

**VIRTIS**ISTITUTO NAZIONALE  
DI ASTROFISICA

**ROSETTA - VIRTIS**  
**To Planetary Science Archive**  
**Interface Control Document**  
**VIR-INAFAIC-007**  
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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 folds. First it provides users of the VIRTIS instrument with detailed description of the product and a description of how it was generated, including data sources and destinations. Secondly, it is the official interface between our instrument team and the archiving authority.

### 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

#### 1.2.1. 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 VIRTIS instrument on Rosetta 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, and data files. Standards used to generate the products are explained. The design of the data set structure and the data product is given. Examples of the data labels are given.

### 1.4. Intended Readership

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

### 1.5. Applicable Documents

- [AD 1].** Planetary Data System Preparation Workbook, February 1, 1995, Version 3.1, JPL, D-7669, Part1

- [AD 2]. Planetary Data System Standards Reference, August 3, 2003, Version 3.6, JPL, D-7669, Part 2
- [AD 3]. Rosetta Archive Generation, Validation and Transfer Plan, January 10, 2006, RO-EST-PL-5011
- [AD 4]. Rosetta Archive Conventions, January 10, 2006, RO-EST-TN-3372
- [AD 5]. Planetary Science Data Dictionary, Revision D, JPL D-7116, July 15, 1996
- [AD 6]. VIRTIS Data Archive Format, April 29, 2002, VIR-ORS-RS-1146, Version 3.4
- [AD 7]. Update to VIRTIS Rosetta Archive Format, July 20, 2006, VIR-ORS-RS-2251, Issue 2.5
- [AD 8]. VIRTIS SW Internal Interface Control Document, July 2001, VIR-GAL-IC-028, Issue 7
- [AD 9]. VIRTIS Functional Architecture Specification Document, March 6, 1998, VIR-GAL-SP-045, draft
- [AD 10]. VIRTIS-M OGSE Control System/Unit Tester Interfaces: SW Requirement Specification, March 3, 2000, VIR-GAL-RS-084, Issue 1
- [AD 11]. VIRTIS SW User Requirements, July 2001, VIR-GAL-UR-040, Issue 5.0
- [AD 12]. HW and SW Specifications for the Interconnection between the EGSE and the HSGE during the calibration tests, February 14, 2001, VIR-ST-0-0003-IAS, Issue 2.
- [AD 13]. VIRTIS EGSE Requirement Specification, January 25, 2000, VIR-GAL-RS-062, Issue 3
- [AD 14]. VIRTIS On-Board Data Handling SW Interface Control Document, June 18, 2001, VIR-GAL-IC-0048, Version 6
- [AD 15]. VIRTIS SW Requirement Document, December 6, 2000, VIR-DLR-RS-003, Version 2, draft 1
- [AD 16]. VIRTIS Experiment User Manual, July 2003, RO-VIR-UM-001, issue 3
- [AD 17]. VIRTIS M Calibration Report, October 2006, VIR-INAF-MA-002, issue 2
- [AD 18]. VIRTIS H Calibration, June 2013, LES-RP-YYYY, issue 1
- [AD 19]. VIRTIS PDS/IDL software library VVX-LES-SW-2264, issue 3.0 (LECTURE\_PDS.PDF in the archive)
- [AD 20]. VIRTIS Rosetta geometry files VVX-LES-TN-2338, Issue 0.6, June 2013 (VIRTIS\_GEOMETRY.PDF in the archive)

### 1.6. Relationships to Other Interfaces

Raw data PDS cubes are generated by the EGSE [AD 13]: any change in the EGSE generation process would necessarily affect this document. Any future reprocessing of the data, for whatever reason, even if the labels are not affected, must be taken into account and described in this document.

### 1.7. Acronyms and Abbreviations

- ADC:** Analog Digital Converter
- ASDC:** ASI Data Centre
- CMWS:** Control and Monitoring WorkStation
- DHSU:** Data Handling System Unit
- EDR:** Experimental Data Record
- EGSE:** Electrical Ground Support Equipment
- FPA:** Focal Plane Arrays

**HK:** HouseKeeping parameters

**IDL:** Interactive Data Language

**IR:** InfraRed

**ISIS:** Integrated Software for Imagers and Spectrometers

**ITF:** Instrument Transfer Function

**ME:** Main Electronic

**OBT:** On-Board Time

**PC-OPB:** PC-Optical Bench

**PEM:** Proximity Electronic Module

**PDS:** Planetary Data System

**PI:** Principal Investigator

**PIWS:** Principal Investigator WorkStation

**PSA:** Planetary Science Archive

**QM:** Qualification Model

**RDDS:** Rosetta Data Distribution System

**RTU:** Remote Terminal Unit

**SI:** Systeme International d'unites

**SCET:** SpaceCraft Elapsed Time

**UTC:** Universal Time Corrected

## 1.8. Contact Names and Addresses

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## 2. Overview of Instrument Design, Data Handling Process and Product Generation

### 2.1. Scientific Objectives

The primary scientific objectives of VIRTIS during the Rosetta mission are:

- study the cometary nucleus and its environment;
- determine the nature of the solids on the nucleus surface;
- identify the gaseous species,
- characterize the physical conditions of the coma,
- measure the temperature of the nucleus.

Secondary objectives include helping with the selection of landing sites and providing support to other instruments.

Tertiary objectives include the detection and characterization of the asteroids during flybys.

#### 2.1.1. VIRTIS-M Nucleus Science Objectives

- Identify different ices and ice mixtures and determine their spatial distribution for albedo values ranging from 0.02 to 0.4.
- Identify the carbonaceous materials and determine the overall continuum slopes of the spectra.
- Determine the physical microstructure and nature of the surface grains by measuring the spectrophotometric phase curve with a relative radiometric accuracy of 1%.
- Identify the silicates, hydrates and other minerals with a spectral resolution of  $\lambda/\Delta\lambda > 100$  in the full spectral band.
- With a spatial resolution of a few tens of meters, globally map the nucleus and determine the spatial distribution of the various mineralogical types and their mixtures using both the spectral features and the overall brightness.
- Detect and monitor active areas on the comet surface to understand the operating physical processes and identify the associated material types.

#### 2.1.2. VIRTIS-M Coma Science Objectives

- With a resolving power of 100, determine the global distribution of gas and dust in the inner coma with to absolute and relative radiometric accuracy  $< 20\%$  and  $1\%$  relative. Determine the thermal properties of the dust.
- Identify and map the strong molecular emissions in the near ultraviolet and visible spectral band, including the main water dissociation product OH at 0.28  $\mu\text{m}$  and 0.31  $\mu\text{m}$ , CN, C<sub>3</sub>, NH, CH and CO<sup>+</sup> ions, and the neutral radicals CN and C<sub>2</sub>. With a high spatial resolution of 250  $\mu\text{rad}$  and a moderate spectral resolution of 500, correlate the evolution of radicals with that of their parent molecules. Correlate the results of these measurements with ground based telescopic observations.
- Map the composition and evolution of gas and dust jets in the coma and correlate it with the mineralogical composition and spatial morphology of active regions on the nucleus surface.

#### 2.1.3. VIRTIS-H Nucleus & Coma Science Objectives

- With a S/N  $> 100$  and resolving power higher than 1000, determine the composition of ices on the nucleus surface by resolving the absorption bands of condensed molecules between 2 and 3 microns.
- In the 2 to 5  $\mu\text{m}$  band, identify molecules in the gas, and measure rotational temperature. With a resolving power of 1500 at 3.5  $\mu\text{m}$ , identify the hydrocarbon emission in the 3 to 4  $\mu\text{m}$  band.
- Determine the composition of the dust grains in the coma by observing emission features in the fundamental bands between 2.5 and 5  $\mu\text{m}$  at less than 2 A.U.

#### 2.1.4. VIRTIS Asteroid Science Objectives

The asteroid part of Rosetta mission will include the encounter with two asteroids, 21 Lutetia and 2867 Steins. VIRTIS will allow the determination of the global and local properties of the target asteroids.

The scientific goals achievable with a minor planet encounter are:

- The characterization of the global shape of the asteroid and the knowledge of its physical properties: size, shape, pole and rotational period, density.
- The study of the morphological characteristics (local features, craters distribution, evidence of possible regolith) and mineralogical composition (heterogeneity of the surface, identification of local chemical provinces, first layer texture).
- The analysis of the asteroid environment to detect the presence of dust or gas.

#### 2.2. Instrument Description

The VIRTIS (Visible InfraRed Thermal Imaging Spectrometer) instrument combines a double capability: (1) high-resolution visible and infrared imaging in the 0.25 - 5  $\mu\text{m}$  range at moderate spectral resolution (VIRTIS-M channel) and (2) high-resolution spectroscopy in the 2-5  $\mu\text{m}$  range (VIRTIS-H channel). The two channels will observe the same comet areas in combined modes to take full advantage of their complementarities. VIRTIS-M (named -M in the following) is characterized by a single optical head consisting of a Shafer telescope combined with an Offner imaging spectrometer and by two two-dimensional FPAs: the VIS (0.25-1  $\mu\text{m}$ ) and IR (1-5  $\mu\text{m}$ ). VIRTIS-H (-H) is a high-resolution infrared cross-dispersed spectrometer using a prism and a grating. The 2-5  $\mu\text{m}$  spectrum is dispersed in 9 orders on a focal-plane detector array. The main characteristics of VIRTIS can be found in the Table 2-1.

VIRTIS MAIN CHARACTERISTICS AND REQUIREMENTS			
	VIRTIS-M Visible	VIRTIS – M InfraRed	VIRTIS - H
Spectral Range (nm)	220.1 - 1046.0	952.8 - 5059.2	Order 0 4.05-5.03 <sup>1</sup> Order 1 3.47-4.32 Order 2 3.04-3.78 Order 3 2.70-3.37 Order 4 2.43-3.03 Order 5 2.21-2.76 Order 6 2.03-2.53 Order 7 1.88-2.33
Spectral Resolution $\lambda/\Delta\lambda$	100 - 380	70 - 360	1300-3000
Spectral Sampling (nm) <sup>2</sup>	1.89	9.44	0.6
Field of View (mrad x mrad)	63.6 (slit) x 64.2 (scan)	63.6 (slit) x 64.2 (scan)	0.583 x 1.749
Max Spatial Resolution ( $\mu$ rad)	248.6 (slit) x 250.8 (scan)		
Pointing	+Zsc and Boresighted with Osiris, NavCam		
Telescope	Shafer Telescope	Shafer Telescope	Off axis parabolic mirror
Pupil Diameter (mm)	47.5		32
Imaging F#	5.6	3.2	2.04
Etendue (m <sup>2</sup> sr)	4.6x10 <sup>-11</sup>	7.5x10 <sup>-11</sup>	.8x10 <sup>-9</sup>
Slit Dimension (mm)	0.038 x 9.53		0.029 x 0.089
Spectrometer	Offner Relay	Offner Relay	Echelle spectrometer
Detectors	Thomson TH7896 CCD	CdHgTe <sup>3</sup>	CdHgTe <sup>3</sup>
Sensitivity Area Format	508 x 1024	270 x 436	270 x 436
Pixel Pitch ( $\mu$ m)	19	38	38
Operating temp. (K)	150 to 190	65 to 90	65 to 90
Spectral range ( $\mu$ m)	0.25 to 1.05	0.95 to 5.0	0.95 to 5.0
Mean Dark Current	< 1 e <sup>-1</sup> /s	< 10 fA @ 70K	< 10 fA @ 70K
Radiometric Resolution SNR	> 100	> 100	> 100 @ 3.3 micron
Radiometric Accuracy			
Absolute	< 20%	< 20%	< 20%
Relative	< 1%	< 1%	< 1%

Table 2-1: VIRTIS characteristics and performances overview.

<sup>1</sup> The real physical orders are from 6 to 13.

<sup>2</sup> This depends on the selected mode of operation; here it is reported the maximum value (no pixel summing).

<sup>3</sup> VIRTIS-M and -H make use of identical IR detectors.

### 2.2.1. Technical Description

The instrument is divided into 4 separate modules: the Optics Module - which houses the two -M and -H optical heads and the Stirling cycle cryocoolers used to cool the IR detectors to 70 K -, the two Proximity Electronics Modules (PEM) required to drive the two optical heads, the Main Electronics Module - which contains the Data Handling and Support Unit, for the data storage and processing, the power supply and control electronics of the cryocoolers and the power supply for the overall instrument.

**Proximity Electronics Modules** Each optical head requires specific electronics to drive the CCD, the two IRFPAs, the covers, the thermal control; the PEMs are two small boxes interfaced directly to the S/C and placed in the vicinity of the Optics Module to minimize interference noise.

**Optics Module** The -M imaging spectrometer and the -H Echelle spectrometer optical heads are located inside the Optics Module, which in turn is divided into two regions thermally insulated from each other by means of MultiLayer Insulation (MLI): the Cold Box and the Pallet.

The Pallet is mechanically and thermally connected to the SpaceCraft; inside the Pallet are located the two Stirling cycle cryocoolers. The heat produced by the cryocoolers compressors (a maximum of 24 W in closed loop mode) is dissipated to the spacecraft.

The Cold Box contains the two optical heads and its main function is to act as a thermal buffer between the Optical Heads, working at 130 K, and the external environment (the S/C temperature ranges from 250 to 320 K). The Cold Box is mechanically connected to the Pallet through 8 Titanium rods, whose number and size were selected to minimize conductive heat loads and to avoid distortion upon cooling from room temperature. The structural part of the cold box is a ledge which is supported by the 8 titanium rods; on the ledge, the two optical heads are mechanically fixed.

Thermal insulation of the Cold Box is improved by means of MLI, while thermal dissipation from the Cold Box is achieved by means of a two stages passive radiator: the first stage keep the Cold Box temperature in the range 120-140 K, while the second stage is splitted in two parts, one for each optical head, and allows to reach the required 130 K.

Another important component of the instrument are the two covers; they provide a double function: protection against dust contamination, internal calibration by means of an internally reflecting surface finish. They use a step motor and their operation is controlled by the PEMs.

**VIRTIS-M** - The VIRTIS-M optical head perfectly matches a Shafer telescope to an Offner grating spectrometer to disperse a line image across two FPAs. The Shafer telescope produces an anastigmatic image, while Coma is eliminated by putting the aperture stop near the center of curvature of the primary mirror and thus making the telescope monocentric. The result is a telescope system that relies only on spherical mirrors yet remains diffraction limited over an appreciable spectrum and field: at  $\pm 1.8$  degrees the spot diameters are less than 6  $\mu\text{m}$  in diameter, which is 7 times smaller than the slit width.

The Offner grating spectrometer allows to cover the visible and IR ranges by the realization, on a single grating substrate, of two concentric separate regions having different groove densities: the central one, approximately covering 30% of the grating area is devoted to the visible spectrum, while the external region is used for the IR range. The IR region has a larger area as the reflected infrared solar irradiance is quite low and is not adequately compensated by the infrared emissions of the cold comet.

The visible region of the grating is laminar with rectangular grooves profile, and the groove density is 268 grooves/mm. Moreover, to compensate for the low solar energy and low CCD quantum efficiency in the ultra-violet and near infrared regions, two different groove depths have been used to modify the spectral efficiency of the grating. The resulting efficiency improves the instrument's dynamic range by increasing the S/N at the extreme wavelengths and preventing saturation in the central wavelengths.

Since the infrared channel does not require as high a resolution as the visible channel, the lower MTF caused by the visible zone's obscuration of the infrared pupil is acceptable; the groove density is 54 grooves/mm. In any case, the spot diagrams for all visible and infrared wavelengths at all field positions are within the dimension of a 40  $\mu\text{m}$ /pixel. For the infrared zones, a blazed groove profile is used that results in a peak efficiency at 5  $\mu\text{m}$  to compensate for the low signal levels expected at this wavelength.

**VIRTIS-H.** - In -H the light is collected by an off-axis parabola and then collimated by another off-axis parabola before entering a cross-dispersing prism made of Lithium Fluoride. After exiting the prism, the light is diffracted by a flat reflection grating which disperses in a direction perpendicular to the prism dispersion. The prism allows the low groove density grating, which is the echelle element of the spectrometer, to achieve very high spectral resolution by separating orders 6 through 13 across a two-dimensional detector array: the spectral resolution varies in each order between 1200 and 3500.

Since the -H is not an imaging channel, it is only required to achieve good optical performance at the zero field position. The focal length of the objective is set by the required IFOV and the number of pixels allowed for summing. While the telescope is F/1.6, the objective is F/1.67 and requires five pixels to be summed in the spatial direction to achieve about 1 mrad<sup>2</sup> IFOV, corresponding to 3 pixels (3 x 0.58 mrad x 0.58 mrad).

**Main Electronics Module.** - The Main Electronics is physically separated from the Optics Module. It houses the Power supply for all the experiment, the cooler electronics, the spacecraft interface electronics, for telemetry and telecommanding, the interfaces with the Optics Module subsystems, and the DHSU (Data Handling and Support Unit) which is the electronics for the data handling, processing and for the instrument control.

The data processing and the data handling activities into the DHSU are performed using an on-line philosophy. The data are processed and transferred to the spacecraft in real time. The mass memory (SSR) of the spacecraft is used to store or buffer a large data volume. The Main Electronics contains no additional hardware component for data processing and compression. All data processing is performed by software.

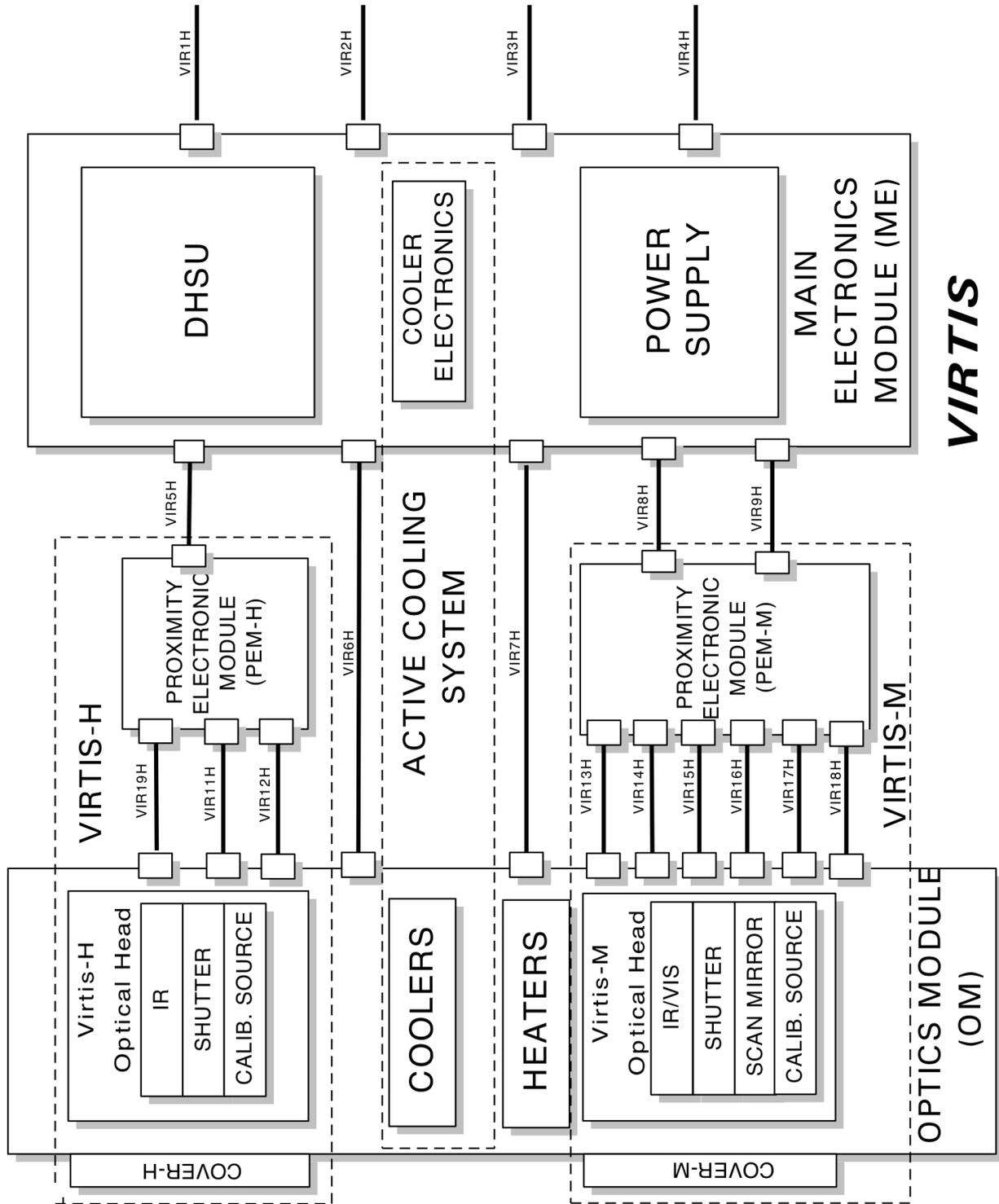


Figure 2-1: VIRTIS functional block diagram.

