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VenusExpress-VIRTIS

To Planetary Science Archive Interface Control Document
(EAICD)

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Prepared by: **S. Erard**

Approved by: **P. Drossart, G. Piccioni**





Venus-Express
VIRTIS EAICD

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Change Log

Version	Date	Sections Changed	Reasons for Change
0.x	29/3/2005	4.3.1	Label input for 3 VIRTIS channels
0.6	23/03/2006	4.3	Label update for 3 channels (raw data), calibrated H files, geometric files (H only) after Rosetta internal review + VVEx team meeting
0.8	22/11/2006	Overall	First complete version
1.0.Draft1	18/05/2007	Overall	First issue, draft1. Modified after EGSE & pipeline update
1.0	18/06/2007	Overall	First issue. Completed after first delivery generation
1.1	11/09/2007	Overall	Minor update after interaction with PSA
1.2	18/07/2008	Overall	Updated after archive review
1.3	10/10/2008	Overall	Minor fixes after check of the revised archive
1.4	1/03/2009	Document names	Names corrected to 27.3 format
	16/04/2009	EAICD name	Referred to everywhere as VIRTIS_EAICD, including in file labels
1.5	3/03/2011	Overall	Fixes after assessment delivery to PSA + New M calibrated data format
	1/09/2011		Introduced version # in history Updated list of possibly missing files in first delivery.
1.6	24/04/2012		General update for final delivery



Acronyms and Abbreviations

ADC: Analog Digital Converter
DDS: Data Distribution System
DN: Digital Numbers (= ADU), count unit in raw data
EDR: Experimental Data Record
EGSE: Electrical Ground Support Equipment
FPA: Focal Plane Arrays
FWHM: Full Width at Half Maximum
HK: HouseKeeping parameters
IDL: Interactive Data Language
IR: InfraRed
ISIS: Integrated Software for Imagers and Spectrometers
ITF: Instrument Transfer Function
ITL: Input TimeLine (telecommand files)
ME: Main Electronic
MSB: Most Significant Byte first
MTP: Medium Term Plan - basic period for observation planning (~1 month)
OBT: On-Board Time
PEM: Proximity Electronic Module
PDS: Planetary Data System
PI: Principal Investigator
PSA: Planetary Science Archive
RDR: Reduced Data Record
SCET: SpaceCraft Elapsed Time (on-board time measured in s from launch)
SAP: Science Activity Plan
SI: Système International d'unités
TM: Telemetry
UTC: Universal Time Corrected
VEx: Venus-Express
VIRTIS: Visible Infra Red Thermal Imaging Spectrometer
VOI: Venus Orbit Insertion (a series of orbits to reach the final one)



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1 Introduction

1.1 Purpose and Scope

The purpose of this EAICD (Experimenter to (Science) Archive Interface Control Document) is two fold. First it provides users of the 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 the VIRTIS 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 Venus-Express from the s/c until insertion into the PSA for ESA. It includes information on how data were processed, formatted, labeled and uniquely identified. The document discusses general naming schemes for data volumes, data sets, data and label files. Standards used to generate the products are described. Software that may be used to access the products is discussed further on.

The design of the data set structure and data products is given. Examples of labels are provided in appendix E.



The core documentation of the VIRTIS VEx archive and data set consists in:

- VIRTIS_EAICD.PDF, the EAICD (the present document)
- VIRTIS_GEOMETRY.PDF, the documentation to the geometry files [AD 13]
- The data calibration documents for the M and H channels [AD 14] and [AD 15]
- LECTURE_PDS.PDF, the data access software documentation [AD 16]

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.

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** Planetary Science Data Dictionary, Revision D, JPL D-7116, July 15, 1996
- **AD 4** VEx Archive Generation, Validation and Transfer Plan, VEX-RSSD-PL-001. Issue 1.1, 7 June 2004
- **AD 5** VEx Archive Conventions, VEX-RSSD-TN-036. Issue 2 rev. 1, 11 March 2008
- **AD 6** Science Cases Definition, VEX-T.ASTR-TCN-00665, Issue 1, 03/06/03
- **AD 9** VIRTIS VEx SW Internal Interface Control Document, VVX-GAF-IC-002 (VVX-VIR-UM-001, attachment 6) December 20, 2003
- **AD 10** FM VIRTIS Experiment User Manual (Delta Documentation) VVX-VIR-UM-001 Issue 2, 23/12/2004
- **AD 11** VIRTIS VEx On-Board Data Handling SW Interface Control Document. VIR-GAF-IC-0003, Issue 5, 6/9/2004
- **AD 12** VIRTIS VEx Software User Manual. VVX-DLR-MA-001, Issue 5.0, 23/9/2007
- **AD 13** VIRTIS VEx geometry files formatting VVX-LES-SW-2268, Issue 1.2, July 2008 (VIRTIS_GEOMETRY.PDF in the archive)
- **AD 14** VIRTIS-M Calibration Document. VVX-VIR-RP-08, issue 1.1, 26 May 2008
- **AD 15** VIRTIS-H Calibration. VIR-LES-RP-2333, issue 1.4, 24 July 2008
- **AD 16** VIRTIS PDS/IDL software library VVX-LES-SW-2264, issue 2.8.1 (LECTURE_PDS.PDF in the archive)

1.6 Relationships to Other Interfaces

Raw data PDS cubes are generated by the VIRTIS EGSE: 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 Contact Names and Addresses

Stéphane Erard, LESIA / Observatoire de Paris-Meudon
Archive Manager
stephane.erard@obspm.fr
+0033 (0) 1 45 07 78 19

Pierre Drossart, LESIA / Observatoire de Paris-Meudon
Operations, H calibration, data validation (coPI)
pierre.drossart@obspm.fr
+0039 (0) 6 49 93 44 45

Giuseppe Piccioni, INAF / IASF
Operations, VIRTIS-M Spice products, M calibration, data validation (coPI)
giuseppe.piccioni@iasf-roma.inaf.it
+0039 (0) 6 49 93 44 45

Florence Henry, LESIA / Observatoire de Paris-Meudon
Data handling, automatic processing, H calibration, delivery
florence.henry@obspm.fr
+0033 (0) 1 45 07 78 95

Romolo Politi, INAF / IASF
Data handling, M calibration
romolo.politi@iasf-roma.inaf.it
+00 39 06 49 93 47 10

Sophie Jacquino, LESIA / Observatoire de Paris-Meudon
Geometry computation, Data handling, pipe-line maintenance
+0033 (0) 1 45 07 74 79

On temporary positions, left:

Alejandro Cardesin, INAF / IASF
Data handling, M calibration

Katia Garceran, LESIA / Observatoire de Paris-Meudon
Geometry computation

Pascal Lambert, LESIA / Observatoire de Paris-Meudon
Geometry computation

Xavier Bonnin, LESIA / Observatoire de Paris-Meudon
Geometry computatio

Vincent Serrano, LESIA / Observatoire de Paris-Meudon
Data handling, pipe-line maintenance



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

2.1 Scientific Objectives

VIRTIS (Visible Infra Red Thermal Imaging Spectrometer) is an imaging spectrometer which allows Venus Express to map details of the Venus planet from the surface to the mesosphere. Therefore its scientific objectives cover a large field, not only in meteorology of the middle atmosphere, as expected from optical remote sensing instruments, but also in mineralogy, through the near infrared deep windows sounding down to the surface, and in aeronomy of the upper atmosphere, through non-LTE emissions of CO₂.

Main unresolved questions on the planet Venus concern the stability of the cloud layers : are they permanently reformed from volcanism or low level surface/atmosphere interaction, or are they transient, related to episodic volcanism ? The meteorology of Venus atmosphere, and in particular the superrotation which let the upper layers rotating in 4 days when the solid planet rotates in 243 days is also a mystery which is important not only for the case of Venus, but also for other planetary bodies (like Titan), and for hydrodynamics modeling. The surface of Venus is mostly known from the radar observations by Magellan; a systematic mapping in the infrared window at medium resolution (30 km) could bring new clues to the knowledge of the mineralogy of Venus, in particular the dichotomy between low/high altitudes region in radar reflectivity, if related to optical anomalies.

VIRTIS is constituted of three data channels in one compact instrument. Two of these channels, one visible (0.25-1 μ m) and one infrared (1-5 μ m) are committed to spectral mapping, and are housed in the Mapper (-M) optical subsystem. One channel is devoted solely to spectroscopy at high resolution, and is housed in the High resolution (-H) optical subsystem (2-5 μ m). Both channels usually operate simultaneously, but can also work separately, depending on observing modes. They are boresighted and combined operations therefore provide a spectral image of 64 mrad from the two VIRTIS-M channels, associated with one (or several) spectrum from VIRTIS-H channel.

