUCT_TYPE                  = EDR
STANDARD_DATA_PRODUCT_ID      = "OMEGA GEOMETRY"
PRODUCT_CREATION_TIME         = 2004-09-29T17:14:02.000
PRODUCER_INSTITUTION_NAME     = IAS
PI_PDS_USER_ID                = BIBRING
SPACECRAFT_NAME               = "MARS EXPRESS"
MISSION_PHASE_NAME            = "MC PHASE 1"
INSTRUMENT_NAME               = "Observatoire Mineralogie, Eau, Glaces, Activite"
INSTRUMENT_ID                 = OMEGA
TARGET_TYPE                   = PLANET
TARGET_NAME                   = MARS
START_TIME                    = 2004-01-14T00:19:12.032
STOP_TIME                     = 2004-01-14T00:23:03.059
SPACECRAFT_CLOCK_START_COUNT  = "22054009.23265"
SPACECRAFT_CLOCK_STOP_COUNT   = "22054240.00630"

/* DESCRIPTIVE DATA ELEMENTS */
ORBIT_NUMBER                  = 18
SPACECRAFT_POINTING_MODE      = "NADIR"
SPACECRAFT_POINTING_MODE_DESC = "The NADIR pointing mode is used for science observations
                                 nominally around the pericentre. In this pointing mode the
                                 Z-axis of the spacecraft points towards the centre of Mars
                                 and the X-axis perpendicular to the ground track."
^MEX_ORIENTATION_DESC         = "MEX_ORIENTATION_DESC.TXT"
MAXIMUM_LATITUDE              = -54.594
MINIMUM_LATITUDE              = -65.256
EASTERNMOST_LONGITUDE         = 322.959
WESTERNMOST_LONGITUDE         = 318.126
SLANT_DISTANCE                = 1112.73
SOLAR_LONGITUDE               = 333.1
SOLAR_DISTANCE                = 223058058.31
```

```
SUB_SOLAR_LONGITUDE           = 297.174
SUB_SOLAR_LATITUDE            = -11.118
^DATA_DESC                    = "GEOCUBE_DESC.TXT"
DATA_QUALITY_ID               = "NULL"
SOFTWARE_NAME                 = "GEOMEG V4 / 2"
SPICE_FILE_NAME               = "ATNM_P030602191822_00088.BC,
                                 ORMM__031222180906_00052.BSP,
                                 MEX_040730_STEP.TSC,
                                 MEX_OMEGA_V04.TI,
                                 MEX_V05.TF,
                                 DE405S.BSP,
                                 MAR033_2000-2025.BSP,
                                 MARS_IAU2000_v0.TPC,
                                 NAIF0007.TLS"

/* DATA OBJECT DEFINITIONS */
OBJECT                        = QUBE
  AXES                        = 3
  AXIS_NAME                   = (SAMPLE,BAND,LINE)
  CORE_ITEMS                  = (64,51,576)
  CORE_ITEM_BYTES             = 4
  CORE_ITEM_TYPE              = LSB_SIGNED_INTEGER
  CORE_BASE                   = 0.0
  CORE_MULTIPLIER             = 1.0
  SUFFIX_BYTES                = 4
  SUFFIX_ITEMS                = (0,0,0)
  CORE_VALID_MINIMUM          = "NULL"
  CORE_NULL                   = "NULL"
  CORE_LOW_REPR_SATURATION    = -2147483648
  CORE_LOW_INSTR_SATURATION   = -2147483648
  CORE_HIGH_REPR_SATURATION   =  2147483647
  CORE_HIGH_INSTR_SATURATION  =  2147483647
  CORE_NAME                   = "RAW DATA NUMBER"
  CORE_UNIT                   = DIMENSIONLESS
END_OBJECT                    = QUBE

END
```

D PDS Glossary

Archive An archive consists of one or more data sets along with all the documentation and ancillary information needed to understand and use the data. An archive is a logical construct independent of the medium on which it is stored.

Archive Volume, Archive Volume Set A volume is a unit of media on which data products are stored; for example, one CD-ROM or DVD-ROM. An archive volume is a volume containing all or part of an archive; that is, data products plus documentation and ancillary files. When an archive spans multiple volumes, they are called an archive volume set. Usually the documentation and some ancillary files are repeated on each volume of the set, so that a single volume can be used alone.

Catalog Information Descriptive information about a data set (e.g. mission description, spacecraft description, instrument description), expressed in Object Description Language (ODL), which is suitable for loading into a PDS catalog.

Data Product A labeled grouping of data resulting from a scientific observation, usually stored in one file. A product label identifies, describes, and defines the structure of the data. An example of a data product is a planetary image, a spectrum table, or a time series table.

Data Set An accumulation of data products. A data set together with supporting documentation and ancillary files is an archive.

To Do Items

- ☐ 1 (p. 20): Update Data Set ID Formation
- ☐ 2 (p. 21): Correct information on time standards
- ☐ 3 (p. 30): Add more detailed description of instrument mode
- ☐ 4 (p. 31): Add more detailed description of instrument mode
- ☐ 5 (p. 31): Add information on how those times are obtained