## Instrument operations

VIRTIS produces the following types of TM data:

1. TC verification reports;
2. H/K data reports;
3. Event reports;
4. Memory reports;
5. Science reports (science data).

They are transmitted to the S/C DMS through the RTU I/F except the Science reports that are transmitted on the High Speed I/F. If this is not available (e.g. failure) the instrument can be commanded to start a degraded Science mode which does not use the High Speed link. In this case the Science reports are transferred via the RTU I/F like the other TMs.

### 2.2.2. VIRTIS-M Operation modes

Possible VIRTIS-M operation modes, coded with the INSTRUMENT\_MODE\_ID parameter in the PDS header, are the following:

- |    |                              |
|----|------------------------------|
| 1  | M_Off                        |
| 2  | M_Cool_Dow                   |
| 3  | M_Idle                       |
| 4  | M_Annealing                  |
| 5  | M_PEM_On                     |
| 6  | M_Test                       |
| 7  | M_Calibration                |
| 8  | M_Science_High_Spectral_1    |
| 9  | M_Science_High_Spectral_2    |
| 10 | M_Science_High_Spectral_3    |
| 11 | M_Science_High_Spatial_1     |
| 12 | M_Science_High_Spatial_2     |
| 13 | M_Science_High_Spatial_3     |
| 14 | M_Science_Nominal_1          |
| 15 | M_Science_Nominal_2          |
| 16 | M_Science_Nominal_3          |
| 17 | M_Science_Nominal_Compressed |
| 18 | M_Science_Reduced_Slit       |
| 19 | M_User_Defined               |
| 20 | M_Degraded                   |
| 63 | M_ME_Test                    |

### 2.2.3. VIRTIS-H Operation modes

- |   |             |
|---|-------------|
| 1 | H_Off       |
| 2 | H_Cool_Down |
| 3 | H_Idle      |
| 4 | H_Annealing |

- 5 H\_PEM\_On
- 6 H\_Test
- 7 H\_Calibration
- 8 H\_Nominal\_Simulation
- 9 H\_Science\_Maximum\_Data\_Rate
- 10 H\_Science\_Nominal\_Data\_Rate
- 11 H\_Science\_Minimum\_Data\_Rate
- 12 (deleted)
- 13 H\_Science\_Backup
- 14 H\_User\_Defined
- 15 (deleted)
- 16 (deleted)
- 17 (deleted)
- 18 H\_Spectral\_Calibration\_Simulation
- 19 H\_Degraded
- 63 H\_ME\_Test

### 2.3. Science Data Formats

#### 2.3.1. VIRTIS-M Science Data Format

*Science data generated by the VIRTIS-M VIS and VIRTIS-M IR are stream of 16bit words, each corresponding to one pixel. Detector data are acquired on a spectral basis (spectrum by spectrum). In*

Figure 2-2 a sketch of the detectors and their alignment with respect to the slit and spectrum direction is reported. The axes are aligned to the axes of the spacecraft.

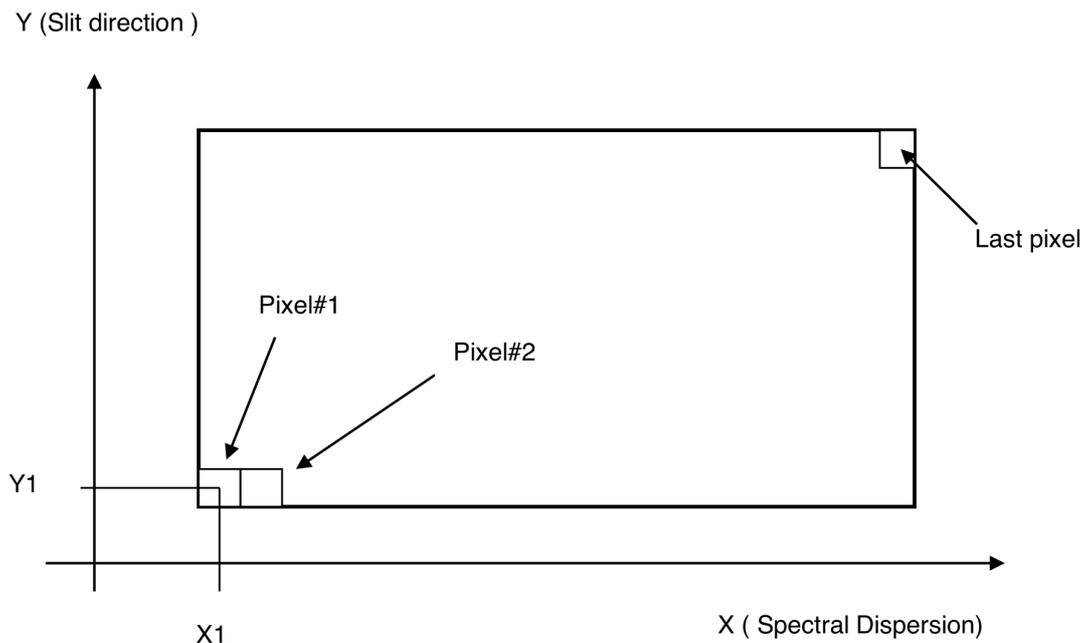


Figure 2-2: Data Organization on the CCD and IR detectors of VIRTIS-M.

The VIS CCD detector is a frame transfer detector of 1024x1024 CCD elements, thus only 512x1024 pixels are usable as image area. Moreover, each detector element has a physical size which is the half of the IR detector pixel, thus summation of 2x2 pixels shall be performed by the PEM to match spatial resolution of the IR channel. This action is performed directly by the PEM and is transparent to the final user.

The ME receives from the CCD 438 spectral and 256 spatial pixels and from the M-IR in full window mode receives 438 spectral and 270 spatial pixels. For compatibility with an integer binning value these formats are further reduced to a common 432x256 by the ME.

For M-IR the ME can command the PEM to produce a reduced window (438 spectral and 90 spatial pixels) to be used in the M\_reduced\_slit mode. In this case 90 pixels in the central area of the slit are selected.

### 2.3.2. VIRTIS-M Internal Calibration Data Format

Instrumental performances can be checked during in-flight conditions thanks to the internal calibration sequence. VIRTIS-M, in fact, can acquire reference signals thanks to the combined use of cover, shutter and VIS and IR lamps. These lamps, housed on the side of the telescope, illuminate the internal side of the external cover. The cover is placed near the entrance pupil of the instrument to minimize optical aberrations. The window of each lamp contains a transparent filter (holmium for the VIS, polystyrene for the IR) to introduce some well-shaped spectral absorption features on the overall spectrum. The signal coming from the two lamps can be used to:

- check the in-flight stability of the instrumental spectral response;
- check the in-flight stability of the flat-field;
- monitor the evolution of defective pixels (number and distribution);
- perform a check on the relative radiometric response of the instrument.

The internal calibration mode, implemented in the VIRTIS-M on-board software, consists in the acquisition of a sequence of 35 frames: 5 electronic offsets, 5 backgrounds, 5 dark currents, 5 acquisitions of the IR lamp, 5 acquisitions of the VIS lamp, 5 dark currents and 5 backgrounds.

Table 2-2 contains a description of the instrument configuration during each internal calibration step.

Internal calibration cubes are coded with INSTRUMENT\_MODE\_ID=7 in the PDS header.

Configuration	Frame number	Cover	Shutter	Scan mirror	IR Lamp	VIS Lamp	Vis Texp (s)	IR Texp (s)
Electronic offset	1-5	Closed	Open	Boresight	Off	Off	0.0	0.0
Background	6-10; 31-35	Closed	Open	Boresight	Off	Off	20.0	0.5
Dark current	11-15; 26-30	Closed	Closed	Boresight	Off	Off	20.0	0.5
IR Lamp acquisition	16-20	Close	Open	Boresight	On	Off	20.0	0.5
Vis lamp acquisition	21-25	Close	Open	Boresight	Off	On	1.0	0.1

Table 2-2: VIRTIS-M internal calibration sequence

### 2.3.3. VIRTIS-H Science Data Format

VIRTIS-H uses the same IR detector as VIRTIS-M however, due to the different design of the two channels, the detector is used rather differently.

VIRTIS-H is a high resolution spectrometer and does not perform imaging; the H-IR detector is used to acquire spectra spread over its surface, thus only a portion of the pixels contains useful scientific data. The 8 spectral orders are spread over the entire surface matrix. In each spectral order the spectrum covers 432x5 pixels (where 5 pixels represent the image of the slit size when imaged on the detector).

Thus overall only 15% of the 438x270 pixels matrix surface is used. To reduce the overall data rate and volume, H uses the so called Pixel Map which gives the exact location of the spectra over the H-IR detector. The ME calculates the location of the pixels to be downloaded and passes it to PEM-H which then downloads them accordingly. The downloaded data are the H\_SPECTRUM, a set of 432x8x5. A H\_Spectrum can be defined as a composition of the 8 orders imaged on the H-IR detector; the H\_Spectrum is extracted from the two-dimensional detector by using a map of the lighted pixels based on 8 spectral orders of 432 elements and a width of 5 pixel for each order. The 5 pixels are reduced to 1 pixel by averaging. The H\_Spectrum is composed of 3456 pixels.

As H has no spatial resolution the 5 pixels are averaged together, thus the final end-product in the H\_Nominal acquisition mode is a 3456 (or 432x8) pixels spectrum representing the full spectral range of the instrument from 1.88 through 5.03  $\mu\text{m}$ .

However, the PEM-H can also be commanded to download the full frame to ME in the *Calibration* and *Science Backup* modes. In this case all the 432x256 pixels are sent to ME.

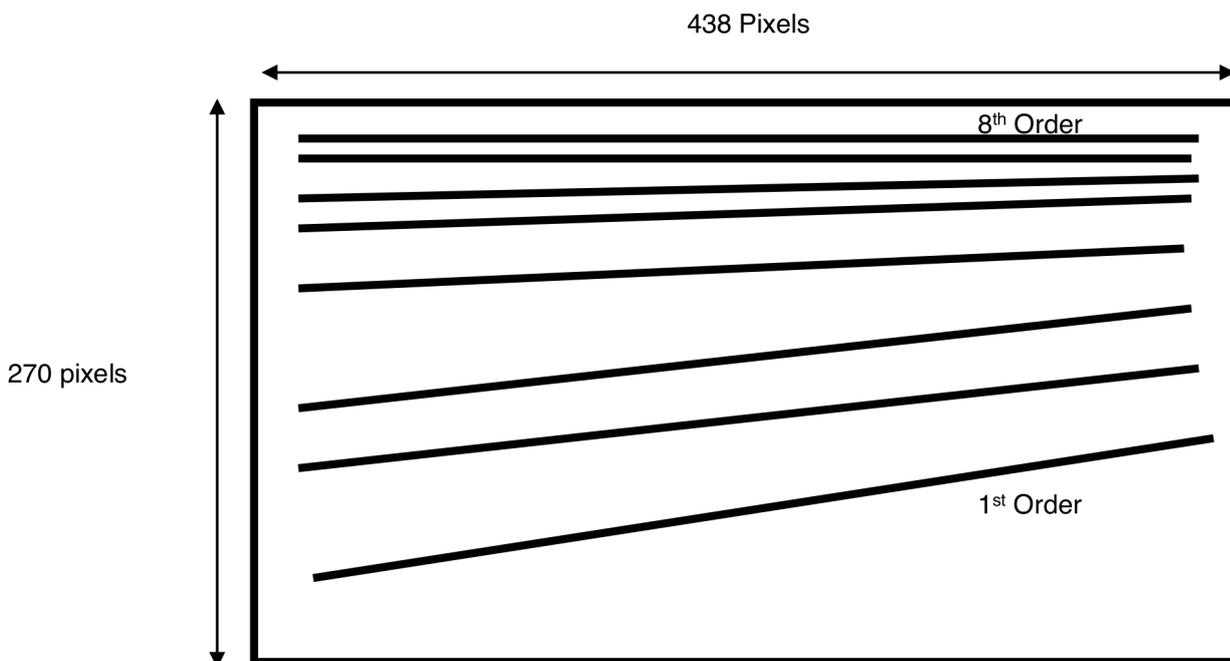


Figure 2-3: Spectral orders distributed over the IR FPA area. Only 15% of the matrix contains scientific data.

#### 2.3.4. VIRTIS-H Internal Calibration Data Format

A sequence of internal calibration of Virtis-H is operated as follows [AD 18]

**Slit\_spectral\_calibration** : 3 images (H\_Image\_Slice) with Cover closed, H-Shutter closed then S-lamp switched on, using functional param. integration time H\_INT\_SPECT\_S

**Telescope\_spectral\_calibration** : 2 images (H\_image\_slice) with H-shutter closed, then T\_lamp switched on, using functional param. integration time H\_INT\_SPECT\_T

**Image\_slice\_radiometric\_calibration** : 2 images, one H-shutter closed, then R-lamp switched on, using functional param. integration time H\_INT\_RADIO

**Spectrum Radiometric Calibration** : same, using the H\_spectrum mode (dark with shutter closed, and then R-lamp on)

The total of an internal calibration is 7xH\_Image\_Slice + 2 H\_spectrum. The purpose of the internal calibration is the verification of the pixel map and wavelength pixel map (through telescope spectral calibration), the radiometric evolution of the VIRTIS-H chain (lamps+spectrometer+detector), which can be followed along the mission, and the functionality of the on board spectral reconstruction by comparing the H\_spectrum mode to Image\_Slice mode on the same radiometric calibration image.

The slit calibration using the S-lamp is redundant with the T-lamp, but provides in addition a check of the integrity of the detector, by illuminating a large part of the detector (by scattered light), to follow the bad pixels evolution.

#### 2.3.5. Calibration pipeline for VIRTIS-M

VIRTIS-M calibration pipeline is described in [AD 17], which contains the algorithms used to transform raw digital numbers in spectral radiance ( $W m^{-2} \mu m^{-1} sterad^{-1}$ ). In this document are described the methods used to retrieve:

- Spectral calibration: correspondence between band number and wavelength (nm);
- Geometrical calibration: optical misalignment between -M Vis and IR channels boresights; in field distortions;
- Spatial calibration: flat field matrix;
- Radiometric calibration: instrumental transfer function necessary to convert DNs in spectral radiance ( $W m^{-2} \mu m^{-1} sterad^{-1}$ );

by using on ground calibration data and measurements. A section describes step by step the algorithms necessary to calibrate raw data.

The following calibration files of VIRTIS-M are distributed with this data release:

**VIRTIS M VIS SPECAL 10 V1.DAT**: spectral calibration for VIRTIS-M visible channel;

**VIRTIS M IR SPECALI 10 V1.DAT**: spectral calibration for VIRTIS-M infrared channel;

**VIRTIS M VIS RESP 10 V1.DAT**: high resolution responsivity for VIRTIS-M visible channel;

**VIRTIS M IR RESP 10 V1.DAT**: high resolution responsivity for VIRTIS-M infrared channel;

The version of the file is part of the filename (V1). As calibrations never ends but evolves during the instrument life, further improved procedures and updated files will be released during the development of the mission; in this case the version number will be changed.

A raw data cube contains the not calibrated signal in DN; dark currents and thermal background are automatically subtracted from the data by an on-board processing performed by the Main Electronics (ME). The counts can be converted in physical units of spectral radiance Rad ( $W m^{-2} \mu m^{-1} sterad^{-1}$ ) by using the following formulas:

$$Rad(\lambda(b), s, l)_{VIS} = \frac{DN(\lambda(b), s, l)_{VIS}}{t_{VIS} \cdot R(\lambda(b), s)_{VIS}}$$

$$Rad(\lambda(b), s, l)_{IR} = \frac{DN(\lambda(b), s, l)_{IR}}{t_{IR} \cdot R(\lambda(b), s)_{IR}}$$

where  $\lambda(b)$  is the wavelength associated to band  $b$  according to spectral calibration tables of VIS and IR channels;  $s$  and  $l$  correspond to sample and line location of the pixel in the original cube;  $t$  is the integration time (in seconds) indicated in the PDS header of the file for VIS and IR channels;  $R(\lambda(b), s, l)$  is the responsivity matrix for VIS and IR channels (files *VIRTIS\_M\_VIS\_RESP\_10\_V1.DAT* and *VIRTIS\_M\_IR\_RESP\_10\_V1.DAT*). This calculus can be applied to high resolution acquisitions (432 bands times 256 samples); in nominal modes where spatial and/or spectral resolutions are reduced, it is necessary to interpolate both spectral tables and responsivity matrices according to binning values.

After the calibration all the pixels that in the raw data have a value equal or greater than 18000 DN will be flagged as saturated with the value -1000.

### 2.3.6. Calibration pipeline for VIRTIS-H

The calibration of VIRTIS-H spectra is performed in Meudon and is described in detail in [AD 18]. In H nominal mode, spectral orders are extracted on board from the detector image by summing the intensity of pixels illuminated through the slit. For each spectral order the central  $y$  coordinate corresponding to a given  $x$  coordinate is computed using a second order polynomial in  $x$ . The coefficients are computed with respect to the detector coordinates (438x270) and not with respect to the data cube coordinates (432x256).

The label keywords *VIR\_H\_START\_X\_POSITION* and *VIR\_H\_START\_Y\_POSITION* indicate the position of the first pixel to be taken into account. The coefficients of these polynomials are stored in the data file labels (label keyword *VIR\_H\_PIXEL\_MAP\_COEF*). The 5 pixels centered in  $y$  on this pixel are then summed:

```
canal = findgen(438)      ; index vector (0, 1, ... 438)
Ycoord = fltarr(8,438)
for i = 0, 7 do begin
  Ycoord[i,*] = coef[i,0]+ coef[i,1] * canal + coef[i,2] * canal^2
  for x = 0, 431 do $
    sum[i,x] = total(image[x, Ycoord(i,x+0.5)-2: Ycoord(i,x+0.5)+2])
endfor
```

Dead pixels, as identified from the file *DEADPIXELMAP.DAT*, are not included in the sum. The same procedure is applied on ground to extract spectra from data transferred in "backup" mode (when complete detector images are transferred).

A first order radiometric calibration is used during this mission phase. It consists in subtracting the last dark current acquired before the data, and in dividing the result by the flat-field and by the integration time. Non linearity is neglected for the time being.

During observations, dark currents alternate with data acquisitions. In nominal mode, they are transferred separately from the data to preserve the efficiency of the compression procedure, and are therefore stored in separated files with related names. Dark currents corresponding to the data are identified through their SCET, which can be reconstructed from the first 3 values in the qube sideplane:

```
Escet = qube.suffix(0:2,0,0)
scet= Ulong( Escet(0) ) * 2UL ^ 16UL + Ulong( ESCet(1) ) $
+ double( ESCet(2) ) / 2d ^ 16d
```

In backup mode, dark currents consist in detector images interleaved in the data file. They are identified through element 5 in the sideplane (starting from 0):

```
idark = where((qube.suffix(5,0,*) and '2000'X) NE 0);
where '2000'X stands for 2000hexa = 8192 decimal
```

In some instances, dark frames are acquired when the shutter is still partially open. These corrupted darks are identified manually, and are filtered from the index vector. The regular dark frames are then interpolated through time. The last dark acquired (subtracted on board) is re-added to the data, and the interpolated value is subtracted - this corrects the zero-level from temperature fluctuations during acquisition.