2.1.1 Description Of Scientific Objectives

As a generalist instrument, VIRTIS has many scientific objectives, which are listed below. They may be summarized in what we call a "tomography" of the Venus atmosphere, i.e. a mapping of the various layers of Venus from the surface itself up to the mesosphere. Such maps, obtained with a repetition rate related to the dynamics of the atmosphere will give access to a dynamical study of Venus atmosphere, to approach with unprecedented constraints the problem of the dynamic of the atmosphere of Venus (and in particular its superrotation), the composition of the deep atmosphere, and the interaction between volcanism and atmospheric composition, the cloud structure, with the specific question of the UV absorbers, and the dynamic of the mesosphere, with specific questions related to the general problem of atmospheric escape.

The main scientific goals of VIRTIS at Venus are the following:

- Study of the lower atmosphere composition (CO, OCS, SO₂, H₂O) from 1-2.5 μ m night side atmospheric windows
- Study of the cloud structure, composition and scattering properties
- Cloud tracking in the UV and IR, for retrieval of the vertical field of wind velocities
- Measurements of the temperature field
- Lightning search
- Mesospheric sounding
- Search for variations related to surface/atmosphere interaction
- Temperature mapping of the surface



- Search for seismic wave activity (tentative)

In addition, VIRTIS also provides true color high definition images of Venus of great value for public outreach program.

2.1.2 Observation Modes For Scientific Objectives

The scientific objectives are very different between day and night side conditions. In particular, the deep atmospheric windows located at 0.9, 1.0, 1.1, 1.18, 1.28, 1.31, 1.74 and 2.3 μm are sensitive during night side observations to thermal emission coming from the surface (in the shortest wavelength) up to about 30 km (to be compared to the cloud level at about 60 km altitude). The solar reflection by the clouds on the day side contributes to more than 10000 times the thermal emission flux, and completely overwhelms the thermal emission of the deeper layers.

VIRTIS-M: main purpose = spectral mapping visible and infrared at moderate spectral resolution

Night side

- Surface mapping (using measurements at 1.02, 1.1, and 1.18 μm)
- O₂ emission (at 1.27 μm)
- Lower atmospheric sounding (H₂O)
- Lightning search

Day side

- UV cloud absorber signature / correlation with IR absorptions
- O₂ emission (at 1.27 μm), also observed at day
- CO₂ non LTE emissions (nadir and limb observations)

VIRTIS-H: main purpose = high spectral resolution for minor constituent detections, and rotation/vibration structure resolved in spectral bands

Night side:

- 2.3 micron lower atmosphere sounding: OCS, CO, H₂O measurement (30 km altitude)
- thermal profile from CO₂ 4.3 μm profile inversion

Day side:

- Fluorescent emission at 4.3 micron (nadir and limb)
- Cloud IR absorptions

Due to the high sensitivity of its infrared detectors, the observations with VIRTIS give a high signal to noise on the day side in a very short time; night side observations on the contrary need longer integration (of the order of 1 s or more), still fully compatible with orbital operations. The main difficulty for reconstructing images of the planet is the dwell time, too short at pericenter to allow VIRTIS to build images. This remark has lead the VIRTIS team to require observations at different positions along the orbit, contrary to the Mars Express observation strategy.

Spacecraft operations are grouped in "science cases" at mission level. These are described in [AD 6] and in the file VEX_SCIENCE_CASE_ID_DESC.TXT provided in the DOCUMENT directory. They are recalled in Table 2.1.



Case ID	Science goal
0	Unknown, N/A (calibration sessions + target \neq Venus)
1	Observation of the northern hemisphere from pericenter
2	Off pericenter observations by the nadir looking instruments
3	Global spectro-imaging by VIRTIS from apocenter
4	VeRA bi-static sounding
5	Stellar occultation by SPICAV
6	Solar occultation by SPICAV / SOIR
7	Limb observations
8	Earth radio occultation by VeRA
9	VeRa sounding of solar corona in conjunctions
10	VeRa study of gravity anomalies

Table 2.1 – Definition of VEx science cases

More details about VIRTIS operations are provided in the Experiment Flight Manual [AD 10].

2.2 Instrument Design

The VIRTIS instrument combines a double capability: (1) high-resolution visible and infrared imaging in the 0.25-5 μm range at moderate spectral resolution (VIRTIS-M channel) and (2) high-resolution spectroscopy in the 2-5 μm range (VIRTIS-H channel). The two channels will observe the same target 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 μm) and IR (1-5 μm). VIRTIS-H (-H) is a high-resolution infrared cross-dispersed spectrometer using a prism and a grating. The 2-5 μm spectrum is dispersed in 8 orders on a focal-plane detector array.

The main characteristics of VIRTIS can be found in Table 2.2.



	VIRTIS – M Visible	VIRTIS – M InfraRed	VIRTIS - H (1)
Spectral Range (μm) (4)	0.2882 – 1.1093	1.0305 – 5.1226	Or0 4.01206-4.98496 Or1 3.44270-4.28568 Or2 3.01190-3.75586 Or3 2.67698-3.33965 Or4 2.40859-3.00570 Or5 2.18903-2.73220 Or6 2.00565-2.50468 Or7 1.85100-2.31194
Spectral Resolution $\lambda/\Delta\lambda$	100 – 380	70 – 360	1300-3000
Spectral Sampling (nm) (2)	1.89	9.44	0.6
Field of View (mrad x mrad)	63.6 (slit) x 64.2 (scan) (5)		0.567x1.73
Max Spatial Resolution (μrad)	248.6 (slit) x 250.8 (scan) (5)		
Pointing	+Zsc		
Telescope	Shafer Telescope	Shafer Telescope	Off axis parabolic mirror
Pupil Diameter (mm)	47.5		32
Imaging F#	5.6	3.2	2.04
Etendue ($\text{m}^2 \text{sr}$)	4.6×10^{-11}	7.5×10^{-11}	$.8 \times 10^{-9}$
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 (3)	CdHgTe (3)
Sensitivity Area Format	512 x 1024	270 x 438	270 x 438
Pixel Pitch (μm)	19	38	38
Operating temp. (K)	150 to 190	65 to 90	65 to 90
Spectral range (μm)	0.25 to 1.05	0.95 to 5.0	0.95 to 5.0
Mean Dark Current	$< 1 \text{ e}^{-1}/\text{s}$	$< 10 \text{ fA @ 70K}$	$< 10 \text{ fA @ 70K}$
Radiometric Resolution SNR	> 100	> 100	$> 100 @ 3.3 \mu\text{m}$
Radiometric Accuracy			
Absolute	$< 20\%$	$< 20\%$	$< 20\%$
Relative	$< 1\%$	$< 1\%$	$< 1\%$

- (1)** The actual grating orders used range from 6 to 13
- (2)** This depends on the selected mode of operation; here is reported the maximum value (no pixel summing)
- (3)** VIRTIS-M and -H make use of identical IR detectors.
- (4)** Spectral range measured on sample files. May depend on temperature, specially for M.
- (5)** Slit direction: along the slit; scan direction: across the slit.

Table 2.2 – VIRTIS VEx characteristics and performances overview

2.2.1 Technical Description

The instrument is divided into 4 separate modules (fig. 2.1): 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 IR FPAs, 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 stage passive radiator: the first stage keep the Cold Box temperature in the range 120-140 K, while the second stage is split 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 +/- 1.8 degrees the spot diameters are less than 6 microns 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 relative surfaces derive from the original design of VIRTIS for the Rosetta mission, but are also adapted to nightside observations of Venus).

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 microns pixel. For the infrared zones, a blazed groove profile is used that results in a peak efficiency at 5 μm to compensate for the low signal levels expected at this wavelength.

A scanning mirror is located on the optical path of VIRTIS-M, allowing to adjust the boresight direction during observation, and therefore providing pointing flexibility. Scanning is performed orthogonally to the slit direction i.e., along the track in the general case (except when the platform is depointed). The scanning mirror cycles between two positions with a regular step controlled by the ME.

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 mrad² IFOV, corresponding to 3 pixels (3 x .58 mrad x .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.