Conversion to physical units is a complicated process which accounts for non-linearity. It is described in details in [AD 18]. This results in data calibrated in radiance, with unit  $W/m^2/sr/\mu m$ .

The wavelengths and FWHM in  $\mu m$  are carefully fit on the data and convolved with the instrument function. They are provided in the file *Grid-10-09-28.fits* and need not be recomputed each time.

Derivation and monitoring of the calibration functions and parameters are described in the document [AD 18]. Because the procedure is long and requires access to the full ground calibration archive, H calibrated files are computed in Meudon and are distributed on-line to the science team at:

*otarie.obspm.fr / VEx VIRTIS instrument*

These files are included in the archive once the calibration procedure is estimated to be accurate enough.

### Open issues:

Non-conformities still exist in the EGSE at the time of writing. Two mains consequences are identified, which will be fixed after the next update of the EGSE:

- Data documentation is performed incorrectly, with the HK parameters shifted relative to the data in H nominal mode. In the current files, the sideplanes therefore contain HK parameters transferred during the time interval corresponding to the next set of 64 spectra, i.e. HK in period  $t_1$  are stored with the data in period  $t_0$ . As a consequence, HK packets transferred during the acquisition of the first 64-spectra set are not stored in the PDS file because there are no corresponding data.

In this version of the archive, the pixel map coefficients may be replaced by a pre-launch version. The files affected are some of the raw data files in backup mode, and most calibrated files. The correct pixel map can be found in the labels of raw data files acquired in nominal mode.

## 2.4. Data Handling Process

Table 2-3 describes the VIRTIS data processing levels as used in this document. The archive contains both the EDR and RDR (level 2 and 3) data.

Processing Level ID (CODMAC level)	PRODUCT_TYPE	Description
1	UDR	Raw data that have been separated by instrument and sorted by orbit number. Contains all TM from VIRTIS (science and housekeeping data).
2	EDR	PDS formatted data, including decompressed science data, housekeeping selection, and geometry data. Science data are still in DN.
3	RDR	Science data calibrated in physical units (radiance) + timing as OBT
5	DDR	High level derived product such as compositional maps...

Table 2-3: Data level definition.

All the data products are generated by the VIRTIS team according to the following scheme, summarized in image.4:

- The PI Institution (INAF - Rome) retrieves the VIRTIS instrument data records (Level 1a data) from the Rosetta Data Distribution System (RDDS) using the EGSE. Both instrument telemetry and ancillary data are being stored at the PI processing facility as they accumulates over the course of the mission, to provide the capability to reprocess data in case of errors or to accommodate new information referring to existing data sets. For example, orbit reconstruction for the same data will improve in several stages over the course of the mission, and it is thus expected that geometry files will have to be regenerated.
- From the instrument data records, the EGSE generates Level 1b data files; the labels are completed, with the exception of the information that must be extracted from the SPICE files. Label templates are stored in the EGSE.
- Calibrated datasets are prepared in Rome for delivery to Co-Is.
- All the data are mirrored to LESIA-Meudon; a copy of the data sets is sent to the ROSETTA ASDC server, located at ESRIN in Frascati.
- At the end of the proprietary period PDS-compliant and validated data sets are delivered to the ESA Planetary Science Archive by means of the ESA-provided tool PVV that has been installed on a machine at the PI Institution. The final data delivery to the PSA is done by the PI Institution (INAF - Rome), that has the responsibility of assembling the data sets in the proper way and of maintaining all the related documents. A copy of the data set is sent to the ROSETTA ASDC server, located at ESRIN in Frascati.

After the proprietary period, currently foreseen at 6-month (see [AD 3]), validated, PDS-compliant data of Level 1b are delivered to the ESA Planetary Science Archive by means of the ESA-provided tool PVV that has been installed on a machine at the PI Institution. The final data delivery to the PSA is done by

the PI Institution (INAF - Rome), that has the responsibility of assembling the data sets in the proper way and of maintaining all the related documents.

The responsible of the overall data archiving process is Maria Teresa Capria; the person who actually is sending data to ESTEC, and using and keeping PVV software is Romolo Politi. Gianrico Filacchione is working on the calibration of the data and on the preparation of the calibration files; Florence Henry is responsible for the reconstruction of the observation geometry through the standard SPICE software. Geometry files are prepared by the LESIA-Meudon team.

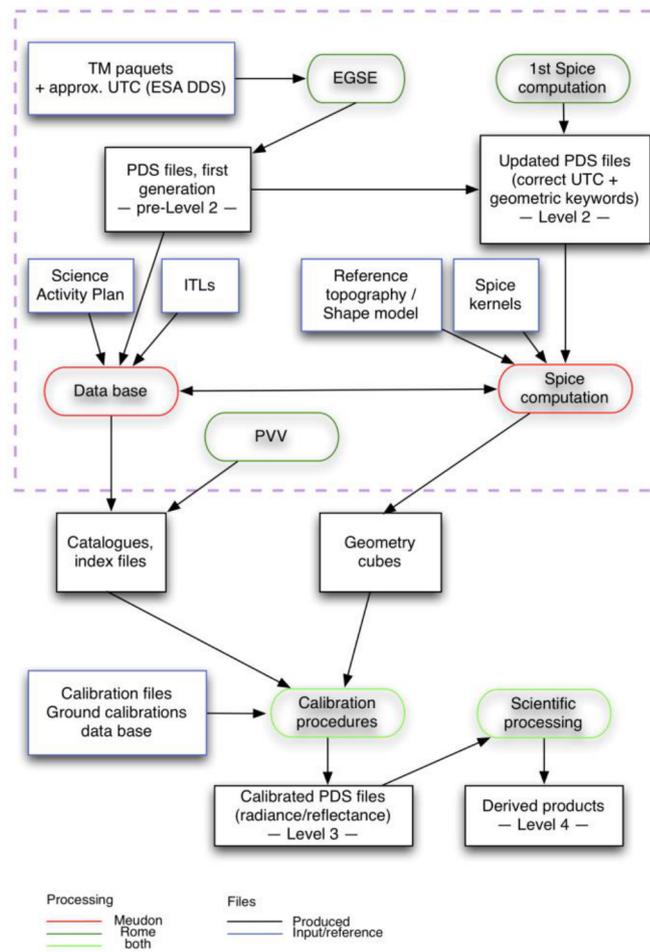


Figure 2-4: VIRTIS/Rosetta data set generation.

## 2.5. Overview of Data Products

### 2.5.1. Pre-Flight Data Products

We have no pre-flight data products to deliver.

### 2.5.2. Sub-System Tests

Sub-system tests performed on VIRTIS are useful only for engineering purposes, so the VIRTIS team does not plan to deliver sub-system test data products, as they would be useless for the analysis and interpretation of the acquired flight data.

### 2.5.3. Instrument Calibrations

Calibration runs of the instrument involved the determination of the instrument performance and of ITF (Instrument Transfer Function). These data are used for the calibration of scientific data and are processed to produce calibration files that are part of standard data product releases.

### 2.5.4. Other Files written during Calibration

We have no other file produced during the calibration process.

### 2.5.5. In-Flight Data Products

VIRTIS flight data products include:

- Level CODMAC 2 data: PDS-formatted raw data in DN, derived from telemetry with decompression, quality checked, time ordered, and sorted by channel/FPA. This includes both observations and flight calibrations. File extension is .QUB.
- -Geometry data: PDS-formatted geometry data, providing useful quantities such as coordinates and viewing angles for all observing sessions on a pixel basis. File extension is .GEO.
- Level CODMAC 3 data: PDS-formatted calibrated data in radiance. File extension is .CAL for calibrated data.
- VIRTIS-H calibrated data have separated dark cubes which contain only the spectra acquired with the shutter closed. File extension is .DRK.

### 2.5.6. Software

All the software needed to access the data is developed and maintained by the VIRTIS team; an IDL package able to read all PDS VIRTIS data products, and a related document, are being delivered with the data. The data handling procedure is described in section 2.4. Software used in this procedure have been developed and maintained jointly for the VIRTIS experiments on board Rosetta and Venus-Express. The EGSE software produces the initial PDS files from TM data. It allows monitoring the data flux and instrument health by looking at all the housekeeping parameters, and also has basic data viewing capabilities. The EGSE is written in Windows- specific languages and is not included in the archive.

The data base software in LESIA is a multi-experiment tool developed locally for low-level data handling and cataloguing, and on-line data processing. It is developed in php-postgreSQL and uses the VIRTIS IDL library (Lecture-PDS), with extensions. It is not included in the archive. Geometry computations are performed by a specific IDL library (GeoRos) relying on the Spice toolkit for IDL (ICY, version N0062). This module is not included in the archive.

The data calibration software for H is an extension of the data base software, and uses additional IDL routines. It makes frequent requests to the ground-calibration database, and therefore cannot be used outside LESIA. Data calibration for M is performed using stand-alone IDL routines developed in INAF-Rome. Owing to the difficulty of the process, the calibration software is not included in the archive.

Instead, calibrated data are provided in PDS format for all channels and sub-sessions. The user is made aware that this "best-effort" level-3 processing tools may be superseded by later versions as the understanding of the instrument behaviour during the mission continues to improve. Basic access to the data files is provided under IDL and GDL through the Lecture-PDS library. This is a versatile, multi-platform PDS library mainly focused on imaging spectroscopy and imaging data sets (Qube and Image objects). It includes a specific front-end and special routines to handle housekeeping parameters, timing information, and geometric data for the VIRTIS data sets. This library is included in the archive as a compressed ZIP archive in the EXTRAS directory, and is documented elsewhere [AD 19].

Software tools used for scientific analysis of VIRTIS observations are not included in the archive.

#### 2.5.7. Documentation

The documentation distributed with VIRTIS data sets, to be found in the DOCUMENT directory of standard data set distributions, is consisting of

- the present document, available both in PDF format and as pure ASCII text;
- the VIRTIS User Manual, available in PDF format: *VIRTIS\_EXP\_USER\_MANUAL*;
- a text and PDF document ([AD 17]) describing the calibration process of VIRTIS\_M: *VIRTIS\_M\_CALIBRATION\_REPORT*;
- a text and PDF document ([AD 18]) describing the calibration process of VIRTIS\_H: *VIRTIS\_H\_CALIBRATION*;
- the documentation to the geometry files (*VIRTIS\_GEOMETRY.PDF*);
- the documentation to the IDL library (*LECTURE\_PDS.PDF*).

The software is located in the EXTRAS directory. All routines are gathered in a single ZIP archive with a unique label.

#### 2.5.8. Derived and other Data Products

To the moment, the delivery of derived data or data resulting from a cooperation with other instruments is not foreseen.

#### 2.5.9. Ancillary Data Usage

Ancillary data used in VIRTIS data product generation are needed to correctly reference observations in space and time. Geometric information accompanying instrument is produced by means of software based on the SPICE library, released by the Navigation and Ancillary Data Facility (NAIF) of JPL. Spacecraft trajectory and attitude data produced by ESOC are accessed through the SPICE library in the form of pre-processed data files (called kernels) produced by RSSD.

Specific C- kernels are produced by the VIRTIS-Rosetta team in Rome to handle the scanning mirror positions of the M channels. One such file is generated for each mission phase, and is stored in the GEOMETRY directory. Spice kernels used for geometric computation are indicated in the file labels under the keyword *SPICE\_FILE\_NAME*. All these kernels are included in the corresponding Rosetta SPICE data set maintained by the PSA.

### 3. Archive Format and Content

This section describes the features of the VIRTIS Standard Product Archive volumes, including the file names, file contents, and file types, which apply to all VIRTIS data sets. More details on the data sets are provided in Section 4.

#### 3.1. Format and Conventions

##### 3.1.1. Deliveries and Archive Volume Format

Delivery of data from the VIRTIS team to the PSA for archiving is done through Internet, using the PVV tool, according to the release concept described in [AD 3]. In conformity with guidelines also provided in [AD 3], data are organized so that one VIRTIS data set will coincide with a single logical volume. . An example is shown in Table 3-1.

Data Set Name	Volume ID
ROSETTA-ORBITER EARTH VIRTIS 2 EAR1 V1.0	ROVIR_1007

Table 3-1: VIRTIS Data Sets and corresponding Volume ID's example.

##### 3.1.2. Data Set ID Formation

The value of this keyword is formed following the PDS rules and the Rosetta archive conventions as written in[AD 4]. For each delivery, the raw data from a mission phase will be found in a dataset. An example is shown in Table 3-2

Data Set Name	Data Set ID
ROSETTA-ORBITER EARTH VIRTIS 2 EAR1 V1.0	RO-E-VIRTIS-2-EAR1-V1.0

Table 3-2: VIRTIS Data Set ID's example.

##### 3.1.3. Data Directory Naming Convention

The /data directory is structured in three subdirectories:

*/data/VIRTIS\_M\_VIS*: contains VIRTIS-M VIS channel cubes;

*/data/VIRTIS\_M\_IR*: contains VIRTIS-M IR channel cubes;

*/data/VIRTIS\_H*: contains VIRTIS-H channel cubes;

##### 3.1.4. Filenaming Convention

All data product files throughout different VIRTIS data sets will be named using the same file naming convention. Data cubes are named according to the suffix indicating the channel, the spacecraft clock reset number and the acquisition SC\_CLOCK\_START\_COUNT (integer part).

The possible suffix values are the related to the data transfer mode:

**V:** M-Vis data;

**I:** M-IR data;

**H:** H image transfer mode (backup observation mode);

**S:** H single spectrum transfer mode (including dark current files in nominal mode);

**T:** H "64-spectra frame" transfer mode (nominal mode).

For example, acquisitions starting at `SC_CLOCK_START_COUNT = 1/21983325.39258` (1/ is the clock reset number) are named:

```
V_SC_CLOCK_START_COUNT.QUB = V1_21983325.QUB
I_SC_CLOCK_START_COUNT.QUB = I1_21983325.QUB
T_SC_CLOCK_START_COUNT.QUB = T1_21983325.QUB
```

Due to internal synchronization delays, simultaneous acquisitions could be shifted by few seconds among the three channels.

### 3.2. Standards Used in Data Product Generation

#### 3.2.1. PDS Standards

All the data released by the VIRTIS Team for archiving are compliant with the Planetary Data System (PDS3) standard. This standard imposes requirements on several aspects of the data product generation process, among which the need for a detailed documentation describing the origin, structure and processing undergone by data, for their accurate location in space and time, and in general for all auxiliary and ancillary data which are needed for the scientific use of the data products. This information has to be provided in an Object Description Language (ODL), in the format `keyword = value`, where `keyword` is a standard term used to label a parameter (e.g. `latitude`), and `value` is any allowed information quantifying that parameter.

#### 3.2.2. Time Standards

Time information is normally provided both in UTC formatted as ISO time strings and in spacecraft clock count (number of seconds elapsed since last clock resynchronization in the spacecraft frame).

##### 3.2.2.1. *START\_TIME and STOP\_TIME values formation*

The PDS formation rule for dates and time in UTC is: `YYYY-MM-DDThh:mm:ss.fff` or `YYYY-DDDThh:mm:ss.fff`, with:

- YYYY year (0000-9999);
- MM month (01-12);
- DD day of month (01-31);
- DDD day of year (001-366);
- 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).

##### 3.2.2.2. *SC\_CLOCK\_START\_COUNT and SC\_CLOCK\_STOP\_COUNT*

The `SC_CLOCK*COUNTS` represents 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  $2^{-16} = 1.52 \cdot 10^{-5}$  seconds. Thus the OBT is represented as a decimal real number in floating-point notation with 5 digits after a full stop character. A reset of the spacecraft clock is represented by an integer number followed by a slash, e.g. "1/" or "2/".

**Example 1:** SPACECRAFT\_CLOCK\_START\_COUNT = "1/21983325.39258"

**Example 2:** SPACECRAFT\_CLOCK\_START\_COUNT = "21983325.39258"

**Example 3:** SPACECRAFT\_CLOCK\_START\_COUNT = "2/0000325.39008"

Example 1 and Example 2 are representing the same time instance.

Timing is provided in the raw data Qubes sideplanes and in the geometry Qubes for reference and synchronization purpose. It is available as binary SCET encoded on 3 short integers (2 bytes each) as follows:

$$\text{scet} = \text{Scet0} * (2 \wedge 16) + \text{Scet1} + \text{Scet2} / (2 \wedge 16)$$

### 3.2.2.3. *OBT to UTC time conversion*

Universal Time Coordinate (UTC) is a function of the time correlation packages and the on-board time. The time correlation packages are archived and distributed in the SPICE auxiliary data set and contain a linear segment that map the on-board time to UTC time. The linear segment is represented by a time offset and a time gradient. The conversion function is:

$$\text{Time in UTC} = \text{offset} + ( \text{OBT}(\text{seconds}) + ( \text{OBT}(\text{fractional part}) * 2 \wedge -16 ) ) * \text{gradient}$$

### 3.2.3. Reference Systems

During the cruise phase of Rosetta, always the planetocentric body-fixed rotating coordinate system is used in order to compute geometric quantities relative to targets in the solar system. The planetocentric latitude is the angle between the equatorial plane and a vector connecting the point of interest and the origin of the coordinate system. Latitudes are defined to be positive in the northern hemisphere of the body, where north is in the direction of Earth's angular momentum vector, i.e., pointing toward the northern hemisphere of the solar system invariant plane. Longitudes increase toward the east, making the planetocentric system right-handed.

The easternmost (rightmost) longitude of a target is the maximum numerical value of longitude unless it crosses the Prime Meridian. For the Earth and the Moon, PDS supports the traditional use of the range [-180,180] in which case the easternmost (rightmost) longitude is the maximum numerical value of longitude unless it crosses 180. As regards the longitude, for the Earth and the Moon, the traditional use of the range [-180,180] is allowed. More information on the subject can be found in *VIRTISROS\_GEOMETRY.PDF* released within the data-set.

### 3.2.4. Other Applicable Standards

N/A

### 3.3. Data Validation

Validation of data is performed at different levels of detail and using different procedures. A first validation of the content of the data is taking place directly at the EGSE, where it is possible to have an idea of the completeness of telemetry and of the instrument behavior. The result is introduced in the file labels through the DATA\_QUALITY\_ID keyword: the associated value is 0 if TM data packets are missing, or 1 otherwise.

Data are compressed on board and decompressed in the EGSE. 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 word the corresponding data slice is set to 0. Missing data can therefore correspond either to actually missing TM packets, or to a severe error from the decompression routine. However, all perverted compressed data yielding inconsistent signal are not necessarily identified at this level.

Processing and calibration tools are built on the best knowledge available on the instrument from ground calibration, self-consistency checks and comparison with other experiments.

Use by the original VIRTIS team is the best possible validation of the data set. This understanding will evolve with the learning curve on the actual behavior of VIRTIS around its targets. The signal/noise ratio obtained by VIRTIS can exceed 1000 over parts of the wavelength range, with no binning. No ground calibration can provide that level of confidence, and small systematic errors, as well as linearity or crosstalk issues, will certainly remain at this level. As a reminder, an absolute photometric calibration level of 10% is considered an ambitious goal for this type of experiments, and can only be achieved after careful cross-comparison of actual data with the results of ground calibration and that of other experiments.

### 3.4. Content

#### 3.4.1. Volume Set

As the concept of a volume as defined in the PDS standard is based on physical media, e.g. CD-Rs, the PSA does not use the name volume. Instead, the concept of deliveries is defined for the PSA and the term delivery is used for the PSA. However, here and in the following sections we will use the word "volume" to refer to a standard PDS directory structure for a data set in which the entire data set consists of a single (virtual) volume. Different VIRTIS data sets will be organized as separate virtual volumes, and the concept of volume set will not be used.