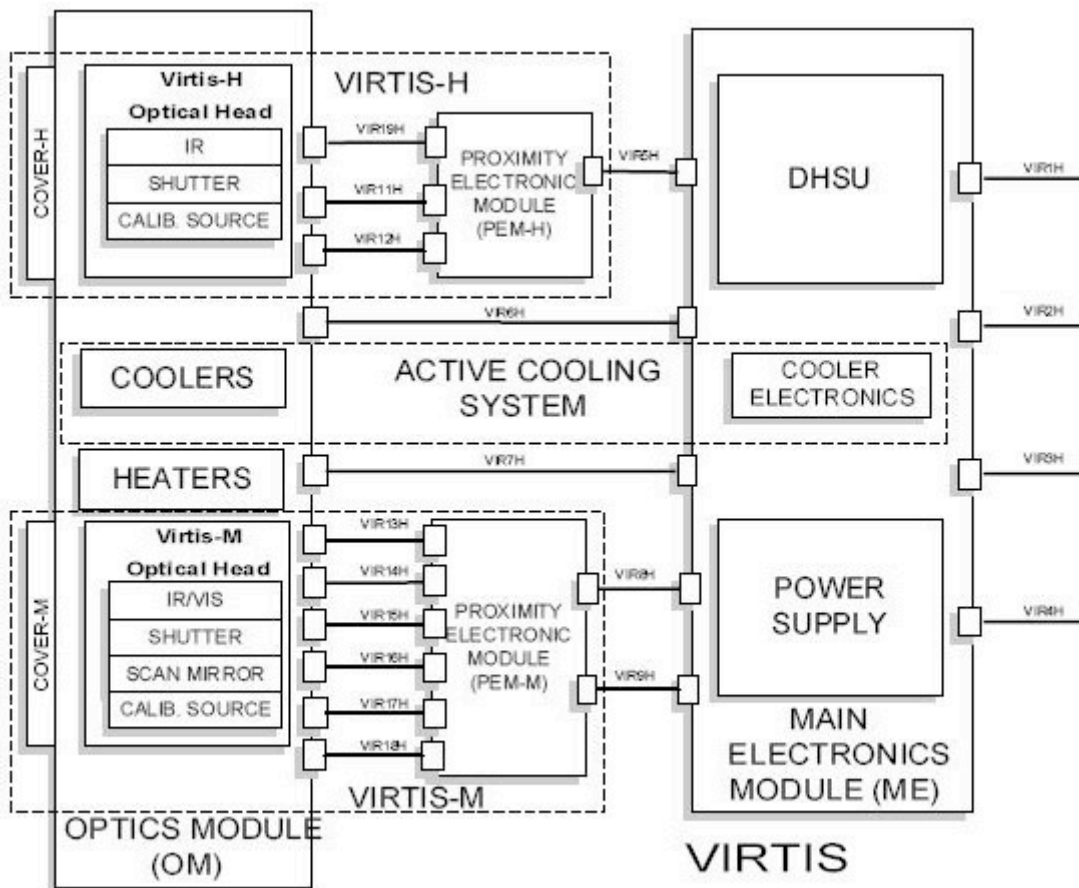


Figure 2.1 – VIRTIS functional block diagram



2.2.2 Instrument Operations

VIRTIS produces the following types of TM data:

- TC verification reports;
- H/K data reports;
- Event reports;
- Memory reports;
- 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.

The acquisition schemes for H and M are described in document [AD 9]. Detailed information about on board data handling is provided in documents [AD 11] and [AD 12].

2.2.2.1 VIRTIS-M Operation Modes

The possible VIRTIS-M operation modes, encoded with the INSTRUMENT_MODE_ID parameter in the PDS header, are the following:

1 M_Off
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
19 M_User_Defined
20 M_Degraded
63 M_ME_Test

2.2.2.2 VIRTIS-H Operation Modes

The possible VIRTIS-H operation modes, encoded with the INSTRUMENT_MODE_ID parameter in the PDS header, are the following:

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
18 H_Spectral_Calibration_Simulation
19 H_Degraded
63 H_ME_Test

2.3 Data Handling Process

2.3.1 Science Data Formats

The acquisition schemes for H and M are described in document [AD 9]. Detailed information about on board data handling is provided in document [AD 11] and [AD 12].

2.3.1.1 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.

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 is 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 size by the ME. This is done by selecting a region on the matrix, starting at position (X1, Y1) as shown in Figure 2.2. The values of X1 and Y1 are transferred as housekeeping parameters but are expected to remain constant during the mission duration.

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.

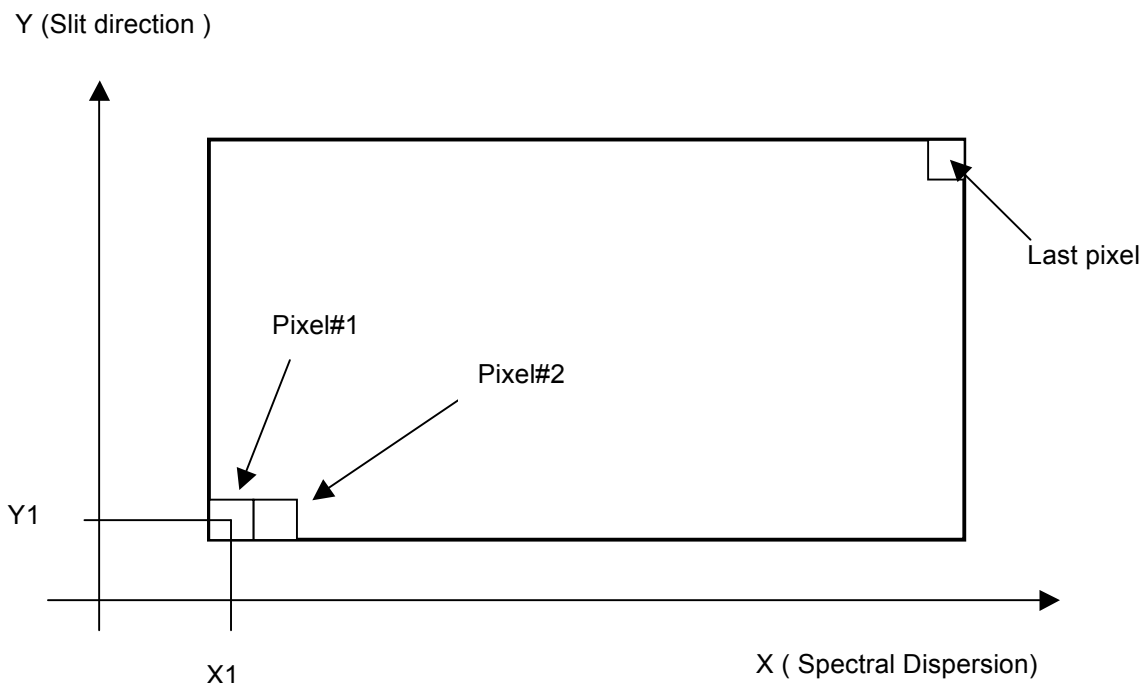


Figure 2.2 Data Organization on the CCD and IR detectors of VIRTIS-M.
The final dimensions in nominal mode are in both cases 432x256.

2.3.1.2 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 2.3 contains a description of the instrument configuration during each internal calibration step.

Internal calibrations are identified with INSTRUMENT_MODE_ID=7 in the PDS label. These sequences use several successive integration times/repetition times, which are available in the qube sideplane.



Configuration	Frame number	Cover	Shutter	Scan mirror	IR lamp	VIS lamp	IR Texp (s)	VIS Texp (s)
Electronic offset	1-5	Closed	Open	Boresight	Off	Off	0.0	0.0
Background	6-10	Closed	Open	Boresight	Off	Off	0.5	1.0
Dark current	11-15	Closed	Closed	Boresight	Off	Off	0.5	1.0
IR lamp acquisition	16-20	Closed	Open	Boresight	On	Off	0.5	20.0
VIS lamp acquisition	21-25	Closed	Open	Boresight	Off	On	0.02	1.0
Dark current	26-30	Closed	Closed	Boresight	Off	Off	0.5	1.0
Background	31-35	Closed	Open	Boresight	Off	Off	0.5	0.5