#### 3.4.2. Data Set

The value of the keyword DATA\_SET\_NAME is formed following the PDS rules and the Rosetta archive conventions as written in [AD 4], so, for example, the DATA\_SET\_NAME for first Lutetia data set delivery will have the value:

ROSETTA-ORBITER LUTETIA VIRTIS 2 AST2 V1.0

#### 3.4.3. Directories

VIRTIS data sets are organized into one data set on one virtual volume and use the standard PDS volume structure. This structure is described in Section 19.3 of [AD 2], and shown in the figure below.

The content of each directory shown in Figure 3-1 is detailed in the following sections.

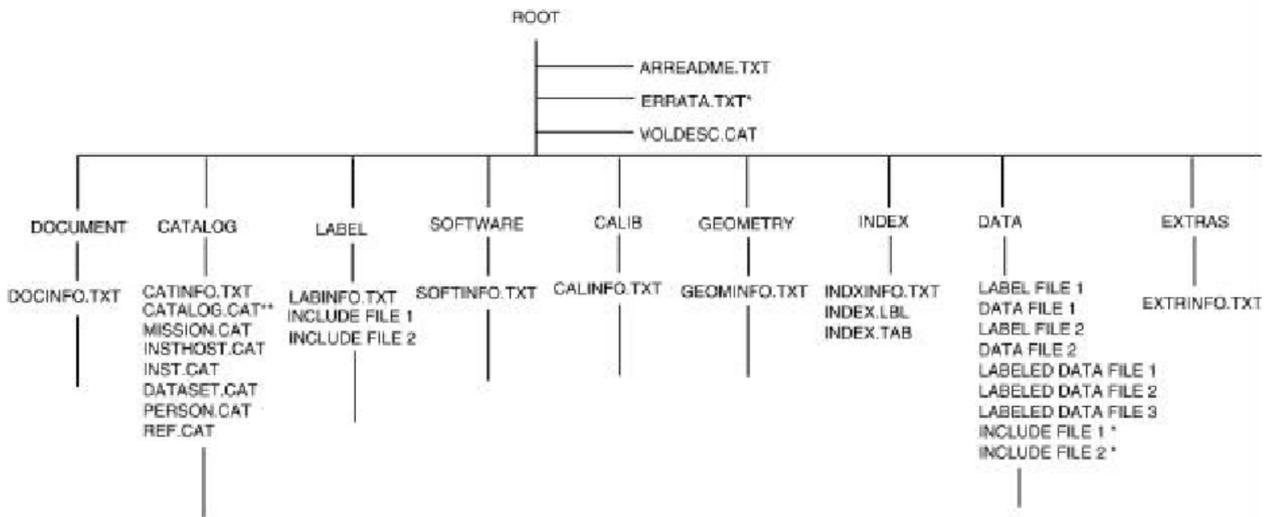


Figure 3-1: Standard PDS volume set organization: one data set, one volume.

### 3.4.3.1. Root Directory

Files in this directory are provided by the VIRTIS science team, and will remain the same across different volumes.

File Name	File Contents
AAREADME.TXT	Volume content and format information
VOLDESC.CAT	Description of the contents of the volume in a PDS format readable by both humans and computers

Table 3-3: Files located in the root directory of a VIRTIS data volume.

### 3.4.3.2. Calibration Directory

In the CALIB directory the last available versions of calibration files for all the channels can be found:

- VIRTIS\_M\_VIS\_RESP\_10\_V1.DAT** = 432x256 double precision matrix (binary) containing the VIRTIS-M-VIS Instrumental Transfer Function, including the VIS flat-Field.
- VIRTIS\_M\_IR\_RESP\_10\_V1.DAT** = 432x256 double precision matrix (binary) containing the VIRTIS-M-IR Instrumental Transfer Function, including the VIS flat-Field.
- VIRTIS\_M\_HRES\_SPECAL\_10\_V1.TAB** = 432 row ASCII table containing the wavelengths of the VIRTIS-M-VIS and -M-IR channels in High Resolution Mode.
- VIRTIS\_M\_NRES\_SPECAL\_10\_V1.TAB** = 144 row ASCII table containing the wavelengths of the VIRTIS-M-VIS and -M-IR channels in Nominal Resolution Mode.
- VIRTIS\_RESAMPLED\_IR\_NOM.TAB** = Kurucz solar irradiance from 1 AU resampled at ROSETTA VIRTIS\_M-IR sampling and resolution in nominal resolution mode (144 bands).

<b>VIRTIS_RESAMPLED_IR_HIGH.TAB</b>	= Kurucz solar irradiance from 1 AU resampled at ROSETTA VIRTIS_M-IR sampling and resolution in high resolution mode (428 bands).
<b>VIRTIS_RESAMPLED_VIS_NOM.TAB</b>	= Kurucz solar irradiance from 1 AU resampled at ROSETTA VIRTIS_M-VIS sampling and resolution in nominal resolution mode (144 bands).
<b>VIRTIS_RESAMPLED_VIS_HIGH.TAB</b>	= Kurucz solar irradiance from 1 AU resampled at ROSETTA VIRTIS_M-VIS sampling and resolution in high resolution mode (428 bands).
<b>HSOLEILROS2014.TAB</b>	= Solar irradiance from 1 AU resampled at ROSETTA VIRTIS_H sampling and resolution).
<b>DEADPIXELMAP</b>	= pixels not included in the summing of the intensity of pixels illuminated through the slit.
<b>VIRTIS_H_SPECTRAL_COEF_V1.TAB</b>	= Contains the coefficients of the polynomials used to compute the wavelengths of VIRTIS -H channels.
<b>VIRTIS_H_SPECTRAL_WIDTH_V1.TAB</b>	= Contains the coefficients of the polynomials used to compute the FWHM of VIRTIS -H channels.
<b>VIRTIS_H_TRANSFERT_FCT_V1.TAB</b>	= Contains the transfer function for VIRTIS -H channels. Each column corresponds to one VIRTIS -H spectral order.

The two calibration pipelines are described in [AD 17] and [AD 18].

#### 3.4.3.3. *Catalog Directory*

Files in this directory are catalogue files, that is files containing PDS catalogue objects. Such objects provide high-level information suitable for loading into a database to facilitate searches across data sets, collections and volumes. These files are provided by the VIRTIS science team, with the concurrence of the PSA, and will remain the same across different volumes.

File Name	File Contains
CATINFO.TXT	Text description of the directory contents
MISSION.CAT	PDS catalogue object for the mission
INSTHOST.CAT	PDS catalogue object for the spacecraft
INST.CAT	PDS catalogue object for the instrument
TARGET.CAT	PDS catalogue object for the targets
DATASET.CAT	PDS catalogue object for the VIRTIS data set
REF.CAT	PDS catalogue object for references appearing in the documentation

Table 3-4: Files located in the CATALOG subdirectory of a VIRTIS data volume.

#### 3.4.3.4. *Index Directory*

This directory contains indexes, that is files with information that allows a user to locate data of interest. Within the Planetary Science Archive (PSA), index files fulfill two more purposes. First, some index files

are read by database software and allow the ingestion of additional parameters into the database. Secondly, the PSA is using the index files to check for correct deliveries of data set revisions into the PSA. Indexes are written as INDEX\_TABLE objects, that is a specific type of PDS ASCII TABLE objects, and are provided with detached PDS label files.

The set of index files for VIRTIS, as required in [AD 3], is:

File Name	File Contents
INDXINFO.TXT	Text description of the directory contents
INDEX.LBL	Detached PDS label to describe INDEX.TAB
INDEX.TAB	PDS table, listing all files in the DATA directory for the corresponding release and revision.

Table 3-5: Files located in the INDEX subdirectory of a VIRTIS data volume.

The Index File (.LBL and .TAB) contains a lists all data files on the volume, the path to the directory containing the file and the name of the file in the archive. For each file information is given about time at which data in the file begin/end, number of rows and number of bytes in rows in the .TAB file.

#### 3.4.3.5. *Browse Directory and Browse Files*

This directory is not used in VIRTIS data volumes.

#### 3.4.3.6. *Geometry Directory*

The geometry directory contains additional CK Spice kernels describing the M-scanning mirror positions for each sub-session, and generated by the team. Each CK encompasses a mission phase. The file names have the following format:

ROS\_VIRTIS\_YYMMDD\_yymmdd\_VV.BC

where YYMMDD is the start date  
 yymmdd is the stop date  
 VV is a version number, starting from 01

A detached PDS label is also provided for each CK file.

#### 3.4.3.7. *Software Directory*

The software we are delivering, being a set of IDL procedures, will be found in the directory DOCUMENT.

#### 3.4.3.8. *Gazetter Directory*

This directory is not used in VIRTIS data volumes.

#### 3.4.3.9. *Label Directory*

This directory is not used in VIRTIS data volumes.

3.4.3.10. *Document Directory*

Files in this directory are provided by the VIRTIS science team, and are the same for all the volumes.

File Name	File Contents
DOCINFO.TXT	Text description of the directory contents
*****.LBL	PDS labels for all the documents contained in the directory
RO_VIRTIS_EAICD.ASC	VIRTIS EAICD (this document) in ASCII text
RO_VIRTIS_EAICD.PDF	VIRTIS EAICD (this document) in PDF format
VIRTIS_EXP_USER_MANUAL.PDF	VIRTIS User Manual in PDF format
VIRTIS_M_CALIBRATION_REPORT.ASC	VIRTIS_M Calibration report ASCII text
VIRTIS_M_CALIBRATION_REPORT.PDF	VIRTIS_M Calibration report in PDF format
VIRTIS_H_CALIBRATION.ASC	VIRTIS_H documentation in ASCII text
VIRTIS_H_CALIBRATION.PDF	VIRTIS_H documentation in PDF format
Additional docs:	
VIRTISROS_GEOMETRY.PDF	Documentation to the geometry files in PDF format
VIRTIS_PDS_IDL_SW_MANUAL.PDF	IDL software documentation in PDF format
VIR-IAS_*****.PDF	IDL library to read and handle VIRTIS data, as a GZIP archive (Only in Cruise Phases)

Table 3-6: Files located in the DOCUMENT subdirectory of a VIRTIS data volume.

3.4.3.11. *Extras Directory*

- **VIRTISPDS.ZIP**: IDL library to read and handle VIRTIS data, as a GZIP archive;
- **VIRTISPDS.LBL**: Combined label for the IDL library;

3.4.3.12. *Data Directory*

The DATA directory contains the actual data products generated by the VIRTIS team. Data files are organized into subdirectories, each containing data collected over one channel:

For Level CODMAC 2:

- /DATA/VIRTIS\_M\_VIS**: contains VIRTIS-M VIS channel cubes;
- /DATA/VIRTIS\_M\_IR**: contains VIRTIS-M IR channel cubes;
- /DATA/VIRTIS\_H**: contains VIRTIS-H channel cubes.

For Level CODMAC 3:

- /DATA/CAL/VIRTIS\_M\_VIS**: contains VIRTIS-M VIS channel cubes;
- /DATA/CAL/VIRTIS\_M\_IR**: contains VIRTIS-M IR channel cubes;
- /DATA/CAL/VIRTIS\_H**: contains VIRTIS-H channel cubes;
- /DATA/GEO/VIRTIS\_M\_VIS**: contains VIRTIS-M VIS geometry files;
- /DATA/GEO/VIRTIS\_M\_IR**: contains VIRTIS-M IR geometry files;
- /DATA/GEO/VIRTIS\_H**: contains VIRTIS-H geometry files;

## 4. Detailed Interface Specifications

### 4.1. Structure and Organization Overview

Measurements are provided as DN per spectral channel in Qube objects, with housekeeping parameters in the sideplanes. Data from the three focal planes are stored in separate files.

The logical object Qube is composed by a data area and an attached label. The data area is composed by a 3-dimension matrix containing science measurements (the core) and a sideplane containing the housekeeping. Data produced during a sub-session by each of the three focal planes (VIS, IR and H) are always stored in separate PDS-formatted files. For each channel, science data and dark frames are stored in the same file, interleaved in the Qube core, in the order in which they are transmitted. Each frame of the Qube core corresponds to a frame in the sideplane containing the HK parameters acquired at the corresponding time. Some housekeepings values that remain constant during a sub-session, such as those defining the observation mode, are also stored in the label as keywords values.

In summary, a raw data cube is composed by a sequence of: frame (Nband x Nsample values) + housekeeping parameter values (Nband x number of rows required to accommodate all the housekeeping parameters)(Figure 2-1). The data area starts always with an empty record, corresponding to the HISTORY object. This is necessary in order to maintain the compatibility with the ISIS software.

#### 4.1.1. Data storage and grouping

Data storage in the PDS files is determined by the data production mode of the instrument. The overall scheme to store raw data in calibration and during flight for -M and -H channels is described in the following sections.

##### 4.1.1.1. *Raw data storage for -M channel*

Raw data from the Visible and the IR FPA are stored in different files as Qube objects, so as to simplify data handling. For each FPA, science data and dark frames are stored in the same file, interleaved in the Qube core, and appear in the order they are transmitted. Each frame of the Qube core corresponds to a frame in the sideplane that contains the housekeeping parameters acquired at the corresponding time.

It is important to remember here that the data QUBE contains raw DN corrected for dark current: thanks to the integrated shutter, in fact, it's possible to acquire dark current frames at regular intervals during the scan. Each time VIRTIS start a new cube, it collects a dark frame that is automatically subtracted by the main electronics from the successive frames. Dark frames are acquired at intervals given by the DARK\_ACQUISITION\_RATE parameter and are temporally stored in the QUBE along the scan. During the dark acquisition the scanning mirror is not moved to avoid the loss of a line along the scan. Dark frames must be removed from the cubes during the calibration process. This is done by checking the dark flag in the cube suffix, as explained in section 2.3.6

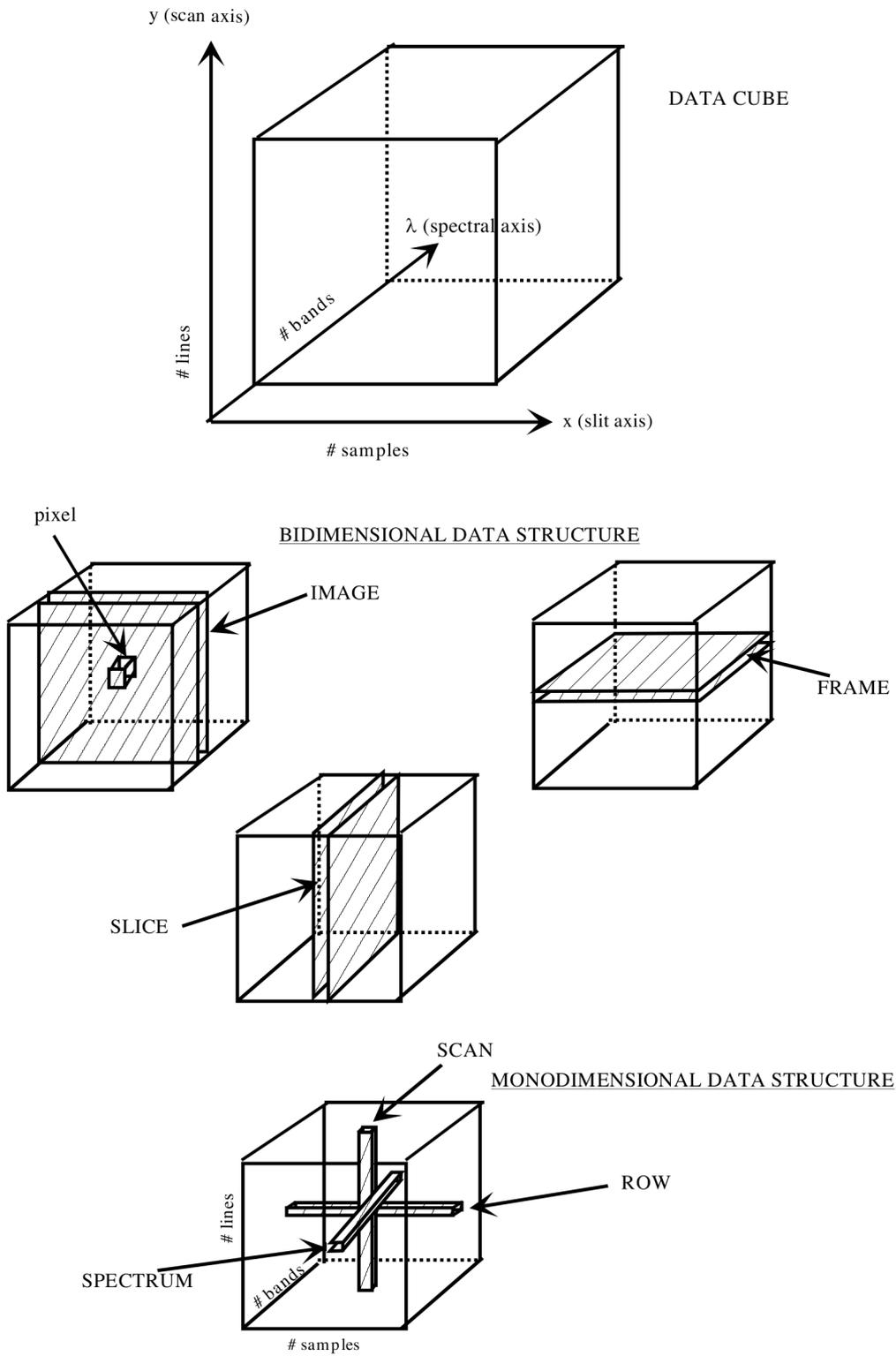


Figure 4-1: Structure of the cube data

4.1.1.2. *Raw data storage for -H channel*

Data are transferred by the ME according to one of three possible transfer modes: "image" (432 X 256 pixels), "spectrum" (sequence of 3456 measurements), and "64-spectra slice" (groups of 64 spectra compressed together). The data transferred through different modes cannot be stored together in a Qube object, because of their different dimensions. The operative modes are combinations of these three transfer modes, and therefore a specific data storage scheme is defined for each operating mode. These include:

**Nominal mode.** Data measurements are grouped as sets of 64 spectra and transferred as "64-spectra slice", interleaved with dark measurements transferred as "spectrum". Two files are written together:

- a qube, the core of which contains the measured spectra grouped in sets of 64 (3456 X 64 X sequence length).
- a qube, the core of which contains the dark spectra (3456 X 1 X number of dark spectra). Notice that the number of dark measurements associated to one "spectral slice" depends on operational parameters, and can vary from several dark frames for a single set of spectra to less than one dark per set.

The sideplane of each qube contains the corresponding housekeeping parameters.

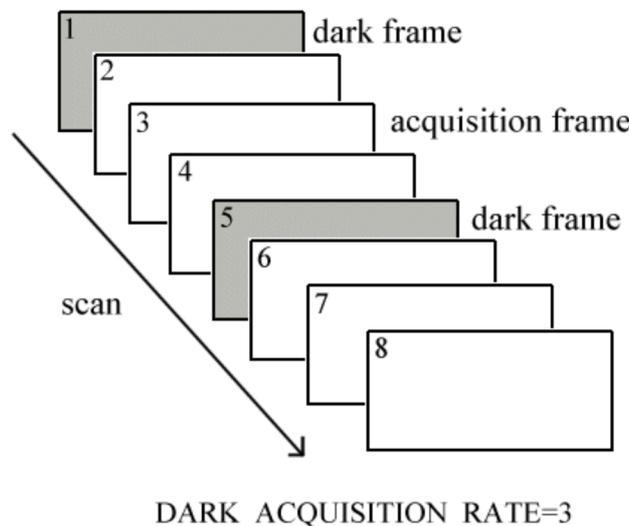


Figure 4-2: Structure of dark frames acquisition.

**Nominal simulation mode.** The data are produced by the instrument itself and contain known patterns used for calibration purposes. As long as data formatting is concerned this mode is formally identical to the nominal mode.

**Backup mode.** Data measurements and interleaved dark measurements are transferred as images acquired in long sequences (notice that, despite its name, this is a usual functioning mode for science observations). Only one file is written:

- a qube, the core of which contains the measured image frames and dark frames (432 X 256 X number of images acquired).

The sideplane of the qube contains the housekeeping parameters corresponding to each frame.

**Calibration mode.** A group of 7 images and a group of two spectra are acquired in sequence. Two short files are written:

- a qube, the core of which contains the images of the detector (432 X 256 X 7).
- a qube, the core of which contains the spectrum and the associated dark frame (3456 X 1 X 2).

The sideplanes of each qube contain the corresponding housekeeping parameters.

**Spectral calibration simulation.** A group of 2 images is produced, which are stored together in sequence. One single file is written:

- a qube, the core of which contains 2 images of the detector (432 X 256 X 2).

The sideplanes of the qube contains the corresponding housekeeping parameters.

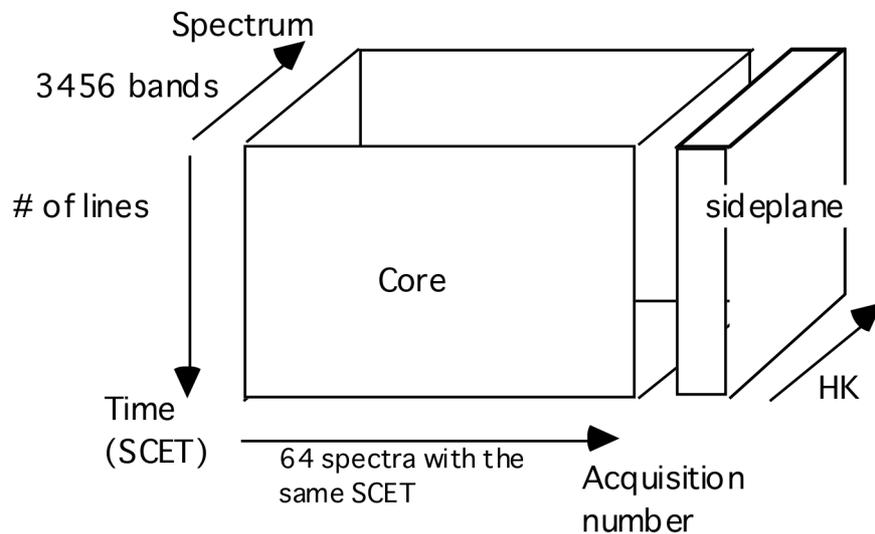


Figure 4-3: VIRTIS H data cube in 64-spectra mode. In this case, each frame contains the 64 spectra transferred together. The # of bands is equal to 3456.

#### 4.1.1.2.1. Core structure

A QUBE core is a 3-dimension structure containing science measurements (Figure 4-1). The axes of the QUBE are called BAND (spectral band defined by the wavelength), SAMPLE (spatial direction along the slit), and LINE (corresponding to different acquisitions, either a scan or a temporal axis). Individual elements of the QUBE are called pixels.

The three types of 2-dimension structures in a QUBE are called:

- **FRAME** (fixed LINE), provided by the detector at a given time;
- **IMAGE** (fixed BAND), a spatial information reconstituted through time at a given wavelength;
- **SLICE** (fixed SAMPLE), which is the third type of cut.

The three types of 1-dimension structures in a QUBE are called:

- **ROW** (fixed BAND and LINE), spatial information acquired in a single time step at a given wavelength;
- **SPECTRUM** (fixed LINE and SAMPLE), relative to a given footprint on the target;
- **SCAN** (fixed BAND and SAMPLE), spatial information reconstructed through time.

The storage order is always (Band, Sample, Line) (i.e., band interleaved by pixel, or BIP), following the order of the telemetry data flow.

The data produced by Virtis-H are either (Figure 4-3) sets of spectra acquired in sequence but transferred with the same SCET (formally similar to M data), or 3D data with 2 spectral dimensions (detector images). The same definitions as above apply in this case; the only difference concerns the SAMPLE axis, which may contain either a set of spectra with the same SCET, or one of the detector dimensions, i.e. the second spectral axis. A FRAME always contains data transferred with the same SCET, but in the case of spectra they are actually acquired at different times.

#### 4.1.1.2.2. Sideplane structure

The sideplane contains all the HK related to the frames; it can be visualized as a supplementary plane (Image.9). There are many HK (a detailed list is contained in the appendix D), and it would be almost impossible to store them in a different way; moreover, most of them refer only to the corresponding frame and not to the whole session. Each frame of the Qube core corresponds to a frame in the sideplane that contains the housekeeping parameters acquired at the corresponding time. All HK parameters are stored in the Qube sideplanes as integer variables (ie., using a constant number of bits whatever the dynamic range and the number of bits used to store the information in the telemetry data flow). Practically, this means that one (or some) complete line is added to each frame, the length of which is equal to the number of spectral bands, even if the number of housekeeping parameters stored in this line is smaller; in this case, this extra line must be padded with zeros. The sideplane corresponding to a frame in the cube is a set of rows containing information that document this frame. Each row of the sideplane has a number of items equal to the number of spectral bands in the cube core.

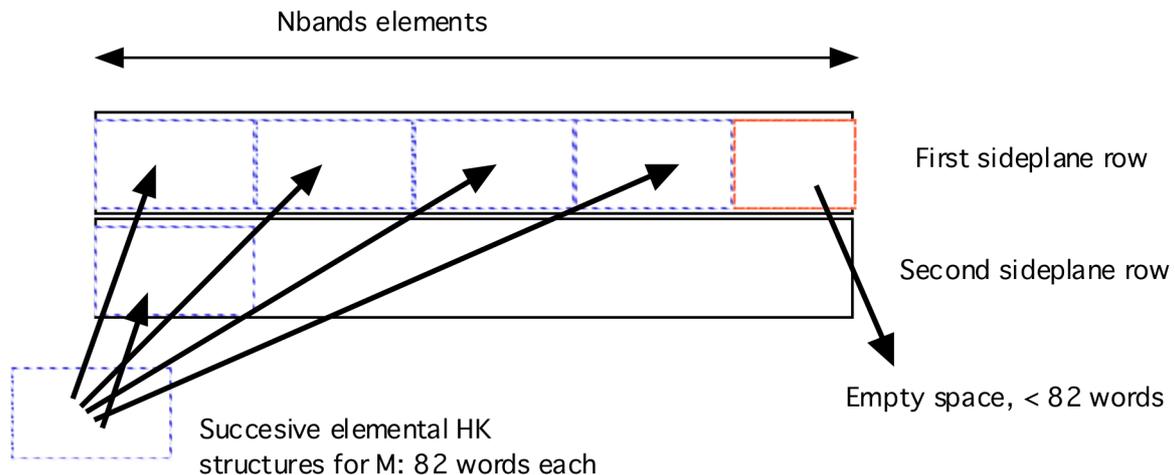


Figure 4-4: Organization of the sideplanes.

The information is stored according to the following rules:

- All data units (HK and other) are stored as two-bytes words exactly as they are transferred from the spacecraft. In particular, the byte ordering is preserved (MSB);
- Elemental HK structures corresponding to the same frame are written in sequence along a sideplane row until there is no more space to add a complete structure in the row (ie., a sideplane row should always contain an entire number of structures). The end of the row is then padded

with binary 0, and the following structure is written at the beginning of the next row (this is intended to keep the same index number in all rows for a given data, see Figure 4-3).

- The number of sideplane rows actually used is identical for each frame. It must be reported in the label with the SUFFIX\_ITEM keyword.

It is important to remember here that the data QUBE contains raw DN corrected for dark current: thanks to the integrated shutter, in fact, it's possible to acquire dark current frames at regular intervals during the scan. Each time VIRTIS start a new cube, it collects a dark frame that is automatically subtracted by the main electronics from the successive frames. Dark frames are acquired at intervals given by the DARK\_ACQUISITION\_RATE parameter and are temporally stored in the QUBE along the scan. During the dark acquisition the scanning mirror is not moved to avoid the loss of a line along the scan. For this reason, in order to extract an image from the cube it's necessary to remove dark current frames. These can be identified thanks to the shutter status value (SHUTT CMD=1 shutter closed, dark current; SHUTT CMD=0 shutter open, acquisition) stored in the HK.

#### 4.1.1.3. *Calibrated data storage for -M channel*

Calibrated VIRTIS-M data are stored in files with one-to-one correspondence with the raw data files, except for calibration sessions which are obviously not calibrated. The M calibrated files contains one qube with a bottomplane and a backplane.

All files first contain a HISTORY object, 512 bytes long, filled with ASCII 0.

The backplane consists of 3 frames containing reference data for each spectel: wavelength and FWHM (in microns), then absolute uncertainty on the signal (1-sigma deviation).

The QUBE contains the data calibrated in radiance. Dark frames are removed from the qube, which is therefore smaller than the original raw data qube along the Z/time axis. The x dimension of the qube provides spectral measurements in increasing wavelength order. Data are scaled in  $W/m^2/sr/\mu m$  and are stored as binary floating points on 4 bytes, MSB encoding. A single row of the backplane is used to store the SCET associated to the whole frame, encoded on the first 3 2-bytes integers of this row (see section 3.2.2). This SCET is reconstructed at mid-exposure.

#### 4.1.1.4. *Calibrated data storage for -H channel*

Calibrated VIRTIS-H data are stored in files with one-to-one correspondence with the raw data files, except for calibration sessions which are obviously not calibrated.

All files first contain a HISTORY object, 512 bytes long, filled with ASCII 0. This is a relic from previous requirements that are no longer relevant.

The TABLE object has 3 columns of 3456 elements containing reference data for each spectel: wavelength and FWHM (in microns), then absolute uncertainty on the signal (1-sigma deviation).

The QUBE object contains the data calibrated in radiance. Since only one spatial dimension is available for H, all spectra are grouped in a single dimension whatever the acquisition mode is (qube dimensions are 3456x1xz). In this scheme, spectral redundancy is preserved between overlapping orders, and measurements are therefore not sorted in wavelength order.

Data are scaled in  $W/m^2/sr/\mu m$  and are stored as binary floating points on 4 bytes, MSB encoding. The backplane is used to store the SCET associated to each spectrum, encoded on 3 2- bytes integers (see

section 3.2.2). This SCET is reconstructed at mid-exposure for each spectrum, from TM timing and acquisition rate parameters.

## 4.2. Data Product Design

### 4.2.1. Design of data for VIRTIS-M and H focal planes

All the data are organized in the logical structure called Qube; PDS labels describing the content of data files are always attached. The label provides descriptive information about the associated cube. PDS labels for all VIRTIS cubes have the same structure. Most of the keywords belong to one of the following groups:

- File information;
- Data description;
- Information on science operations;
- Instrument status description;
- Data object (qube) description

Keywords belonging to the above groups are listed in the following sections, while the last section describes the other keywords. Examples of actual labels are provided in Appendix C; more details on the possible values of each keyword and the origin of each value can be found in Appendix B. In the following sections, the value field has been filled only when it has a constant value, at least for this delivery.

Some of the keywords are beginning with "ROSETTA:": these keywords are locally defined (or non standard) keywords, used to store information related to the instrument that standard keywords cannot accommodate. Following the official PDS documentation, they are identified in the labels as:

<namespace>:<keyword\_name>

where <namespace> is the mission name.

#### 4.2.1.1. File information

PDS data product labels contain data element information that describes the physical structure of a data product file. The PDS file characteristic data elements are:

```

PDS_VERSION_ID           = PDS3
LABEL_REVISION_NOTE      = "SE-MTC, 6/06/2013"
PRODUCT_ID               =
ORIGINAL_PRODUCT_ID      =
RECORD_TYPE              = FIXED_LENGTH
RECORD_BYTES             = 512
FILE_RECORDS             =
LABEL_RECORDS            =
FILE_STATE               = CLEAN
PDS_VERSION_ID           = PDS3
END
LABEL_REVISION_NOTE      =
^HISTORY                 =
^QUBE                    =
PRODUCER_ID              = ROSETTA_VIRTIS_TEAM
PRODUCER_FULL_NAME       = "CAPACCIONI"
PRODUCER_INSTITUTION_NAME = "ISTITUTO NAZIONALE DI ASTROFISICA"
PRODUCT_CREATION_TIME    =
TELEMETRY_SOURCE_ID      = "VIRTIS_EGSE3"
  
```

SOFTWARE\_VERSION\_ID =

*PDS\_VERSION\_ID* states that the archive is written according to the PDS3 standard.

The *LABEL\_REVISION\_NOTE* references the version of the label template used when writing the file.

The keyword *PRODUCT\_ID* gives the actual name of the file containing the qube data, while *ORIGINAL\_PRODUCT\_ID* contains the name the qube had on the EGSE, at the beginning of the pipeline producing the data.

*RECORD\_TYPE* is the record format of the file; all VIRTIS data files will be using a fixed-length record format. *RECORD\_BYTES* is the number of bytes in a record. *FILE\_RECORDS* is the length of the data file in records number, including the label; *LABEL\_RECORDS* is the label length in records number.

*FILE\_STATE* identifies the correct and incorrect data files and is required for use with ISIS. Possible values are "CLEAN" and "DIRTY": the file status is "DIRTY" only when an inconsistency is found when reconstructing the file on the EGSE.

*^QUBE* is the pointer to the data object contained in the file. *^HISTORY* is a pointer to an ASCII field located between the label and the data. This object is always empty and one-record long (512 bytes set to ASCII 0). This is an early PSA requirement, preserved for the consistency of the pipeline.

*PRODUCT\_CREATION\_TIME* contains the date and time in which the PDS file was created. *TELEMETRY\_SOURCE\_ID* identifies the EGSE used to produce the data file.

*PRODUCER\_INSTITUTION\_NAME* identifies the organization responsible for developing the data products.

*SOFTWARE\_VERSION\_ID* tracks the processing applied to the current data product. It lists the software routines and versions used throughout the file history: on-board software version, low-level data handling to generate the PDS raw data file, plus calibration or geometry computation routines, and possibly intermediate reformatting routines.

#### 4.2.1.2. *Data description*

The keywords listed in this group describe data set, mission, mission phase, instrument type and so on.

```

DATA_SET_NAME           =
DATA_SET_ID             =
PRODUCT_TYPE            = EDR
PROCESSING_LEVEL_ID     = 2
STANDARD_DATA_PRODUCT_ID = "VIRTIS DATA"
MISSION_NAME            = "INTERNATIONAL ROSETTA MISSION"
MISSION_ID              = ROSETTA
INSTRUMENT_HOST_NAME    = "ROSETTA-ORBITER"
INSTRUMENT_HOST_ID      = RO
MISSION_PHASE_NAME      =
PI_PDS_USER_ID          = CAPACCIONI
INSTRUMENT_NAME         = "VISIBLE AND INFRARED THERMAL
                        IMAGING SPECTROMETER"
INSTRUMENT_ID           = "VIRTIS"
INSTRUMENT_TYPE         = "IMAGING SPECTROMETER"
INSTRUMENT_DESC         = "RO_VIRTIS.EAICD.ASC"
ROSETTA: CHANNEL_ID     =
DATA_QUALITY_ID         =
  
```

DATA\_QUALITY\_DESC = "0: INCOMPLETE ; 1: COMPLETE"

STANDARD\_DATA\_PRODUCT\_ID identifies data ("VIRTIS DATA") from geometry ("VIRTIS GEOMETRY") for use in further processing.

DATA\_QUALITY\_ID is a data quality indicator. Possible values are 0 if lines are missing, 1 if the data are complete, "NULL" is no diagnostic.

CHANNEL\_ID is a mission specific KW that identifies the instrument channel producing the data and can have 3 possible values: "VIRTIS\_M\_VIS", "VIRTIS\_M\_IR" and VIRTIS\_H.

^INSTRUMENT\_DESC is a pointer to a file that gives a description of the instrument, in this case this same document.

#### 4.2.1.3. *Science operations description*

The keywords listed in this group are related to the science operation: they contain the information on the target, the timing and so on. This is the group in which the geometric keywords are listed: the values necessary to complete these keywords must be generated with a software code accessing SPICE files.

TARGET\_TYPE =  
 TARGET\_NAME =  
 START\_TIME =  
 STOP\_TIME =  
 SPACECRAFT\_CLOCK\_START\_COUNT =  
 SPACECRAFT\_CLOCK\_STOP\_COUNT =  
 ORBIT\_NUMBER = "N/A"  
 OBSERVATION\_TYPE =  
 SC\_SUN\_POSITION\_VECTOR =  
 SC\_TARGET\_POSITION\_VECTOR =  
 SC\_TARGET\_VELOCITY\_VECTOR =  
 COORDINATE\_SYSTEM\_ID = "NULL"  
 COORDINATE\_SYSTEM\_NAME = "PLANETOCENTRIC"  
 DECLINATION =  
 RIGHT\_ASCENSION =  
 MAXIMUM\_LATITUDE =  
 MINIMUM\_LATITUDE =  
 EASTERNMOST\_LONGITUDE =  
 WESTERNMOST\_LONGITUDE =  
 SPACECRAFT\_ALTITUDE =  
 PHASE\_ANGLE =  
 SUB\_SPACECRAFT\_LATITUDE =  
 SUB\_SPACECRAFT\_LONGITUDE =  
 SOLAR\_DISTANCE =  
 SUB\_SOLAR\_LATITUDE =  
 SUB\_SOLAR\_LONGITUDE =  
 SPICE\_FILE\_NAME =

NOTE = " The values of the keywords SC\_SUN\_POSITION\_VECTOR, SC\_TARGET\_POSITION\_VECTOR and SC\_TARGET\_VELOCITY\_VECTOR are related to the J2000 frame.

The values of SUB\_SPACECRAFT\_LATITUDE and SUB\_SPACECRAFT\_LONGITUDE are northern latitude and eastern longitude in the planetocentric frame defined by the shape model. All values are computed at mid-session.

Distances are given in <km>, velocities in <km/s>, angles in <deg>"

*START\_TIME* and *STOP\_TIME* give the corrected UTC spacecraft time of start and stop of observation; the second keyword must always be present even if the stop time is unknown or unavailable. Time strings format is described in the appendix C.

*SPACECRAFT\_CLOCK\_START\_COUNT* and *SPACECRAFT\_CLOCK\_STOP\_COUNT* store the spacecraft time in its original form on the TM packet header; time string format is described in the appendix C.

*ORBIT\_NUMBER* is not used for Rosetta, and always set to "N/A".

*OBSERVATION\_TYPE* identifies the general type of the observation.

*SPICE\_FILE\_NAME* is a pointer to the list of SPICE kernels used to compute the values related to the geometric keywords.

*NOTE* is a constant information string requested by the PSA.

### **The geometric keywords**

All geometry computation is performed in Meudon using a specific GeoRos software based on the Spice library.

For the VIRTIS-M channel, the approach of self-generating "type 2" CK kernels (through the MSOPCK program supplied by the JPL NAIF team) reproducing the attitude of the internal scan mirror of VIRTIS, for a time interval corresponding to a given observation, is adopted. The list of Spice kernels used is provided through the *SPICE\_FILE\_NAME* keyword.

The inertial reference frame is assumed to be the Earth mean equator of J2000 frame ('EMEJ2000', named 'J2000' in this document for concision). All quantities are computed at mid-session time. Quantities related to the targets (coordinates...) are computed by projecting the FOV on a DTM or shape model, and use the same coordinate frame at the surface. The corresponding file is also identified through the *SPICE\_FILE\_NAME* keyword. Whenever the quantities are not defined, they are replaced by the code -999.99 (e.g. *DECLINATION* when the spacecraft is not in inertial mode, or for internal calibrations). For vectors, this applies to all individual components.

### **SC\_SUN\_POSITION\_VECTOR**

It is a 3-elements vector indicating the X-, Y-, and Z- components of the position vector from the spacecraft to Sun center, expressed in J2000 coordinates, and corrected for light time and stellar aberration. Each component is expressed in km, F14.3 format.

### **SC\_TARGET\_POSITION\_VECTOR**

It is a 3-elements vector indicating the X-, Y-, Z- components of the position vector from the spacecraft to target center expressed in J2000 coordinates, and corrected for planetary (light time) and stellar aberration. Each component is expressed in km, F14.3 format.