Table 2.3 – VIRTIS-M internal calibration sequence

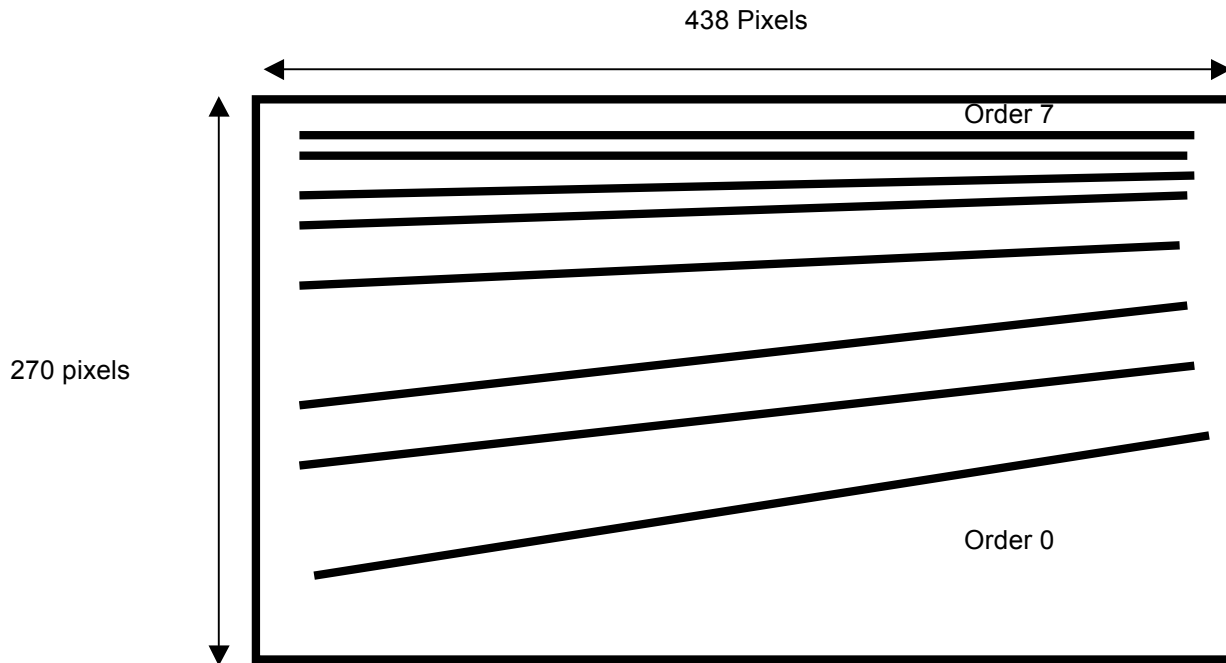
2.3.1.3 VIRTIS-H Science Data Format

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

VIRTIS-H is a high resolution, cross-dispersion spectrometer and does not perform imaging. The 8 spectral orders are spread over the entire detector surface, thus only a portion of the pixels contains useful scientific data (see figure 2.3). In each spectral order the spectrum covers 432x5 pixels, where the 5 pixels represent the image of the slit on the detector.

Overall only 15% of the 438x270 pixels matrix surface are illuminated through the slit. To reduce the overall data rate and volume, H spectra are usually reconstructed on board before transmission (*Science Nominal mode*). H uses a "Pixel Map" which gives the exact location of the spectra over the H-IR detector. The ME calculates the location of the pixels and passes it to the PEM-H which then downloads them accordingly. The downloaded data are sets of 432x8x5 pixels extracted from the two-dimensional detector: 8 spectral orders of 432 elements (wavelengths) and a width of 5 pixels for each order. The 5 pixels along the slit width are summed by the ME; pixels with low response identified in the "Dead Pixel Map" are not included in this sum. The resulting H_Spectrum is composed of 3456 pixels, or measurements in each of the 8 orders, representing the full spectral range of the instrument from 1.88 to 5.03 micron.

The PEM-H can also be commanded to download the full frame to the ME in the *Calibration* and *Science Backup* modes. In this case a region 432x256 pixels in size is selected by the PEM and sent to ME (H_Image_Slice), in a way similar to the M-IR mode. The selected region starts at position (X_win, Y_win). The values of X_win and Y_win are transferred as housekeeping parameters but are expected to remain constant during the mission duration.



*Figure 2.3 Spectrum projection over the H-channel FPA.
Wavelengths increase from right to left and top to bottom.*

2.3.1.4 VIRTIS-H Internal Calibration Data Format

A sequence of internal calibration of VIRTIS-H is operated as follows (see [AD 15]):

1. 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
2. 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
3. Image_slice_radiometric_calibration : 2 images, one H-shutter closed, then R-lamp switched on, using functional param. integration time H_INT_RADIO
4. Spectrum_Radiometric_Calibration : same, using the H_spectrum mode (dark with shutter closed, and then R-lamp on)

Table 2.4 contains a description of the instrument configuration during each internal calibration step.

The total of an internal calibration is $7 \times H_Image_Slice + 2 H_spectrum$. 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 evolution of dead pixels.

Internal calibrations are identified with INSTRUMENT_MODE_ID=7 in the PDS label. These sequences use several successive integration times/repetition times, which are available in the qube sideplane.

Phase #	Cover	Shutter	Slit Lamp	Telescope Lamp	Radiometric Lamp	Mode
1	Closed	Open	OFF	OFF	OFF	Slit Calibration — Background
	Closed	Closed	OFF	OFF	OFF	Slit Calibration — Dark
	Closed	Open	ON	OFF	OFF	Slit Calibration — Lamp
2	Closed	Closed	OFF	OFF	OFF	Telescope Calibration — Dark
	Closed	Open	OFF	ON	OFF	Telescope Calibration — Lamp ON
3	Closed	Closed	OFF	OFF	OFF	Radiometric Calibration (Image) — dark
	Closed	Open	OFF	OFF	ON	Radiometric Calibration (Image) — Lamp ON
4	Closed	Closed	OFF	OFF	OFF	Radiometric Calibration (Spectrum)
	Closed	Open	OFF	OFF	ON	Radiometric Calibration (Spectrum) — Lamp ON

Table 2.4 – VIRTIS-H internal calibration sequence

2.3.1.5 Data Transfer Modes

The imaging channels (M-visible and M-IR) always produce detector images, with one spatial and one spectral dimension. Each of these “frames” is compressed independently on board, and is transmitted with its acquisition SCET (this is called “image transfer mode”). The frame dimensions vary depending on operation mode. The second spatial dimension is acquired through time and depends on session duration and repetition time. This second dimension is acquired either by letting the field of view drift on the planet, or by changing the viewing direction with the scanning mirror.

The H channel produces data which are transmitted by the ME according to one of three possible transfer modes: “image” (432 × 256 pixels frame), “spectrum” (sequence of 3456 spectral measurements reconstructed from the detector image), and “64-spectra frame” (groups of 64 successive spectra compressed together). In the later case, the timing associated with the 64-spectra frame is the SCET of the last acquisition. The “image” transfer mode is used during flight calibration sequences, to check the location of the slit image on the detector, and in the backup acquisition mode. The “64-spectra frame” mode is used in the nominal acquisition mode, with spectra reconstructed on board to save bandwidth. The “spectrum” mode is used during calibration sequences, and also to transfer dark current measurements in “64-spectra frame” mode. The operating modes are combinations of these three transfer modes, and therefore a specific data storage scheme is defined for each operating mode (see section 4.3).

In all cases, dark current frames are acquired together with the data at a required rate. They are subtracted from the signal, then the data are compressed on board. For M, and for H in “image” mode or “spectrum” mode, compressed dark currents measurements are transferred the same way as the data. For H in 64-spectra frame mode however, dark current spectra are compressed and transferred independently, one by one. Because the dimensions are different, they are stored separately from the data. This structure is preserved in raw data qubes, but is simplified for calibrated data.



2.3.1.6 Calibration Pipeline for VIRTIS-M

VIRTIS-M calibration pipeline is described in [AD 14], which contains the algorithms used to transform raw digital numbers in spectral radiance ($W m^{-2} sr^{-1} \mu m^{-1}$). In this document are described the methods used to retrieve:

- Spectral calibration: correspondence between band number and wavelength (μm);
- Spatial calibration: flat field matrix;
- Radiometric calibration: instrumental transfer function necessary to convert DNs in spectral radiance ($W m^{-2} sr^{-1} \mu m^{-1}$);
- Post processing corrections (such as stripe removal...)

by using on ground calibration data and measurements. A section describes step by step the algorithms necessary to calibrate raw data. As calibrations never end but evolve during the instrument life, further improved procedures and updated files will be released during the development of the mission. Basic operations only are described in this section:

- The spectral calibration is a steep function of spectrometer temperature, and is described in details in [AD 14].
- Geometrical discrepancies (including optical misalignment between M channels, and in-field distortions) are not corrected, but are handled through the Spice system to compute accurate pointing directions for each pixel. Additional information is available in [AD 13].
- Raw data cubes contain the telemetry signal in DN; dark currents and thermal background are subtracted from the data by on-board processing performed in the Main Electronics (ME). This on-board removal is only an approximation which can be improved as discussed in [AD14].

Measured dark frames consist in detector images interleaved in the data file. They are identified through element 5 in the sideplane (starting from 0):

`idark = where((cube.suffix(5,0,*) and '2000'X) NE 0) ; index of dark frames`

- Once the dark current is subtracted properly, the counts can be converted in physical units of spectral radiance ($W m^{-2} sr^{-1} \mu m^{-1}$) by a simple linear transform:

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

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

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 label of the file for VIS and IR channels; $R(\lambda(b), s, l)$ is the ITF/flat-field for the VIS or IR channel. These files are used to perform spectral calibration along the slit, and spatial calibration across the slit.