### **SC\_TARGET\_VELOCITY\_VECTOR**

It is a 3-elements vector indicating the X-, Y-, Z- components of the velocity vector of target relative to the spacecraft, expressed in J2000 coordinates, and corrected for light time and stellar aberration. Each component is expressed in km s<sup>-1</sup>, F14.3 format.

*COORDINATE\_SYSTEM\_ID* = "NULL"  
*COORDINATE\_SYSTEM\_NAME* = "PLANETOCENTRIC"

These keywords provide, respectively, the ID and full name of the coordinate system used on the target. The above default values are replaced by a description of the frame related to the DTM or shape model in use. Coordinates always follow the IAU 2009 standard for planetocentric coordinates: eastward longitudes, north pole defined so that the rotation of small bodies is always direct, or, for planets, pointing toward the northern hemisphere of the solar System invariant plane.

#### **DECLINATION - RIGHT\_ASCENSION**

These two keywords specify a constant direction of VIRTIS boresight when the spacecraft is in inertial pointing mode. In other situations they are set to -999.99. Both values are provided in degrees.

#### **MAXIMUM\_LATITUDE - MINIMUM\_LATITUDE**

These two keywords specify the northernmost and southernmost latitudes on the target, computed in the body-fixed, rotating coordinate system specified by the *COORDINATE\_SYSTEM\_NAME* keyword. Each value is expressed in degrees in the [-90,90] range, these values are intended to provide a rough idea of the footprint on the target.

#### **EASTERNMOST\_LONGITUDE - WESTERNMOST\_LONGITUDE**

These two keywords specify the easternmost and westernmost longitudes on the target, computed in the body-fixed, rotating coordinate systems specified by the *COORDINATE\_SYSTEM\_NAME* keyword. Each value is expressed in degrees, in the [0,360] range. These values are intended to provide a rough idea of the footprint on the target.

#### **SPACECRAFT\_ALTITUDE**

This keyword provides the distance from the spacecraft to the nearest point on a reference surface of the target body, in km.

#### **PHASE\_ANGLE**

This keyword specifies the phase angle of the target (i.e., the angle between a vector to the illumination source - namely the Sun - and a vector to the spacecraft). Expressed in degrees in the [0,180] range.

#### **SUB\_SPACECRAFT\_LATITUDE - SUB\_SPACECRAFT\_LONGITUDE**

These two keywords provide the coordinates of the sub-spacecraft point on the target body, corrected for planetary (light time) and stellar aberration. These numbers are computed in the body-fixed, rotating coordinate systems specified by the *COORDINATE\_SYSTEM\_NAME* keyword. Both the coordinates are expressed in degrees, in the [0,360] range.

#### **SOLAR\_DISTANCE**

This keyword provides the distance from the Sun to the target of an observation. In the computation, no aberration correction is applied, so that the real position of the Sun is considered. Expressed in km.

#### **SUB\_SOLAR\_LATITUDE - SUB\_SOLAR\_LONGITUDE**

These two keywords provide the coordinates of the subsolar point on the target body, corrected for planetary (light time) and stellar aberration. These numbers are computed in the body-fixed, rotating coordinate systems specified by the *COORDINATE\_SYSTEM\_NAME* keyword. Both coordinates are expressed in degrees.

#### 4.2.1.4. *Instrument status description*

The instrument status description and the operating parameters are contained in the following keywords, that are different for the two focal planes. Hereafter the keywords for M\_VIS and M\_IR files can be found. It should be noted that the names of two keywords, *ROSETTA:VIR\_VIS\_START\_X\_POSITION* and *ROSETTA:VIR\_VIS\_START\_Y\_POSITION*, depend on the channel: in the case of the infrared channel VIS must be substituted by IR.

```

INSTRUMENT_MODE_ID           =
INSTRUMENT_MODE_DESC         = "RO_VIRTIS_EAICD.ASC"
INST_CMPRS_NAME              =
INST_CMPRS_RATE              =
ROSETTA:VIR_VIS_START_X_POSITION =
ROSETTA:VIR_VIS_START_Y_POSITION =
ROSETTA:SCAN_MODE_ID        =
SCAN_PARAMETER               =
SCAN_PARAMETER_DESC          = ("SCAN_START_ANGLE",
                               "SCAN_STOP_ANGLE",
                               "SCAN_STEP_ANGLE",
                               "SCAN_STEP_NUMBER")
SCAN_PARAMETER_UNIT          = ("DEGREE", "DEGREE",
                               "DEGREE", "DIMENSIONLESS")
FRAME_PARAMETER              =
FRAME_PARAMETER_DESC         = ("EXPOSURE_DURATION",
                               "FRAME_SUMMING",
                               "EXTERNAL_REPETITION_TIME",
                               "DARK_ACQUISITION_RATE")
FRAME_PARAMETER_UNIT         = ("S", "DIMENSIONLESS", "S",
                               "DIMENSIONLESS")
MAXIMUM_INSTRUMENT_TEMPERATURE =
INSTRUMENT_TEMPERATURE_POINT = ("FOCAL_PLANE", "TELESCOPE",
                               "SPECTROMETER", "CRYOCOOLER")
INSTRUMENT_TEMPERATURE_UNIT  = ("K", "K", "K", "K")

```

This is the same group of keywords, shown for VIRTIS\_H files, and followed by 3 keywords found only on -H data:

```

INSTRUMENT_MODE_ID           =
INSTRUMENT_MODE_DESC         = "RO_VIRTIS_EAICD.ASC"
INST_CMPRS_NAME              =
INST_CMPRS_RATE              =
INST_CMPRS_RATIO            =
ROSETTA:VIR_H_START_X_POSITION =
ROSETTA:VIR_H_START_Y_POSITION =
FRAME_PARAMETER              =
FRAME_PARAMETER_DESC         = ("EXPOSURE_DURATION",
                               "FRAME_SUMMING",
                               "FRAME_ACQUISITION_RATE",
                               "INTERNAL_REPETITION_TIME",
                               "DARK_ACQUISITION_RATE")
FRAME_PARAMETER_UNIT         = ("MS", "DIMENSIONLESS",
                               "DIMENSIONLESS", "MS",
                               "DIMENSIONLESS")
MAXIMUM_INSTRUMENT_TEMPERATURE =
INSTRUMENT_TEMPERATURE_POINT = ("FOCAL_PLANE", "GRATING",

```

```

INSTRUMENT_TEMPERATURE_UNIT = ("PRISM", "CRYOCOOLER")
ROSETTA:VIRTIS_DEAD_PIXEL_MAP_FILE_NAME = ("K", "K", "K", "K")
ROSETTA:VIRTIS_H_PIXEL_MAP_COEF = "DEADPIXELMAP.DAT"
ROSETTA:VIRTIS_H_PIXEL_MAP_COEF_DESC =
( ("C11", "C12", "C13"),
  ("C21", "C22", "C23"),
  ("C31", "C32", "C33"),
  ("C41", "C42", "C43"),
  ("C51", "C52", "C53"),
  ("C61", "C62", "C63"),
  ("C71", "C72", "C73"),
  ("C81", "C82", "C83"))

```

*INSTRUMENT\_MODE\_ID* is a code indicating the observation or calibration mode (see appendix C). This code refers to the VIRTIS operative mode as defined in the document pointed by *^INSTRUMENT\_MODE\_DESC*.

A set of 3 keywords is giving information on the onboard compression software. *INSTR\_CMPR\_NAME* refers to the kind of algorithm applied (none, lossless or wavelet); *INSTR\_CMPR\_RATE* gives requested compression rate in bit/data word; when *INSTR\_CMPR\_NAME = NONE*, the compression ratio is 16 bits/pixel, when *INSTR\_CMPR\_NAME = REVERSIBLE* the compression is lossless and the effective compression ratio cannot be determined in advance (N/A), when *INSTR\_CMPR\_NAME = WAVELET*, the compression rate can be set to 2 bits/pixel, 1.5 bits/pixel, 1 bit/pixel. For details see appendix C.

*ROSETTA:VIR\_VIS\_START\_X\_POSITION* and *ROSETTA:VIR\_VIS\_START\_Y\_POSITION* give the X and Y coordinate of the first CCD pixel used on the M-Vis FPA. This quantity determines the correspondence between wavelength and spectral channels. Analogue couples of keywords are defined for the other two channels.

*ROSETTA:SCAN\_MODE\_ID* refers to the scan mode of Virtis-M. Possible values are 0 (pushbroom, i.e. no scanning), 1 (full scan), 2 (reduced scan). Scanning is performed in the cross-slit direction ie., along the track in the general case (except when the platform is depointed).

A set of 3 keywords (only for -M) gives information on the scan mirror: *SCAN\_PARAMETER*, *SCAN\_PARAMETER\_DESC* and *SCAN\_PARAMETER\_UNIT*. The information given is the start, stop and step angle of the mirror; the values can be both positive and negative as the reference point is the -M boresight. The fourth parameter is the number of acquisitions performed within one single scan unit position.

A set of 3 keywords, slightly different for -M and -H, gives information on the frame acquisition. *EXPOSURE\_DURATION* is the integration time expressed in milliseconds; it is the exposure time of elementary exposures when summing is performed. *FRAME\_SUMMING* is the number of elementary exposures summed during a time step (i.e, to build a frame). The product of *EXPOSURE\_DURATION* and *FRAME\_SUMMING* is the total integration time for each frame. *EXTERNAL\_REPETITION\_TIME* is the time required for a frame acquisition cycle (> *EXPOSURE\_DURATION* x *FRAME\_SUMMING*).

*DARK\_ACQUISITION\_RATE* is the number of frames acquired between two background measurements. *FRAME\_ACQUISITION\_RATE* is the rate of frame acquisition, measured in internal repetition time, for -H only. In internal calibration acquisitions the values of *EXPOSURE\_DURATION*,

*EXTERNAL\_REPETITION\_TIME* (-M) and *INTERNAL\_REPETITION\_TIME* (-H), which are not settable in this case, are replaced by the code -1.

Another group of keywords (*MAXIMUM\_INSTRUMENT\_TEMPERATURE*) provides the maximum temperatures, in Kelvin, measured on predefined points of VIRTIS during the observation sequence. The instantaneous values, referred to each frame, are stored in the cube sideplane and are used to optimize data reduction.

*ROSETTA:VIRTIS\_DEAD\_PIXEL\_MAP\_FILE\_NAME* is a pointer to an external file containing the positions of the dead pixels (only for -H).

*ROSETTA:VIRTIS\_H\_PIXEL\_MAP\_COEF* contains the values of the 24 pixel map coefficients for -H.

#### 4.2.1.5. *Data Objects Definition*

The PDS requires a separate data object definition within the product label for the QUBE object, to describe its structure and associated attributes. The object definition for a QUBE is in the form:

```

OBJECT                = QUBE
AXES                  = 3
AXIS_NAME             = (BAND, SAMPLE, LINE)
CORE_ITEMS            =
CORE_ITEM_BYTES       = 2
CORE_ITEM_TYPE        = MSB_INTEGER
CORE_BASE              = 0.0
CORE_MULTIPLIER       = 1.0
CORE_VALID_MINIMUM    = "NULL"
CORE_NULL             = "NULL"
CORE_LOW_REPR_SATURATION = -32768
CORE_LOW_INSTR_SATURATION = -32768
CORE_HIGH_REPR_SATURATION = 32767
CORE_HIGH_INSTR_SATURATION = 32767
CORE_NAME             = RAW_DATA_NUMBER
CORE_UNIT             = DIMENSIONLESS
SUFFIX_BYTES         = 2
SUFFIX_ITEMS         =
SAMPLE_SUFFIX_NAME    = "HOUSEKEEPING PARAMETERS"
SAMPLE_SUFFIX_UNIT    = DIMENSIONLESS
SAMPLE_SUFFIX_ITEM_BYTES = 2
SAMPLE_SUFFIX_ITEM_TYPE = MSB_INTEGER
SAMPLE_SUFFIX_BASE    = 0.0
SAMPLE_SUFFIX_MULTIPLIER = 1.0
SAMPLE_SUFFIX_VALID_MINIMUM = "NULL"
SAMPLE_SUFFIX_NULL    = 65535
SAMPLE_SUFFIX_LOW_REPR_SAT = 0
SAMPLE_SUFFIX_LOW_INSTR_SAT = 0
SAMPLE_SUFFIX_HIGH_REPR_SAT = 65535
SAMPLE_SUFFIX_HIGH_INSTR_SAT = 65535
^HOUSEKEEPING_DESCRIPTION = "RO_VIRTIS_EAICD.ASC"
END_OBJECT           = QUBE
  
```

#### Keywords describing the Qube

*AXES* is the number of data axes in the Qube object (always 3).

*AXIS\_NAME* indicates the organization of the object, bands interleaved by pixels, or BIP. For -M, it means that a complete spectrum is written contiguously, and spectra acquired at the same time step are written in sequence.

*CORE\_ITEMS* are the dimensions of the data cube. The three values specified are the spectral and spatial dimensions of the detector after binning (derived from *INSTRUMENT\_MODE\_ID*), and the number of frames acquired in the session.

*CORE\_ITEM\_BYTES* and *CORE\_ITEM\_TYPE* give the type of data in the cube core: it is always 16 bits integers, MSB encoding, for raw data, whatever the architecture used to write the raw data files (ie., EGSE will not change byte encoding relative to the output of the instrument). *CORE\_BASE* and *CORE\_MULTIPLIER* allow scaling of data (useful for calibrated data only):

$$\text{true\_value} = \text{base} + (\text{multiplier} * \text{stored\_value}).$$

Values below the keyword *CORE\_VALID\_MINIMUM* are reserved for special use, following an ISIS convention.

*CORE\_NULL* is an optional code indicating invalid data.

<i>CORE_LOW_REPR_SATURATION</i>	= -32768
<i>CORE_LOW_INSTR_SATURATION</i>	= -32768
<i>CORE_HIGH_REPR_SATURATION</i>	= 32767
<i>CORE_HIGH_INSTR_SATURATION</i>	= 32767

These are special values indicating instrument and representation saturation at both ends of the data range.

*CORE\_NAME* is the physical quantity recorded in the cube (required for ISIS).

*CORE\_UNIT* is the unit of data stored in the cube.

### Keywords describing the Sideplane

*SUFFIX\_ITEMS* gives the structure of the suffix area, listed in the storage order defined by *AXIS\_NAME*. The value is (0,NI<sub>s</sub>,0), where NI<sub>s</sub> is the number of lines required to store the housekeeping and ancillary information related to each frame of data. Each line is equivalent to an extra spectrum for each frame. This corresponds to data transfer order and saves the maximum possible space in the file. In this case, it means that NI<sub>s</sub> lines of Nb items will be written after the frame, where Nb is the number of spectral bands.

*SUFFIX\_BYTES* is the allocation in bytes of each suffix data value. This value is always 2 in labels written by EGSE.

*SAMPLE\_SUFFIX\_NAME* = "HOUSEKEEPING PARAMETERS" provides the name of the suffix items along the sample axis.

*SAMPLE\_SUFFIX\_ITEM\_BYTES* provides the sizes in bytes of the suffix items along the sample axis (part of the allocation reserved by *SUFFIX\_BYTES* which is actually used). A storage on two bytes can accommodate all VIRTIS HK.

*SAMPLE\_SUFFIX\_ITEM\_TYPE* provides the byte encoding of suffix items along the sample axis; always 16 bits integers, MSB encoding, for raw data, to remain consistent with core data.

*SAMPLE\_SUFFIX\_UNIT\_NOTE* can be used to comment on suffix area and is reserved for future use.

*^HOUSEKEEPING\_DESCRIPTION* is a pointer to an ASCII file describing the list of housekeeping and event parameters in the order they are stored in the suffix area

It should be noted that the value of the keyword *SUFFIX\_BYTES* is 2 instead of 4, as it would be required for compatibility with ISIS software: we did not follow this convention to avoid a large wasting of space.

```
OBJECT          = HISTORY
  DESCRIPTION    = "Reserved area for ISIS compatibility"
END_OBJECT      = HISTORY
```

A *HISTORY* object is located on top of all data files (not geometry files). This object is always empty and one-record long (512 bytes set to ASCII 0). This is an early PSA requirement, preserved for the consistency of the pipeline.

The calibrated data files include a qube containing the channel calibrated data, while reference information is contained either in a separate table (for H) or in a bottomplane (for M).

The calibrated data qube core is written as single precision floating point, IEEE encoding, BIP interleave mode. Special values are used to flag some cases resulting from the calibration scheme, which are listed in Table 4-1. Negative radiance values larger than -999 are allowed to accommodate measurement uncertainty on sky observations.

PDS keyword	Code	Comments
CORE_VALID_MINIMUM	-999	Minimum valid radiance value
CORE_NULL	-1004	Dead pixels
CORE_LOW_REPR_SATURATION	-1003	
CORE_LOW_INSTR_SATURATION	-1002	
CORE_HIGH_REPR_SATURATION	-1001	
CORE_HIGH_INSTR_SATURATION	-1000	Physical saturation of the FPA

Table 4-1: Pixel Flags

## 5. Appendix A: Software available to read PDS files

The VIRTIS EGSE contains a PDSviewer software written in C able to access and display the formatted VIRTIS data files. This software is not portable (Windows only) and will not be distributed outside the science team.

The VIRTIS team maintains an IDL software library to read Virtis PDS files, including data files and related files such as transfer functions.

This library is being delivered to PSA with a document explaining its content and usage.

Note that the uncompressed files are in upper case. Depending on the OS the user may need to go from upper to lower case.