The following ITF/flat field files of VIRTIS-M are distributed with this data release in the CALIB directory:

- `VEX_VIRTIS_M_VIS_ITF_DUMMY.DAT`: full resolution responsivity for VIRTIS_M-vis;
- `VEX_VIRTIS_M_IR_ITF_V2.DAT`: full resolution responsivity for VIRTIS_M-IR;

The ITF/flat-field for the visible channel (the first of these files) is currently a white uniform image provided for convenience. Although it is perfectly usable in a calibration pipeline, it is considered a dummy flat-field because it provides no correction.



2.3.1.7 Calibration Pipeline for VIRTIS-H

The calibration of VIRTIS-H spectra is performed in the Meudon center, and is described in [AD 15]. 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 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(432) ; index vector (0, 1,... 431)
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 actually 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).

The radiometric calibration used during this mission phase is described in [AD 15]. The last dark current acquired before the data is already subtracted on board. The procedure consists in improving this dark subtraction, then performing both responsivity and non-linearity corrections at once, and finally dividing the result by the integration time. This procedure does not use an actual flat-field, but makes intensive use of the ground calibration database. This results in data calibrated in radiance, with unit $W/m^2/sr/\mu m$.

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) ; index of dark frames
```

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 15].

The wavelengths in μm are derived using a second order polynomial for each spectral order. The coefficients of the polynomials are stored in the file *H_SPECTRAL_COEF.TAB* and are used as follows:

```
canal = findgen(432) + 2
for i = 0, 7 do wavel(i,*) = coefW(0,i) + coefW(1,i) * canal + coefW(2,i) * canal^2
```

FWHM can similarly be computed for each channel using the coefficients stored in the file *H_SPECTRAL_WIDTH.TAB*.



Because the procedure is long and requires access to the full ground calibration archive, calibrated files are computed in Meudon and are distributed on-line to the science team at:

[otarie.obspm.fr / VEx VIRTIS instrument](http://otarie.obspm.fr/VEx_VIRTIS_instrument)

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

Open issue:

A non-conformity still exists in the EGSE at the time of writing. Data decommutation 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 t1 are stored with the data in period t0. 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. This issue will be fixed after the next update of the EGSE.

2.3.2 Ground Data Handling

Table 2.5 describes the VIRTIS data processing levels as used in this document. The archive contains both the EDR and the RDR (levels 2 and 3).

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 2.5 – Data Level Definition

The VIRTIS-VEx data set is generated by the VIRTIS-VEx team according to the following scheme, illustrated in Fig. 2.4:

- Telemetry data packets for VIRTIS are retrieved by INAF-Rome from the VEx Data Distribution System (DDS), and are ingested in the EGSE.
- The EGSE performs session slicing and generates a first version of the raw data files from telemetry (preliminary level 2 data). These files are PDS-formatted and include a label, the data and a selection of housekeeping parameters. After this step geometric keywords and “catalogues” keywords (related to mission operations) are not informed in the label. Besides, events timing in the labels is based on an estimate of UTC provided by the DDS, with poor accuracy.
- These preliminary raw data files are mirrored in LESIA-Meudon, where all relevant information (including label values) is ingested in a database (Otarie). The database also collects extra operational information from the ITL files and from the Science Activity Plan.
- When all Spice kernels become available for a session, the database triggers the geometric computation. The output of this procedure is two-fold: first it writes the geometry file corresponding to each data file. Second, it updates the raw data files by inserting the geometry and catalogue



keyword values, plus the correct UTC timing, in the labels. The session-wide geometry parameters are also stored in the database, and checked for consistency with the SAP. Index files are generated through both the PVV tool and the Otarie database in Meudon.

- The new files are mirrored back to INAF-Rome.
- Calibration procedures are then run separately for M in Rome, for H in Meudon. The calibrated data files are again mirrored at both sites, and distributed on-line to the VIRTIS science team.
- At the end of the proprietary period a PDS-compliant data set is delivered to the ESA Planetary Science Archive.
- Derived data products may be generated by the instrument team as a by-product of data analysis. These products will be archived in the PI institutes, and some of them may be included in the PSA distribution.

Personal involved in data set generation and archiving activities include the following (contact information is given in section 1.7):

The responsible of the overall data archiving process is Stéphane Erard, LESIA, who designed the archive. TM retrieval and first PDS generation, plus maintenance of the M calibration pipe-line is performed by Giuseppe Piccioni, Romolo Politi, and Alejandro Cardesin Moinelo, INAF-Rome. Specific kernels providing the M-mirror positions in Spice-compliant format are generated by Giuseppe Piccioni. Reconstruction of the geometry parameters was developed by Katia Garceran at LESIA then developed and maintained by Xavier Bonnin and Sophie Jacquinod. Data base activities, low level data processing, and maintenance of the H calibration pipe-line is performed by Florence Henry, LESIA, who is also sending the data to PSA. Additional activities were performed by Pascal Lambert (geometry processing) and Vincent Serrano (data handling, pipe-line update) at LESIA.

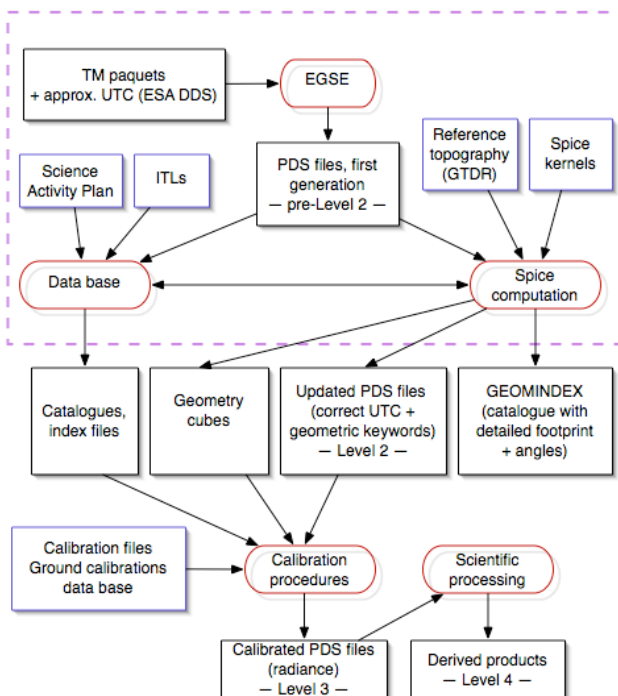


Fig. 2.4: VIRTIS-VEx data set generation

2.4 Overview of Data Products



2.4.1 Pre-Flight Data Products

No pre-flight data product is available for VIRTIS (e.g. ground-based observations, campaigns with the instrument model on Earth, etc).

2.4.2 Sub-System Tests

Detailed sub-system tests have been performed for all three channels. They are archived in the institutes involved in pre-flight activities, and are used for engineering purpose.

2.4.3 Instrument Calibration

Ground-based calibration data are stored in both PI institutes, and are used to monitor the instrument and to calibrate the flight data. These data are not included in the PSA distribution, but are used for data calibration. E.g., calibration files in the PSA distribution (such as transfer functions) are usually derived from these measurements.

2.4.4 Other Files written during Calibration

No other calibration data product is available for VIRTIS.

2.4.5 In-Flight Data Products

VIRTIS flight data products include:

- Level 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. There is a one-to-one correspondence with the observation data files for Venus. File extension is .GEO.
- Level 3 data: PDS-formatted calibrated data in DN. There is a one-to-one correspondence with the observation raw data files when data quality permits. Calibrated dark current files are also available separately for VIRTIS-H. File extension is .CAL for calibrated data, .DRK for H calibrated dark currents. Data from the H channel and M-IR channel have large spectral overlap, although at very different resolutions (both spatial and spectral). In certain situations, they can be compared for cross-correlation purpose.

2.4.6 Software

The data handling procedure is described in section 2.3. Software used in this procedure have been developed and maintained jointly for the VIRTIS experiments on board Rosetta and VEx.

The EGSE software produces the initial PDS files from TM data. It allows monitoring of 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 is a multi-experiment tool developed in LESIA 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 (GeoVirtis) 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 around Venus continues to improve.

Basic access to the data files is provided under IDL 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 DOCUMENT directory, and is documented elsewhere [AD 16].

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

2.4.7 Documentation

The documentation distributed with the VIRTIS VEx archive (in the DOCUMENT directory) mainly consists of:

- the present document (VEX_VIR_EAICD.PDF)
- a document describing the calibration process of VIRTIS-M (*VIRTIS_M_CALIBRATION*)
- a document describing the calibration process of VIRTIS-H (*VIRTIS_H_CALIBRATION.PDF*)
- the documentation to the geometry files (*VIRTIS_GEOMETRY.PDF*)
- the documentation to the IDL library (*LECTURE_PDS.PDF*)
- the VIRTIS User Manual (*VIRTIS_EXP_USER_MANUAL.PDF*)
- documentation to the on-board software in the Main Electronics (VVX-GAF-IC-003.PDF)
- documentation for data acquisition (VVX-GAF-IC-002.PDF)

According to PDS usage, the software is also located in the DOCUMENT directory. All routines are gathered in a single ZIP archive with a unique label.

2.4.8 Derived and other Data Products

Derived data products (level 5 data) may be released at the end of operations for disposition to the science community and public outreach purpose. These could include e.g., compositional maps, wind maps, surface elevation estimates...

2.4.9 Ancillary Data Usage

Geometry computation uses ESOC navigation data in the form of Spice kernels made available by ESA. Specific C- kernels are produced by the VIRTIS-VEx team to handle the scanning mirror positions of the M channels. One such file is generated for each MTP period, 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 VenusExpress SPICE data set whose *DATA_SET_ID* is VEX-E/V-SPICE-6-V1.0

3 Archive Format and Content

3.1 Format and Conventions

3.1.1 Deliveries and Archive Volume Format



The VIRTIS data is delivered according to the “release” procedure, i.e. there is a single data set and data volume. A new release is provided for each mission phase as defined in [AD 5]. The name of the data volume is:

FR/IT_CNRS/INAF_OBSPM/IASF_VEXVIR_1000

3.1.2 Data Set ID Formation

According to the VEx archive conventions [AD 5], the DATA_SET_NAME for the nominal mission is:

VENUS EXPRESS VENUS VIRTIS 2/3 V1.0

and the DATA_SET_ID is:

VEX-V-VIRTIS-2/3-V1.0

Data from mission extensions are grouped together with data set names such as:

VENUS EXPRESS VENUS VIRTIS 2/3 EXT1 V1.0

and DATA_SET_ID:

VEX-V-VIRTIS-2/3-EXT1-V1.0

Mission extension limits are provided in Table 4.2

3.1.3 Data Directory Naming Convention

Data are grouped by orbit in the archive, gathering files for the three channels. This is intended to minimize directory switches when working with the data, and to facilitate comparisons between channels. All orbit directories are split in three directories for raw, calibrated and geometry data; the orbit directories are grouped by MTP periods. MTP periods are the basic time units used during operations planning, lasting about one month.

See 3.4.3.8.

3.1.4 File naming Convention

File names are coded on 9.3 format as follows (see section 4.1)

V<channel + transfer mode><orbit number>_<sub-session number>.<ext>

3.2 Standards Used in Data Product Generation

3.2.1 PDS Standards

VIRTIS PDS data products are intended to comply with the PSA variations on the PDS3 format, including the use of a VEx mission-specific dictionary. Mission specific keywords are introduced by the namespace “VEX:”

All binary data in the PDS files are stored in MSB encoding, either as floating point or 2 bytes integers.

3.2.2 Time Standards



Time information is provided either as UTC [as ISO-formatted time strings], or as on-board time [OBT] encoded as spacecraft elapsed time [SCET]. The OBT provides the number of seconds since last clock reset in the spacecraft frame. Such strings are encoded as:

YYYY-MM-DDThh:mm:ss.fff (ISO string)
"1/21983325.39258" (SCET; the first digit is the reset period ID, starting from 1)