## 6. Appendix B: Examples of actual labels

This is an example of a label for a M-VIS file, called V1\_38807497.qub (M-IR labels are similar):

```

PDS_VERSION_ID = PDS3
LABEL_REVISION_NOTE = "SE-MTC,01/03/2007"

/* File format and length */
PRODUCT_ID      = "V1_38807497.QUB"
ORIGINAL_PRODUCT_ID = "FV43P350.QUB"
RECORD_TYPE     = FIXED_LENGTH
RECORD_BYTES    = 512
FILE_RECORDS    = 15192
LABEL_RECORDS   = 11
FILE_STATE      = CLEAN

/* Pointers to data objects */
^HISTORY = 12
OBJECT    = HISTORY
DESCRIPTION = "Reserved area for ISIS compatibility"
END_OBJECT = HISTORY
^QUBE = 13

/* Producer information */
PRODUCER_ID          = ROSETTA_VIRTIS_TEAM
PRODUCER_FULL_NAME   = "CAPACCIONI"
PRODUCER_INSTITUTION_NAME = "ISTITUTO NAZIONALE ASTROFISICA"
PRODUCT_CREATION_TIME   = 2006-11-10T09:29:12.40
TELEMETRY_SOURCE_ID    = "VIRTIS_EGSE3"
SOFTWARE_VERSION_ID    = {"EGSESOFT 7.0","PDS_CONVERTER_7.0"}

/* Data description parameters */
DATA_SET_NAME        = "ROSETTA-ORBITER CAL VIRTIS 2 CVP V1.0"
DATA_SET_ID          = "RO-CAL-VIRTIS-2-CVP-V1.0"
RELEASE_ID           = 0001
REVISION_ID          = 0000
PRODUCT_TYPE         = EDR
STANDARD_DATA_PRODUCT_ID = "VIRTIS DATA"
PROCESSING_LEVEL_ID  = 2
MISSION_NAME         = "INTERNATIONAL ROSETTA MISSION"

```



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```
MISSION_ID = ROSETTA
INSTRUMENT_HOST_NAME = "ROSETTA-ORBITER"
INSTRUMENT_HOST_ID = RO
MISSION_PHASE_NAME = "COMMISSIONING"
PI_PDS_USER_ID = CAPACCIONI
INSTRUMENT_NAME = "VISIBLE AND INFRARED THERMAL IMAGING
SPECTROMETER"
INSTRUMENT_ID = "VIRTIS"
INSTRUMENT_TYPE = "IMAGING SPECTROMETER"
^INSTRUMENT_DESC = "RO_VIRTIS_EAICD.ASC"
ROSETTA:CHANNEL_ID = "VIRTIS_M_VIS"
DATA_QUALITY_ID = 1
DATA_QUALITY_DESC = "0:INCOMPLETE ; 1:COMPLETE"
```

/\* Science operations information \*/

```
TARGET_TYPE = "CALIBRATION"
TARGET_NAME = "CALIBRATION"
START_TIME = 2004-03-25T03:51:50.850

STOP_TIME = 2004-03-25T04:03:04.673
SPACECRAFT_CLOCK_START_COUNT = "1/38807497.6192"
SPACECRAFT_CLOCK_STOP_COUNT = "1/38808170.60127"
ORBIT_NUMBER = "N/A"
OBSERVATION_TYPE = "N/A"
SC_SUN_POSITION_VECTOR = "NULL"
SC_TARGET_POSITION_VECTOR = ("N/A", "N/A", "N/A")
SC_TARGET_VELOCITY_VECTOR = ("N/A", "N/A", "N/A")
COORDINATE_SYSTEM_ID = "NULL"
COORDINATE_SYSTEM_NAME = "PLANETOCENTRIC"
DECLINATION = -23.375
RIGHT_ASCENSION = 276.222
MAXIMUM_LATITUDE = "N/A"
MINIMUM_LATITUDE = "N/A"
EASTERNMOST_LONGITUDE = "N/A"
WESTERNMOST_LONGITUDE = "N/A"
SPACECRAFT_ALTITUDE = "N/A"
PHASE_ANGLE = "N/A"
SUB_SPACECRAFT_LATITUDE = "N/A"
SUB_SPACECRAFT_LONGITUDE = "N/A"
SOLAR_DISTANCE = "N/A"
SUB_SOLAR_LONGITUDE = "N/A"
SUB_SOLAR_LATITUDE = "N/A"
```

/\* Instrument status \*/

```
INSTRUMENT_MODE_ID = 07
^INSTRUMENT_MODE_DESC = "RO_VIRTIS_EAICD.ASC"
INST_CMPRS_NAME = "NONE"
INST_CMPRS_RATE = 16
INST_CMPRS_RATIO = "NONE"
ROSETTA:VIR_VIS_START_X_POSITION = 5
ROSETTA:VIR_VIS_START_Y_POSITION = 0
ROSETTA:SCAN_MODE_ID = 2
SCAN_PARAMETER = (0.16, 33.07, 0.26, 1.00)
SCAN_PARAMETER_DESC = ("SCAN_START_ANGLE", "SCAN_STOP_ANGLE",
"SCAN_STEP_ANGLE", "SCAN_STEP_NUMBER")
```



```
SCAN_PARAMETER_UNIT = ("DEGREE", "DEGREE", "DEGREE", "DIMENSIONLESS")
FRAME_PARAMETER      = (1.00, 1.00, 5.00, 20.00)
FRAME_PARAMETER_DESC = ("EXPOSURE_DURATION", "FRAME_SUMMING",
                        "EXTERNAL_REPETITION_TIME",
                        "DARK_ACQUISITION_RATE")
FRAME_PARAMETER_UNIT = ("S", "DIMENSIONLESS", "S", "DIMENSIONLESS")
MAXIMUM_INSTRUMENT_TEMPERATURE = (176.33, 143.04, 142.52, 79.80)
INSTRUMENT_TEMPERATURE_POINT   = ("FOCAL_PLANE", "TELESCOPE",
                                    "SPECTROMETER", "CRYOCOOLER")
INSTRUMENT_TEMPERATURE_UNIT    = ("K", "K", "K", "K")
```

```
/* Pointer to navigation data files */
SPICE_FILE_NAME = ("ATNR_P040302093352_00041.BC",
                  "VIRTIS_ck2_F43P.bc",
                  "DE405S.BSP",
                  "ORHR_____00041.BSP",
                  "NAIF0008.TLS",
                  "ROS_060511_STEP.TSC",
                  "ros_virtis_v11.ti",
                  "ros_v08.tf",
                  "PCK00008.TPC")
```

```
/* Cube keywords*/
OBJECT = QUBE
AXES = 3
AXIS_NAME = (BAND, SAMPLE, LINE)
CORE_ITEMS = (432, 256, 35)
CORE_ITEM_BYTES = 2
CORE_ITEM_TYPE = MSB_INTEGER
CORE_BASE = 0.0
CORE_MULTIPLIER = 1.0
CORE_VALID_MINIMUM = "NULL"
CORE_NULL = "NULL"
CORE_LOW_REPR_SATURATION = -32768
CORE_LOW_INSTR_SATURATION = -32768
CORE_HIGH_REPR_SATURATION = 32767
CORE_HIGH_INSTR_SATURATION = 32767
CORE_NAME = RAW_DATA_NUMBER
CORE_UNIT = DIMENSIONLESS

SUFFIX_BYTES = 2
SUFFIX_ITEMS = (0, 1, 0)
SAMPLE_SUFFIX_NAME = "HOUSEKEEPING PARAMETERS"
SAMPLE_SUFFIX_UNIT = DIMENSIONLESS
SAMPLE_SUFFIX_ITEM_BYTES = 2
SAMPLE_SUFFIX_ITEM_TYPE = MSB_UNSIGNED_INTEGER
SAMPLE_SUFFIX_BASE = 0.0
SAMPLE_SUFFIX_MULTIPLIER = 1.0
SAMPLE_SUFFIX_VALID_MINIMUM = "NULL"
SAMPLE_SUFFIX_NULL = 65535
SAMPLE_SUFFIX_LOW_REPR_SAT = 0
SAMPLE_SUFFIX_LOW_INSTR_SAT = 0
SAMPLE_SUFFIX_HIGH_REPR_SAT = 65535
SAMPLE_SUFFIX_HIGH_INSTR_SAT = 65535
^HOUSEKEEPING_DESCRIPTION = "RO_VIRTIS_EAICD.ASC"
```



```
END_OBJECT = QUBE
```

```
END
```

This is an example of a label for an H file, called T1\_38811591.qub:

```
PDS_VERSION_ID = PDS3
LABEL_REVISION_NOTE = "SE-MTC,01/03/2007"

/* File format and length */
PRODUCT_ID      = "T1_38811591.QUB"
ORIGINAL_PRODUCT_ID = "FT43P50.QUB"
RECORD_TYPE     = FIXED_LENGTH
RECORD_BYTES    = 512
FILE_RECORDS    = 5278
LABEL_RECORDS   = 12
FILE_STATE      = CLEAN

/* Pointers to data objects */
^HISTORY = 13
OBJECT    = HISTORY
DESCRIPTION = "Reserved area for ISIS compatibility"
END_OBJECT = HISTORY
^QUBE = 14

/* Producer information */
PRODUCER_ID          = ROSETTA_VIRTIS_TEAM
PRODUCER_FULL_NAME   = "CAPACCIONI"
PRODUCER_INSTITUTION_NAME = "ISTITUTO NAZIONALE DI ASTROFISICA"
PRODUCT_CREATION_TIME = 2006-11-10T09:29:50.21
TELEMETRY_SOURCE_ID  = "VIRTIS_EGSE3"
SOFTWARE_VERSION_ID  = {"EGSESOF7.0","PDS_CONVERTER_7.0"}

/* Data description parameters */
DATA_SET_NAME        = "ROSETTA-ORBITER CAL VIRTIS 2 CVP V1.0"
DATA_SET_ID          = "RO-CAL-VIRTIS-2-CVP-V1.0"
RELEASE_ID           = 0001
REVISION_ID          = 0000
PRODUCT_TYPE         = EDR
PROCESSING_LEVEL_ID  = 2
STANDARD_DATA_PRODUCT_ID = "VIRTIS DATA"
MISSION_NAME         = "INTERNATIONAL ROSETTA MISSION"
MISSION_ID           = ROSETTA
INSTRUMENT_HOST_NAME = "ROSETTA-ORBITER"
INSTRUMENT_HOST_ID   = RO
MISSION_PHASE_NAME   = "COMMISSIONING"
PI_PDS_USER_ID       = CAPACCIONI
INSTRUMENT_NAME      = "VISIBLE AND INFRARED THERMAL IMAGING
                        SPECTROMETER"
INSTRUMENT_ID        = "VIRTIS"
INSTRUMENT_TYPE       = "IMAGING SPECTROMETER"
^INSTRUMENT_DESC      = "RO_VIRTIS_EAICD.ASC"
ROSETTA:CHANNEL_ID    = "VIRTIS_H"
DATA_QUALITY_ID      = 1
```



```
DATA_QUALITY_DESC      = "0:INCOMPLETE ; 1:COMPLETE"

/* Science operations information */
TARGET_TYPE            = "CALIBRATION"
TARGET_NAME            = "CALIBRATION"
START_TIME              = 2004-03-25T05:00:05.149
STOP_TIME               = 2004-03-25T05:13:42.765
SPACECRAFT_CLOCK_START_COUNT = "1/38811591.25691"
SPACECRAFT_CLOCK_STOP_COUNT  = "1/38812408.20890"
ORBIT_NUMBER            = "N/A"
OBSERVATION_TYPE        = "N/A"
SC_SUN_POSITION_VECTOR   = (141327214.48, 13225356.06, 5271133.63)
SC_TARGET_POSITION_VECTOR = ("N/A", "N/A", "N/A")
SC_TARGET_VELOCITY_VECTOR = ("N/A", "N/A", "N/A")
COORDINATE_SYSTEM_ID     = "NULL"
COORDINATE_SYSTEM_NAME   = "PLANETOCENTRIC"
DECLINATION              = -23.372
RIGHT_ASCENSION          = 276.278
MAXIMUM_LATITUDE         = "N/A"
MINIMUM_LATITUDE         = "N/A"
EASTERNMOST_LONGITUDE    = "N/A"
WESTERNMOST_LONGITUDE    = "N/A"
SPACECRAFT_ALTITUDE      = "N/A"
PHASE_ANGLE              = "N/A"
SUB_SPACECRAFT_LATITUDE  = "N/A"
SUB_SPACECRAFT_LONGITUDE = "N/A"
SOLAR_DISTANCE           = "N/A"
SUB_SOLAR_LONGITUDE      = "N/A"
SUB_SOLAR_LATITUDE       = "N/A"

/* Instrument status */
INSTRUMENT_MODE_ID      = 10
^INSTRUMENT_MODE_DESC   = "RO_VIRTIS_EAICD.ASC"
INST_CMPRS_NAME         = "REVERSIBLE"
INST_CMPRS_RATE         = "N/A"
INST_CMPRS_RATIO        = "NONE"
ROSETTA:VIR_H_START_X_POSITION = "NULL"
ROSETTA:VIR_H_START_Y_POSITION = "NULL"
FRAME_PARAMETER         = (600.00, 1.00, 0.00, 2.00, 10.00)
FRAME_PARAMETER_DESC    = ("EXPOSURE_DURATION", "FRAME_SUMMING",
                           "FRAME_ACQUISITION_RATE",
                           "INTERNAL_REPETITION_TIME",
                           "DARK_ACQUISITION_RATE")
FRAME_PARAMETER_UNIT    = ("MS", "DIMENSIONLESS", "DIMENSIONLESS", "MS",
                           "DIMENSIONLESS")
MAXIMUM_INSTRUMENT_TEMPERATURE = (81.46, 140.15, 143.76, 79.70, -1e32)
INSTRUMENT_TEMPERATURE_POINT = ("FOCAL_PLANE", "GRATING",
                                 "PRISM", "CRYOCOOLER")
INSTRUMENT_TEMPERATURE_UNIT = ("K", "K", "K", "K")

ROSETTA:VIR_DEAD_PIXEL_MAP_FILE_NAME = "DEADPIXELMAP.DAT"
ROSETTA:VIR_H_PIXEL_MAP_COEF =
    ((3.842015E+001,1.222768E-001,9.361610E-005),
     (9.109106E+001,9.826208E-002,5.859880E-005),
     (1.261752E+002,8.349553E-002,3.504720E-005),
```



```
(1.517716E+002,6.967339E-002,1.929840E-005),
(1.709789E+002,5.490164E-002,1.546990E-005),
(1.849946E+002,4.500468E-002,1.146040E-005),
(1.953808E+002,4.088580E-002,1.903530E-006),
(2.034616E+002,3.525547E-002,-1.225590E-008)
ROSETTA:VIR_H_PIXEL_MAP_COEF_DESC = (("C11","C12","C13"),
                                      ("C21","C22","C23"),
                                      ("C31","C32","C33"),
                                      ("C41","C42","C43"),
                                      ("C51","C52","C53"),
                                      ("C61","C62","C63"),
                                      ("C71","C72","C73"),
                                      ("C81","C82","C83"))

/* Pointer to navigation data files */
SPICE_FILE_NAME = ("ATNR_P040302093352_00041.BC",
                  "VIRTIS_ck2_F43P.bc",
                  "DE405S.BSP",
                  "ORHR_____00041.BSP",
                  "NAIF0008.TLS",
                  "ROS_060511_STEP.TSC",
                  "ros_virtis_v11.ti",
                  "ros_v08.tf",
                  "PCK00008.TPC")

/* Cube keywords*/
OBJECT = QUBE
AXES = 3
AXIS_NAME = (BAND, SAMPLE, LINE)
CORE_ITEMS = (3456, 64, 6)
CORE_ITEM_BYTES = 2
CORE_ITEM_TYPE = MSB_INTEGER
CORE_BASE = 0.0
CORE_MULTIPLIER = 1.0
CORE_VALID_MINIMUM = "NULL"
CORE_NULL = "NULL"
CORE_LOW_REPR_SATURATION = -32768
CORE_LOW_INSTR_SATURATION = -32768
CORE_HIGH_REPR_SATURATION = 32767
CORE_HIGH_INSTR_SATURATION = 32767
CORE_NAME = RAW_DATA_NUMBER
CORE_UNIT = DIMENSIONLESS

SUFFIX_BYTES = 2
SUFFIX_ITEMS = (0, 1, 0)
SAMPLE_SUFFIX_NAME = "HOUSEKEEPING PARAMETERS"
SAMPLE_SUFFIX_UNIT = DIMENSIONLESS
SAMPLE_SUFFIX_ITEM_BYTES = 2
SAMPLE_SUFFIX_ITEM_TYPE = MSB_UNSIGNED_INTEGER
SAMPLE_SUFFIX_BASE = 0.0
SAMPLE_SUFFIX_MULTIPLIER = 1.0
SAMPLE_SUFFIX_VALID_MINIMUM = "NULL"
SAMPLE_SUFFIX_NULL = 65535
SAMPLE_SUFFIX_LOW_REPR_SAT = 0
SAMPLE_SUFFIX_LOW_INSTR_SAT = 0
```



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```
SAMPLE_SUFFIX_HIGH_REPR_SAT = 65535
SAMPLE_SUFFIX_HIGH_INSTR_SAT = 65535
^HOUSEKEEPING_DESCRIPTION   = "RO_VIRTIS_EAICD.ASC"
END_OBJECT = QUBE
```

END

## 7. Appendix C: Origin of the keyword values

The following table contains origin and possible values for Virtis M-Vis, M-Ir and H cubes. It should be noted that "constant" in the field "origin of value" mostly means that the value should be the same in all the files, not that it cannot never be changed.

Keyword	Possible Values	Origin of Values
PDS_VERSION_ID	PDS3	constant
LABEL_REVISION_NOTE	"SE-MTC, 01/03/2007"	constant
/* File format and length */		
PRODUCT_ID	Suffix indicating the channel + spacecraft clock reset number and the acquisition SC_CLOCK_START_COUNT (integer part)	constant
ORIGINAL_PRODUCT_ID		EGSE
RECORD_TYPE	FIXED_LENGTH	constant
RECORD_BYTES	512	constant
FILE_RECORDS		Total file length / RECORD_BYTES (closest integer greater than or equal to this value)
LABEL_RECORDS		Smallest integer large enough to accommodate the label up to END keyword (ie., label length in byte = LABEL_RECORD * 512)
FILE_STATE	CLEAN	constant
/* Pointers to data objects */		
^HISTORY		LABEL_RECORDS +1
OBJECT	HISTORY	constant
DESCRIPTION	"NULL"	constant
END_OBJECT	HISTORY	constant

Keyword	Possible Values	Origin of Values
^QUBE		LABEL_RECORDS +2
/* Producer information */		
PRODUCER_ID	ROSETTA_VIRTIS_TEAM	constant
PRODUCER_FULL_NAME	"CAPACCIONI"	constant
PRODUCER_INSTITUTION_NAME	"ISTITUTO NAZIONALE DI ASTROFISICA SPAZIALE"	Place where the PDS file is written
PRODUCT_CREATION_TIME	yyyy-mm-ddThh:mm:ss.fff	EGSE, formatted (UTC time when the PDS file is written)
TELEMETRY_SOURCE_ID	"VIRTIS_EGSE<n>"	EGSE (<n> is the version number of EGSE itself)
SOFTWARE_VERSION_ID	{"EGSE_SOFT_<n>", "PDS_CONVERTER_<p>"}	EGSE (<n> and <p> are the version numbers of EGSE software and PDS converter)
/* Data description parameters */		
DATA_SET_NAME	"ROSETTA-ORBITER CAL VIRTIS 2 CVP V1.0"	EGSE, with control from operator
DATA_SET_ID	"RO-CAL-VIRTIS-2-CVP-V1.0"	EGSE, with control from operator
RELEASE_ID	0001	Initial value from EGSE, can be changed
REVISION_ID	0000	Initial value from EGSE, can be changed
PRODUCT_TYPE	EDR	constant
STANDARD_DATA_PRODUCT_ID	"VIRTIS DATA"	constant
PROCESSING_LEVEL_ID	2	EGSE, with control from operator
MISSION_NAME	"INTERNATIONAL ROSETTA MISSION"	constant
MISSION_ID	ROSETTA	constant
INSTRUMENT_HOST_NAME	"ROSETTA-ORBITER"	constant
INSTRUMENT_HOST_ID	RO	constant
MISSION_PHASE_NAME	"EARTH SWING-BY 1"	EGSE, input string from operator
PI_PDS_USER_ID	CAPACCIONI	constant



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Keyword	Possible Values	Origin of Values
INSTRUMENT_NAME	"VISIBLE AND INFRARED THERMAL IMAGING SPECTROMETER"	constant
INSTRUMENT_ID	"VIRTIS"	constant
INSTRUMENT_TYPE	"IMAGING SPECTROMETER"	constant
^INSTRUMENT_DESC	"RO_VIRTIS_EAICD.ASC"	constant
ROSETTA:CHANNEL_ID	"VIRTIS_M_IR"	constant
	"VIRTIS_M_VIS"	constant
	"VIRTIS_H "	constant
DATA_QUALITY_ID	0	if lines are missing
	1	If OK
	"NULL"	"NULL" is no diagnostic
DATA_QUALITY_DESC	"0:INCOMPLETE ; 1: COMPLETE"	constant
/* Science operations information */		
TARGET_TYPE	"PLANET"	EGSE, input string from operator
	"CALIBRATION"	
	"STAR"	
TARGET_NAME	"CALIBRATION"	EGSE, input string from operator
	"EARTH"	
	"MOON"	
START_TIME	yyyy-mm-ddThh:mm:ss.fff	Corrected S/C time in flight (UTC), from RSOC
STOP_TIME	yyyy-mm-ddThh:mm:ss.fff	Corrected S/C time in flight (UTC), from RSOC
SPACECRAFT_CLOCK_START_COUNT	"n/ssssssssss.fffff"	Formatted, from TM packet data field header. n is increased after each resynchronization of the S/C clock, starting from 1