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

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

SCET strings can be accurately converted to UTC and back only through the use of the appropriate Spice kernels.

3.2.3 Reference Systems

All celestial quantities are provided in the J2000 frame. At Venus, the IAU 2000 system is used with planetocentric coordinates and eastward longitudes. Local time is defined so that it increases with UTC at a given location, despite the retrograde rotation. Two reference surfaces are used to project the data: the IAU 200 spheroid, and a conventional cloud layer located 60 km above the datum. Surface elevation is derived from the Magellan GTDR (see details in [AD 13]).

3.2.4 Other Applicable Standards

N/A

3.3 Data Validation

A first level of validation is performed when reading the telemetry packets in the EGSE. 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 (e.g. Magellan GTDR for altimetry data, ground observations and modeling for spectral data). Special attention is paid to zero-level (dark current) and linearity issues, and specific issues are fixed whenever possible at the calibration level — e.g. corrupted H dark currents are filtered out during the calibration procedure, and dark currents are interpolated through time. Results are not currently translated into quality estimates.

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 behaviour of VIRTIS around Venus. 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 cross-talk 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 be achieved only 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

The VIRTIS data is delivered according to the “release” procedure, i.e. the volume set concept is not relevant.

3.4.2 Data Set

The VIRTIS data set is sliced according to successive mission extensions as requested. See 3.1.2

3.4.3 Directories

VIRTIS-VEx deliveries are organized into one virtual volume and use the standard PDS volume structure. This generic PDS structure is described in Section 19.3 of [AD 2], and is shown in Fig. 3.1.

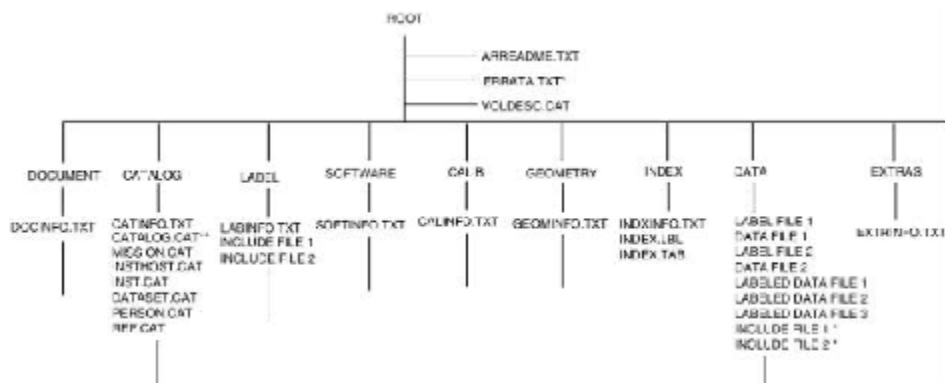


Figure 3.1: Standard PDS volume set organization: one data set, one volume.

The content of each directory shown in Figure 3.1 is detailed in the following sections.

3.4.3.1 Root Directory

Files in this directory are provided by the VIRTIS science team, and will remain the same across different deliveries. These files may differ between different data sets / mission extensions.

File Name	File Contents
AAREADME.TXT	Volume content and format information
VOLDESC.CAT	Description of the contents of the volume
ERRATA.TXT	Identified non conformities in the current version

Table 3.1 – Files located in the root directory of a VIRTIS data volume.



3.4.3.2 Calibration Directory

The CALIB directory contains the last available versions of calibration files for all 3 channels. Notice that these files do not suffice to calibrate the raw data files in the case of H (access to the ground calibration data base is required).

- *VEX_VIRTIS_M_VIS_ITF_DUMMY.DAT* = 432x256 single precision matrix (binary) containing the VIRTIS-M-VIS Instrumental Transfer Function, including the VIS flat-field. Currently a uniform image provided for convenience.
- *VEX_VIRTIS_M_IR_ITF_V2.DAT* = 432x256 single precision matrix (binary) containing the VIRTIS-M-IR Instrumental Transfer Function, including the IR flat-field.
- *DEADPIXELMAP* = list of H pixels excluded when summing the intensity of pixels illuminated through the slit.
- *H_SPECTRAL_COEF* = coefficients of the second order polynomials used to derive the wavelengths in μm (obsolete).
- *H_SPECTRAL_WIDTH* = coefficients of the polynomials used to derive the FWHM (obsolete).

Each file has an associated detached label.

H channels wavelength and width should be taken from the calibrated files (TABLE object) for better accuracy.

3.4.3.3 Catalog Directory

Files in this directory are ASCII files containing PDS catalogue objects. These files are provided by the VIRTIS science team, with the concurrence of the PSA, and are expected to remain unchanged across different deliveries.

File Name	File Contents
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
DATASET.CAT	PDS catalogue object for the VIRTIS data set
TARGET.CAT	PDS catalogue object for observed targets
REF.CAT	PDS catalogue object for references appearing in this documentation
PERSON.CAT	PDS catalogue object for personnel involved
SOFTWARE.CAT	PDS catalogue object for software description
RELEASE.CAT	PDS catalogue object for data set release and revision

Table 3.2 – Files located in the CATALOG subdirectory of a VIRTIS data volume

3.4.3.4 Index Directory



This directory contains indexes, allowing a user to locate data of interest. Indexes are written as INDEX_TABLE objects, that is a specific type of PDS ASCII TABLE objects, and are provided with detached PDS labels.

The main index is INDEX.TAB, which is generated automatically by PSA's PVV software for each delivery. It is mainly a list of data files present in the data set.

The file VIRTIS_INDEX.TAB is generated automatically by the Otarie database. It includes a more relevant set of parameters describing the sessions.

The BROWSE_INDEX.TAB file contains a listing of M channels browse images.

The file GEO_VENUS.TAB initially requested by the PSA (to be written using the GEOLIB software) is no longer included for conformity reasons.

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 sessions in the DATA directory for the corresponding release and revision (produced by PVV)
VIRTIS_INDEX.LBL	Detached PDS label to describe VIRTIS_INDEX.TAB
VIRTIS_INDEX.TAB	Alternative index of data files in the DATA directory, including most relevant parameters
BROWSE_INDEX.LBL	Detached PDS label to describe BROWSE_INDEX.TAB
BROWSE_INDEX.TAB	PDS table providing a list of browse images in the archive.

Table 3.3 – Files located in the INDEX subdirectory of a VIRTIS data volume.

3.4.3.5 Browse Directory and Browse Images

The VIRTIS-VEx archive contains reduced JPEG images for the M-visible and M-IR data files. They provide the calibrated intensity at several wavelengths outlining information for quick look and data selection. Browse images are automatically processed with histogram equalization and Roberts filtering (2-pixel scale gradient), then reduced to ~half image size.

Browse image names are *_x.JPG, where * is the data file name root, and x is a letter ranging from A to G identifying the wavelength or spectral range in use. In addition, the label of the original raw data file is made available as a separate text file, with name *_LABEL.TXT. These text files cannot be used as detached labels to access the raw data files (the data pointers would be wrong).

A common detached label is provided for all browse images and for the label text corresponding to the same cube, with name *_LBL.

Browse images can be viewed using the display functions of any modern operating system. They are grouped in directories corresponding to successive MTPs, so as to facilitate browsing.

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 complete MTP period. The file names have the following format:

VEX_VIRTIS_YYMMDD_yymmdd_VV.BC

where YYMMDD is the start date

yymmdd is the stop date

VV is a version number, starting from 01



These files are generated with no time interval tables (Spice option INCLUDE_INTERVAL_TABLE = 'NO'). A detached PDS label is also provided for each CK file. The files are in binary format, and can be translated to ascii using Spice commands. The ascii header included in these files is available separately in the DOCUMENT directory as CK_HEADER.TXT.

3.4.3.7 Document Directory

This directory includes documentation about the instrument, the data set and the mission, plus data access software. VEX_*.TXT files provided by the PSA have an associated, detached label with extension LBL.

File Name	File Contents
DOCINFO.TXT	Text description of the directory contents
VIRTIS_DOCS.LBL	PDS labels for most documents contained in the directory (those not provided by PSA)
VIRTIS_EAICD.PDF	VIRTIS EAICD (this document) in PDF format
VIRTIS_EAICD.TXT	VIRTIS EAICD (this document) in ASCII text
EAICD_FIG_xx.PNG	Figures from the EAICD
VIRTIS_GEOMETRY.PDF	Documentation to the geometry files in PDF format
VIRTIS_GEOMETRY.TXT	Documentation to the geometry files in ASCII format
GEOMETRY_FIG_xx.PNG	Figures from the geometry documentation
VIRTIS_M_CALIBRATION.PDF	VIRTIS_M Calibration report in PDF format, TBD
VIRTIS_M_CALIBRATION.TXT	VIRTIS_M Calibration report in ASCII text
M_CALIB_FIG_xx.PNG	Figures from the M calibration report
VIRTIS_H_CALIBRATION.PDF	VIRTIS_H documentation in PDF format
VIRTIS_H_CALIBRATION.TXT	VIRTIS_H documentation in ASCII text
H_CALIB_FIG_xx.PNG	Figures from the H calibration document
LECTURE_PDS.PDF	IDL software documentation in PDF format
LECTURE_PDS.TXT	IDL software documentation in ASCII format
LECTUREPDS2_8_1.ZIP	IDL library to read and handle VIRTIS data, as a GZIP archive
LECTUREPDS2_8_1.LBL	Combined label for the IDL library
ZIPINFO.TXT	Reference to ZIP format
ESA_SP_2007.PDF	Virtis technical paper from ESA SP-1295 in PDF format
ESA_SP_2007.TXT	ESA SP-1295 in ASCII
VIRTIS_EXP_USER_MANUAL.PDF	VIRTIS User Manual in PDF format
VIRTIS_EXP_USER_MANUAL.TXT	VIRTIS User Manual in ASCII text
USERMAN_FIG_xx.PNG	Figures from the User manual
VVX-DLR-MA-001.PDF	Documentation to the Virtis VEx on-board software
VVX-DLR-MA-001.TXT	Documentation to the Virtis VEx on-board software, ASCII version
VVX-GAF-IC-002.PDF	Software internal interface control document (including short description of telemetry data)
VVX-GAF-IC-002.TXT	Software internal interface control document, ASCII version
VVX-GAF-IC-003.PDF	On-board data handling software interface control document (including extensive description of TM data)
VVX-GAF-IC-003.TXT	On-board data handling software interface control



	document, ASCII version
CK_HEADER.TXT	Header of Virtis mirror CKs, stored in binary in the GEOMETRY directory
VEX_ORIENTATION_DESC.TXT	Description of spacecraft orientation from PSA
VEX_POINTING_MODE_DESC.TXT	Description of spacecraft pointing modes from PSA
VEX_SCIENCE_CASE_ID_DESC.TXT	Description of observing modes ("science cases") from PSA
VEX_MISSION_CALENDAR_PSA.PDF	Time line and events for the mission/spacecraft, from PSA
VEX_MISSION_CALENDAR_PSA.TXT	Time line and events for the mission/spacecraft, ASCII version