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Keyword	Possible Values	Origin of Values
SPACECRAFT_CLOCK_STOP_COUNT	"n/sssssssssss.fffff"	Formatted, from TM packet data field header. n is increased after each resynchronization of the S/C clock, starting from 1
ORBIT_NUMBER	N/A	
OBSERVATION_TYPE	N/A	
SC_SUN_POSITION_VECTOR		From navigation information
SC_TARGET_POSITION_VECTOR		From navigation information
SC_TARGET_VELOCITY_VECTOR		From navigation information
COORDINATE_SYSTEM_ID	"NULL"	From navigation information
COORDINATE_SYSTEM_NAME	"PLANETOCENTRIC"	constant
DECLINATION		From navigation information, if inertial pointing
RIGHT_ASCENSION		From navigation information, if inertial pointing
MAXIMUM_LATITUDE		To be filled from navigation info. In decimal degrees.
MINIMUM_LATITUDE		To be filled from navigation info. In decimal degrees.
EASTERNMOST_LONGITUDE		To be filled from navigation info. In decimal degrees, Eastward longitudes.
WESTERNMOST_LONGITUDE		To be filled from navigation info. In decimal degrees, Eastward longitudes.
SPACECRAFT_ALTITUDE		To be filled from navigation info. Unit <KM> must be present
PHASE_ANGLE		From navigation information
SUB_SPACECRAFT_LATITUDE		From navigation information
SUB_SPACECRAFT_LONGITUDE		From navigation information
SOLAR_DISTANCE		From navigation information
SUB_SOLAR_LONGITUDE		From navigation information
SUB_SOLAR_LATITUDE		From navigation information



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Keyword	Possible Values	Origin of Values
/* Instrument status */		
INSTRUMENT_MODE_ID	1 M_Off	-M channel; from ME_default_HK V_MODE
	2 M_Cool_Down	
	3 M_Idle	
	4 M_Annealing	
	5 M_PEM_On	
	6 M_Test	
	7 M_Calibration	
	8 M_Science_High_Spectral_1	
	9 M_Science_High_Spectral_2	
	10 M_Science_High_Spectral_3	
	11 M_Science_High_Spatial_1	
	12 M_Science_High_Spatial_2	
	13 M_Science_High_Spatial_3	
	14 M_Science_Nominal_1	
	15 M_Science_Nominal_2	
	16 M_Science_Nominal_3	
	17 M_Science_Nominal_Compressed	
	18 M_Science_Reduced_Slit	



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Keyword	Possible Values	Origin of Values
	19 M_User_Defined	
	20 M_Degraded	
	63 M_ME_Test	
	1 H_Off	-H channel; from ME_default_HK V_MODE
	2 H_Cool_Down	
	3 H_Idle	
	4 H_Annealing	
	5 H_PEM_On	
	6 H_Test	
	7 H_Calibration	
	8 H_Nominal_Simulation	
	9 H_Science_Maximum_Data_Rate	
	10 H_Science_Nominal_Data_Rate	
	11 H_Science_Minimum_Data_Rate	
	12 (deleted)	
	13 H_Science_Backup	
	14 H_User_Defined	
	15 (deleted)	
	16 (deleted)	



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Keyword	Possible Values	Origin of Values
	17 (deleted)	
	18 H_Spectral_Calibration_Simulation	
	19 H_Degraded	
	63 H_ME_Test	
^INSTRUMENT_MODE_DESC	"RO_VIRTIS_EAICD.ASC"	constant
INST_CMPRS_NAME	"NONE"	
	"REVERSIBLE"	
	"WAVELET"	
INST_CMPRS_RATE	16	Keyword units given in bits/pixel. 16 applies when <i>INST_CMPRS_NAME</i> is "NONE", N/A when it is "REVERSIBLE"; when <i>INST_CMPRS_NAME</i> is WAVELET, this kw can take the values 2,1.5 and 1, depending on the compression ratio.
	N/A	
	2	
	1.5	
	1	
INST_CMPRS_RATIO		Effective compression ratio, computed when the data are received on ground
ROSETTA: VIR_VIS_START_X_POSITION	(0 to 437)	(From event reporting TM M_DUMP_FUNCTIONAL_PARAMETERS M_CCD_WIN_X1)



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Keyword	Possible Values	Origin of Values
ROSETTA: VIR_VIS_START_Y_POSITION	(0 to 255)	(From event reporting TM M_DUMP_FUNCTIONAL_PARAMETERS M_CCD_WIN_Y1)
ROSETTA: VIR_IR_START_X_POSITION	(0 to 437)	(From event reporting TM M_DUMP_FUNCTIONAL_PARAMETERS M_IR_WIN_X1)
ROSETTA: VIR_IR_START_Y_POSITION	(0 to 255)	(From event reporting TM M_DUMP_FUNCTIONAL_PARAMETERS M_IR_WIN_Y1)
ROSETTA:SCAN_MODE_ID	0: Pushbroom (point)	From event reporting TM M_DUMP_FUNCTIONAL_PARAMETERS, M_SU
	1: Full scan	
	2: Off	
SCAN_PARAMETER		From event reporting TM M_DUMP_FUNCTIONAL_PARAMETERS, respectively: M_alfa_first - M_alfa_last - M_delta_alfa - M_N_alfa_IRT
SCAN_PARAMETER_DESC	("SCAN_START_ANGLE", "SCAN_STOP_ANGLE", "SCAN_STEP_ANGLE", "SCAN_STEP_NUMBER")	constant
SCAN_PARAMETER_UNIT	("DEGREE", "DEGREE", "DEGREE", "DIMENSIONLESS")	constant
FRAME_PARAMETER		-M channel - First value from M_IR HK: M_IR_EXPO *10 <s> - 2nd and 3rd values from event reporting TM M_DUMP_OPERATIONAL_PARAMETERS: - M_SS



Keyword	Possible Values	Origin of Values
		<p>- M_ERT (decoded, in s) - 4th value from M_DUMP_FUNCTIONAL_PARAMETER:  M_D/BCK_RATE -H channel (From event reporting TM H_DUMP_OPERATIONAL_PARAMETER) - First value: <math>= [ (H\_INT\_SCIENCE\_NUM2*1024) + H\_INT\_SCIENCE\_NUM1 ] * 512/1000</math> &lt;ms&gt;  - Second value (number of summed frames) : = 1 if H_Sum = 0 = H_N_Sum_Frame if H_SUM =1 - Third value (acquisition rate): = H_N_FRAME if H_Sum = 0 = 1 if H_SUM =1 - Fourth value: if H_SUM = 0: = <math>\{[(H\_INT\_SCIENCE\_NUM2*1024) + H\_INT\_SCIENCE\_NUM1] * 512/1000 + Ttrf\} * H\_N\_FRAME</math> if H_SUM = 1 := <math>\{[(H\_INT\_SCIENCE\_NUM2*1024) + H\_INT\_SCIENCE\_NUM1] * 512/1000 + Ttrf\}</math> where: Ttrf = 366.756 (ms) in spectrum or 64-spectral slice transfer mode Ttrf = 1275.576 (ms) in image transfer mode (Ttrf = readout+ idle time) - Fifth value: H_DARK_RATE</p>
FRAME_PARAMETER_DESC	("EXPOSURE_DURATION", "FRAME_SUMMING", "EXTERNAL_REPETITION_TIME", "DARK_ACQUISITION_RATE")	-M channel, constant
	("EXPOSURE_DURATION", "FRAME_SUMMING", "FRAME_ACQUISITION_RATE",	-H channel, constant



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Keyword	Possible Values	Origin of Values
	"INTERNAL_REPETITION_TIME", "DARK_ACQUISITION_RATE")	
FRAME_PARAMETER_UNIT	("S", "DIMENSIONLESS", "S", "DIMENSIONLESS")	-M channel, constant
	("MS", "DIMENSIONLESS", "DIMENSIONLESS", "MS","DIMENSIONLESS")	-H channel, constant
MAXIMUM_INSTRUMENT_TEMPERATURE		-M channel Respectively from: - M_IR HK, M_IR_TEMP - M_IR HK, M_TELE_TEMP - M_IR HK, M_SPECT_TEMP - ME/M general HK, M_COOL_TIP_TEMP Maximum values encountered in the file for the parameters. All are given in K (decoded) -H channel Respectively from: - H HK, HKMs_Temp_FPA - H HK, HKMs_Temp_Grating - H HK, HKMs_Temp_Prism - ME/H general HK, H_COOL_TIP_TEMP Maximum values encountered in the file for the parameters. All are given in K (decoded)
INSTRUMENT_TEMPERATURE_POINT	("FOCAL_PLANE", "TELESCOPE", "SPECTROMETER", "CRYOCOOLER")	-M channel, constant
	("FOCAL_PLANE", "GRATING", "PRISM", "CRYOCOOLER")	-H channel, constant
INSTRUMENT_TEMPERATURE_UNIT	("K", "K", "K", "K")	constant
/* Keywords related only to H_files*/		



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Keyword	Possible Values	Origin of Values
ROSETTA: VIR_H_START_X_POSITION	(0 to 7)	From event reporting TM H_DUMP_FUNCTIONAL_PARAMETERS: H_XWIN
ROSETTA: VIR_H_START_Y_POSITION	(0 to 15)	From event reporting TM H_DUMP_FUNCTIONAL_PARAMETERS: H_YWIN
ROSETTA:VIRTIS_DEAD_PIXEL_MAP_FILE_NAME	"DEADPIXELMAP.DAT"	EGSE (external file name) File used during acquisition
ROSETTA:VIRTIS_H_PIXEL_MAP_COEF		From event reporting TM H_DUMP_PIXEL_MAP_PARAMETERS (24 coefficients for the pixel map)
ROSETTA:VIRTIS_H_PIXEL_MAP_COEF_DESC	(("C11", "C12", "C13"), ("C21", "C22", "C23"), ("C31", "C32", "C33"), ("C41", "C42", "C43"), ("C51", "C52", "C53"), ("C61", "C62", "C63"), ("C71", "C72", "C73"), ("C81", "C82", "C83"))	constant
/* Pointer to navigation data files*/		
SPICE_FILE_NAME		EGSE (navigation file name)
/* Cube keywords */		
OBJECT	QUBE	constant
AXES	3	constant
AXIS_NAME	(BAND,SAMPLE,LINE)	constant
CORE_ITEMS	(x,y,z)	x, y depend on operative mode z depend on session duration
CORE_ITEM_BYTES	2	constant
CORE_ITEM_TYPE	MSB_INTEGER	constant



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Keyword	Possible Values	Origin of Values
CORE_BASE	0.0	constant
CORE_MULTIPLIER	1.0	constant
CORE_VALID_MINIMUM	"NULL"	constant
CORE_NULL	"NULL"	constant
CORE_LOW_REPR_SATURATION	-32768	constant
CORE_LOW_INSTR_SATURATION	-32768	constant
CORE_HIGH_REPR_SATURATION	32768	constant
CORE_HIGH_INSTR_SATURATION	32768	constant
CORE_NAME	RAW_DATA_NUMBER	constant
CORE_UNIT	DIMENSIONLESS	constant
SUFFIX_BYTES	2	constant
SUFFIX_ITEMS	(0, NI <sub>s</sub> , 0)	NI <sub>s</sub> = number of lines required to store the HK (depends on operational parameters)
SAMPLE_SUFFIX_NAME	"HOUSEKEEPING PARAMETERS"	constant
SAMPLE_SUFFIX_UNIT	DIMENSIONLESS	constant
SAMPLE_SUFFIX_ITEM_BYTE	2	constant
SAMPLE_SUFFIX_ITEM_TYPE	MSB_INTEGER	constant
SAMPLE_SUFFIX_BASE	0.0	constant
SAMPLE_SUFFIX_MULTIPLIER	1.0	constant
SAMPLE_SUFFIX_VALID_MINIMUM	"NULL"	constant

Keyword	Possible Values	Origin of Values
SAMPLE_SUFFIX_NULL	65535	constant
SAMPLE_SUFFIX_LOW_REPR_SAT	0	constant
SAMPLE_SUFFIX_LOW_INSTR_SAT	0	constant
SAMPLE_SUFFIX_HIGH_REPR_SAT	65535	constant
SAMPLE_SUFFIX_HIGH_INSTR_SAT	65535	constant
^HOUSEKEEPING_DESCRIPTION	"RO_VIRTIS.EAICD.ASC"	constant
END_OBJECT	QUBE	constant
END		No associated value, must end in CR-LF

## 8. Appendix D: Structure of H- and M- files sideplanes

The following tables show the details of how the sideplanes of VIRTIS qubes are organized. For each word in the sideplane (first column), it is given the telemetry file (second column), the field, word number and data field in that telemetry from which the information is extracted. The word is copied from the telemetry and deposited in the sideplane as it is, without any change.

Word Number	Origin TM	Field in this TM	TM Word number	Data Field
1	First Science reporting TM for this frame	Data Field Header	4	SCET data, 1 <sup>st</sup> word
2			5	SCET data, 2 <sup>nd</sup> word
3			6	SCET data, 3 <sup>rd</sup> word
4		Science Data Header	9	Acquisition ID
5			10	Number of sub-slices + first serial number
6			12	Data Type
7	0		0	Fake, Spare Space



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Word Number	Origin TM	Field in this TM	TM Word number	Data Field
8	VTM_ME_Default_HK_Report (SUD1)	Data Field Header	4	SCET periodic HK, 1 <sup>st</sup> word
9			5	SCET periodic HK, 2 <sup>nd</sup> word
10			6	SCET periodic HK, 3 <sup>rd</sup> word
11		Source Data	10	V_mode
12			11	ME_PWR_STAT
13			12	ME_PS_TEMP
14			13	ME_DPU_TEMP
15			14	ME_DHSU_VOLT
16			15	ME_DHSU_CURR
17			16	EEPROM_VOLT
18			17	IF_ELECTR_VOLT
19	0		0	Fake, Spare Space
20	MTM_ME_General_HK_Report (SID2)	Data Field Header	4	SCET periodic HK, 1 <sup>st</sup> word
21			5	SCET periodic HK, 2 <sup>nd</sup> word
22			6	SCET periodic HK, 3 <sup>rd</sup> word
23		Source Data	10	M_ECA_STAT
24			11	M_COOL_STAT
25			12	M_COOL_TIP_TEMP
26			13	M_COOL_MOT_VOLT
27			14	M_COOL_MOT_CURR
28			15	M_CCD_SEC_VOLT
29	0		0	Fake, Spare Space
30	MTM_VIS_HK_Report (SID4)	Data Field Header	4	SCET HK, 1 <sup>st</sup> word
31			5	SCET HK, 2 <sup>nd</sup> word
32			6	SCET HK, 3 <sup>rd</sup> word
33		Source Data	10	M_CCD_VDR_HK



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Word Number	Origin TM	Field in this TM	TM Word number	Data Field
34			11	M_CCD_VDD_HK
35			12	M_+5_VOLT
36			13	M_+12_VOLT
37			14	M_-12_VOLT
38			15	M_+20_VOLT
39			16	M_+21_VOLT
40			17	M_CCD_LAMP_VOLT
41			18	M_CCD_TEMP_OFFSET
42			19	M_CCD_TEMP
43			20	M_CCD_TEMP_RES
44			21	M_RADIATOR_TEMP
45			22	M_LEDGE_TEMP
46			23	OM_BASE_TEMP
47			24	H_COOLER_TEMP
48			25	M_COOLER_TEMP
49			26	M_CCD_WIN_X1
50			27	M_CCD_WIN_Y1
51			28	M_CCD_WIN_X2
52			29	M_CCD_WIN_Y2
53			33	M_CCD_DELAY
54			31	M_CCD_EXPO
55			32	M_MIRROR_SIN_HK
56			33	M_MIRROR_COS_HK
57			34	M_VIS_FLAG_ST
58	0		0	Fake, Spare Space
59	MTM_IR_HK_Report (SID5)	Data Field Header	4	SCET HK, 1 <sup>st</sup> word



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Word Number	Origin TM	Field in this TM	TM Word number	Data Field
60			5	SCET HK, 2 <sup>nd</sup> word
61			6	SCET HK, 3 <sup>rd</sup> word
62		Source Data	10	M_IR_VDETCOM_HK
63			11	M_IR_VDETADJ_HK
64			12	M_IR_VPOS
65			13	M_IR_VDP
66			14	M_IR_TEMP_OFFSET
67			15	M_IR_TEMP
68			16	M_IR_TEMP_RES
69			17	M_SHUTTER_TEMP
70			18	M_GRATING_TEMP
71			19	M_SPECT_TEMP
72			20	M_TELE_TEMP
73			21	M_SU_MOTOR_TEMP
74			22	M_IR_LAMP_VOLT
75			23	M_SU_MOTOR_CURR
76			24	M_IR_WIN_Y1
77			25	M_IR_WIN_Y2
78			26	M_IR_DELAY
79			27	M_IR_EXPO
80			28	M_IR_LAMP_SHUTTER
81			29	M_IR_FLAG_ST
82	0		0	Fake, Spare Space

Table 8-1: Elemental HK structure for M files sideplane.



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Word Number	Origin TM	Field in this TM	TM Word number	Data Field
1	First Science Reporting Tm for this frame	Data Field Header	4	SCET data, 1 <sup>st</sup> word
2			5	SCET data, 2 <sup>nd</sup> word
3			6	SCET data, 3 <sup>rd</sup> word
4		Science Data Header	9	Acquisition ID
5			10	Number of sub-slices + first serial number
6			12	Data Type
7	0		0	Fake, Spare Space
8	VTM_ME_Default_HK_Report (SID1)	Data Field Header	4	SCET periodic HK, 1 <sup>st</sup> word
9			5	SCET periodic HK, 2 <sup>nd</sup> word
10			6	SCET periodic HK, 3 <sup>rd</sup> word
11		Source Data	10	V_MODE
12			11	ME_PWR_STAT
13			12	ME_PS_TEMP
14			13	ME_DPU_TEMP
15			14	ME_DHSU_VOLT
16			15	ME_DHSU_CURR
17			16	EEPROM_VOLT
18			17	IF_ELECTR_VOLT
19	0		0	Fake, Spare Space
20	HTM_ME_General_HK_Report (SID3)	Data Field Header	4	SCET periodic HK, 1 <sup>st</sup> word
21			5	SCET periodic HK, 2 <sup>nd</sup> word
22			6	SCET periodic HK, 3 <sup>rd</sup> word
23		Source Data	10	H_ECA_STAT
24			11	H_COOL_STAT
25			12	H_COOL_TIP_TEMP
26			13	H_COOL_MOT_VOLT



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Word Number	Origin TM	Field in this TM	TM Word number	Data Field
27			14	H_COOL_MOT_CUR
28			15	H_CCE_SEC_VOLT
29	0		0	Fake, Spare Space
30	HTM_HK_Report Header (SID6)	Data Field	4	SCET HK, 1 <sup>st</sup> word
31			5	SCET HK, 2 <sup>nd</sup> word
32			6	SCET HK, 3 <sup>rd</sup> word
33		Source Data	10	HKRq_Int_Num2
34			11	HKRq_Int_Num1
35			12	HKRq_Bias
36			13	HKRq_I_Lamp
37			14	HKRq_I_Shutter
38			15	HKRq_PEM_Mode
39			16	HKRq_Test_Init
40			17	HK_Rq_Device/On
41			18	HKRq_Cover
42			19	HKMs_Status
43			20	HKMs_V_Line_Ref
44			21	HKMs_Vdet_Dig
45			22	HKMs_Vdet_Ana
46			23	HKMs_V_Detcom
47			24	HKMs_V_Detadj
48			25	HKMs_V+5
49			26	HKMs_V+12
50			27	HKMs_V+21
51			28	HKMs_V-12
52			29	HKMs_Temp_Vref



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Word Number	Origin TM	Field in this TM	TM Word number	Data Field
53			30	HKMs_Det_Temp
54			31	HKMs_Gnd
55			32	HKMs_I_Vdet_Ana
56			33	HKMs_I_Vdet_Dig
57			34	HKMs_I_+5
58			35	HKMs_I_+12
59			36	HKMs_I_Lamp
60			37	HKMs_I_Shutter/Heater
61			38	HKMs_Temp_Prism
62			39	HKMs_Temp_Cal_S
63			40	HKMs_Temp_Cal_T
64			41	HKMs_Temp_Shut
65			42	HKMs_Temp_Grating
66			43	HKMs_Temp_Grating
67			44	HKMs_Temp_FPA
68			45	HKMs_Temp_PEM
69			46	HKDH_Last_Sent_Request
70			47	HKDH_Stop_Readout_Flag
71	0		0	Fake, Spare Space
72	0		0	Fake, Spare Space

Table 8-2: Elemental HK structure for H files sideplane.