*.LBL	Detached labels to the above PSA documents

Table 3.4 – Files located in the DOCUMENT subdirectory of a VIRTIS data volume

3.4.3.8 Data Directory

The data directory is divided into subdirectories which gather the data files by MTP, orbit, and processing level:

/DATA/MTPxxx/VIRnnnn contains data acquired during MTP # xxx (encoded on three digits), orbit # nnnn (encoded on 4 digits)

All orbit directories are split in three subdirectories:

RAW contains all raw data files from the three channels
CALIBRATED contains all calibrated files from the three channels (including H calibrated darks)
GEOMETRY contains all geometry files for the three channels

Initial phases are grouped according to a similar scheme:

/DATA/CRUISE/VIR9999 contains all data acquired during cruise
/DATA/VOI/VIR0000 contains data acquired during orbit insertion (orbit 0)
/DATA/VOCP/VIR000n contains data acquired during orbit commissioning (orbits 5 to 7)

"Missing" orbit directories correspond to periods when VIRTIS did not acquire any data.

See section 4.1 for details.

3.4.3.9 Extras Directory

The EXTRAS directory includes files not required by the PSA, most notably an alternative index of data files with values of the most important parameters. This index has a minimal detached PDS label, so that it can be directly ingested in a table visualizer such as Excel.

VIRTIS_LOG_DEL1.TXT Index for the first delivery

Besides, this directory contain a subdirectory CORRUPTED_DARKS which lists the ordinal numbers of H "corrupted dark" for all sessions before June 13th, 2007 (with the initial on board software). These "corrupted darks" are nominal dark frames which were acquired with the shutter partly open, due to a software anomaly. The successive spectra need to be corrected, as described in document [AD 15]. The names of these files are:

VSnnnn_ss_BAD.TAB ascii tables



VSnnnn_ss_BAD.LBL detached labels

where nnnn is the orbit number, and ss is the session number in this orbit.

4 Detailed Interface Specifications

4.1 Structure and Organization Overview

The DATA directory is subdivided as follows:

/DATA/CRUISE/VIR9999 contains all data acquired during the cruise to Venus
/DATA/VOI/VIR0000 contains all data acquired during orbit 0 (lasting 9 days)
/DATA/VOCP/VIRnnnn contains all data acquired during orbit commissioning (orbits 5 and 7)
/DATA/MTPxxx/VIRnnnn contains all data acquired during MTP # xxx, orbit # nnnn

The MTP and orbit numbers are coded on exactly 3 and 4 digits, completed with 0s if needed, to encompass the duration of the extended mission.

Deliverable mission phases do not include Cruise and Orbit Insertion, therefore the first directories mentioned above are not included, but start with MTP001. All orbit directories are split in three subdirectories: RAW, CALIBRATED, GEOMETRY

Orbit numbers are defined in [AD 5]. The orbital period is 24 h, except for orbit 0 which has a period of 9 days. The Venus Orbit Insertion phase encompasses orbits 0-22, when the final working orbit is reached.

Orbits are grouped in two different ways by ESA: the PSA groups orbits in mission phases (which are used in the labels), whereas operation planning is based on the MTP time line. Mission phases and MTP periods both roughly last one month, but do not match. The MTP structure is used in the VIRTIS archive to maintain consistency with operation sequencing activities in the team, and with other documents (e.g. mirror CKs for VIRTIS-M). The relationship between orbits, mission phases, and MTPs is given in Tables 4.1 and 4.2, together with limits of mission extensions.

In VIRTIS file names and directories, a special orbit numbering is used: VIRTIS orbits conventionally start 7h after pericenter, when the spacecraft points the Earth for transmission. All files acquired between two such events use the same orbit number, and are therefore located in the same directory. This allows to group sequences of observations acquired around apocenter, which in general constitute related VIRTIS observation sets (case 3, global mosaics and movies).

A different convention is used at mission level, where the orbit number changes at apocenter. This latest convention is used to derive the value to the ORBIT_NUMBER keyword in the PDS labels, which can therefore be different from the file name. This keyword value can then be used for cross-instrument comparisons (the value -1 is used in the labels for pre-orbital observations).

Starting date	Start ORBIT_NUMBER	MISSION_PHASE_NAME
2005-11-09	-1 (9999 in file names)	CRUISE
2006-04-11	0	VOI
2006-05-14	23	PHASE 0
2006-06-04	44	PHASE 1
2006-07-11	82	PHASE 2
2006-09-14	146	PHASE 3
2006-11-16	209	PHASE 4
2007-02-01	286	PHASE 5
2007-03-16	330	PHASE 6
2007-04-25	370	PHASE 7



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2007-06-30	436	PHASE 8
2007-08-21	488	PHASE 9
2007-10-04	531	PHASE 10
2007-10-27	554	PHASE 11
2008-01-04	623	PHASE 12
2008-04-01	711	PHASE 13
2008-06-05	776	PHASE 14
2008-08-01	833	PHASE 15
2008-09-23	886	PHASE 16
2008-12-31	985	PHASE 17
2008-12-31	985	PHASE 17
2009-03-02	1046	PHASE 18
2009-05-05	1110	PHASE 19
2009-06-24	1160	PHASE 20
2009-09-20	1248	PHASE 21
2009-10-18	1276	PHASE 22
2009-12-17	1336	PHASE 23
2010-02-02	1383	PHASE 24
2010-04-07	1447	PHASE 25
2010-05-30	1500	PHASE 26
2010-07-12	1543	PHASE 27
2010-07-30	1561	PHASE 28
2010-09-14	1607	PHASE 29
2010-11-19	1672	PHASE 30
2011-01-17	1732	PHASE 31
2011-03-23	1797	PHASE 32
2011-04-26	1831	PHASE 33
2011-06-14	1880	PHASE 34
2011-08-27	1954	PHASE 35
2011-10-25	2013	PHASE 36
2011-12-05	2054	PHASE 37
2012-01-08	2088	PHASE 38
2012-02-05	2116	MTP 76
2012-03-04	2144	MTP 77
2012-04-01	2172	MTP 78
2012-04-29	2200	MTP 79
2012-05-27	2228	MTP 80
2012-06-24	2256	MTP 81
2012-07-22	2284	MTP 82
2012-08-19	2312	MTP 83
2012-09-16	2340	MTP 84
2012-10-14	2368	MTP 85
2012-11-11	2396	MTP 86
2012-12-09	2424	MTP 87

*Table 4.1 – MISSION_PHASE_NAME definition with starting date and orbit
 (as per PSA document "MISSION_PHASE", Feb 2012)*



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MTP / phase	Start date	End date	First orbit number	EXTENSION
CRUISE	2005-11-09	2006-04-11	9999 (in file names)	CRUISE
VOI	2006-04-12 00:00:00	2006-04-20 00:00:00	0	COMMISSIONING
VOCP	2006-04-25 00:00:00	2006-04-29 00:00:00	4	
MTP001	2006-05-06 08:30:46	2006-06-03 08:42:04	16	NOMINAL (starts at orbit 23)
MTP002	2006-06-03 08:42:04	2006-07-01 08:54:50	44	
MTP003	2006-07-01 08:54:50	2006-07-29 09:05:42	72	
MTP004	2006-07-29 09:05:42	2006-08-26 09:56:27	100	
MTP005	2006-08-26 09:56:27	2006-09-23 11:05:47	128	
MTP006	2006-09-23 11:05:47	2006-10-21 12:19:31	156	
MTP007	2006-10-21 12:19:31	2006-11-18 13:27:49	184	
MTP008	2006-11-18 13:27:49	2006-12-16 14:36:17	212	
MTP009	2006-12-16 14:36:17	2007-01-13 14:32:27	240	
MTP010	2007-01-13 14:32:27	2007-02-10 14:09:45	268	
MTP011	2007-02-10 14:09:45	2007-03-10 13:47:02	296	
MTP012	2007-03-10 13:47:02	2007-04-07 13:24:58	324	
MTP013	2007-04-07 13:24:58	2007-05-05 13:11:24	352	
MTP014	2007-05-05 13:11:24	2007-06-02 13:42:33	380	
MTP015	2007-06-02 13:42:33	2007-06-30 13:54:12	408	
MTP016	2007-06-30 13:54:12	2007-07-28 13:17:21	436	
MTP017	2007-07-28 13:17:21	2007-08-25 10:48:20	464	
MTP018	2007-08-25 10:48:20	2007-09-22 08:26:56	492	
MTP019	2007-09-22 08:26:56	2007-10-20 08:34:04	520	
MTP020	2007-10-20 08:34:04	2007-11-17 08:49:49	548	EXTENSION 1
MTP021	2007-11-17 08:49:49	2007-12-15 10:04:05	576	
MTP022	2007-12-15 10:04:05	2008-01-12 10:58:03	604	
MTP023	2008-01-12 10:58:03	2008-02-09 11:49:23	632	
MTP024	2008-02-09 11:49:23	2008-03-08 11:23:39	660	
MTP025	2008-03-08 11:23:39	2008-04-05 10:56:54	688	
MTP026	2008-04-05 10:56:54	2008-05-03 10:30:28	716	
MTP027	2008-05-03 10:30:28	2008-05-31 10:37:59	744	
MTP028	2008-05-31 10:37:59	2008-06-28 11:12:50	772	
MTP029	2008-06-28 11:12:50	2008-07-26 12:09:32	800	
MTP030	2008-07-26 12:09:32	2008-08-23 13:14:06	828	
MTP031	2008-08-23 13:14:06	2008-09-20 14:17:04	856	
MTP032	2008-09-20 14:17:04	2008-10-18 15:19:01	884	
MTP033	2008-10-18 15:19:01	2008-11-15 16:19:28	912	
MTP041	2009-05-30 08:40:31	2010-08-21 14:56:20	1136	EXTENSION 2
MTP057	2010-08-21 14:56:20	Going on	1584	EXTENSION 3

Table 4.2 – MTP periods limits, corresponding orbit number (as used in file names), and mission extensions (limits of data sets)

Each data directory contains files from each channel (VIRTIS-M_visible, VIRTIS-M_IR, VIRTIS-H) for each sub-session acquired during this orbit, grouped by data level in sub-directories (raw, calibrated, geometry).

File names are coded on 9.3 format as follows:

V<channel + transfer mode><orbit number>_<sub-session number>.<ext>



or
VFxxxx_nn.EEE

where:

V is a literal "V" character

F is the channel/transfer mode identifier (one alpha character):

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)

I: M-IR data

V: M-Vis data

xxxx is the orbit number coded on exactly 4 digits (same as in directory string)

nn is the subsession ID (ID of file produced by this channel during this orbit)

EEE is the extension identifying the type and level of data (three alpha characters):

QUB: raw data

GEO: geometry files

CAL: calibrated data

DRK: calibrated dark currents for H

For cruise data files, xxxx = 9999 and nn is the ordinal number of the observation for this channel.

4.2 Data Sets, Definition and Content

The VIRTIS VEx data will be accumulated in one data set using the release concept. This data set includes all level 2 (edited) data and geometry information. Level 3 (calibrated) data are included in the first delivery only for H and M-IR, on a best effort basis.

Releases will proceed in the time line defined by the PSA.

4.3 Data Product Design

4.3.1 Data Product Organization

VIRTIS is composed of three channels (M-visible, M-IR, and H) each composed of an optical system, a separated detector/focal plane array, and a specific proximity electronic module. Because each channel can be operated independently with a variety of operational modes, data from the three channels are stored in separate files.

Data are grouped by "sub-sessions", i.e. are limited in time by start_acquisition / stop_acquisition requests for this particular channel. As a general rule, successive sub-sessions correspond to different science cases (i.e. spacecraft operation mode, see section 2.1.2) and to a given operational mode. In particular, integration time, frame summing, and binning mode remain constant during a science sub-session. For a given sub-session, data transferred using the same transfer mode are grouped in the same file (see below).

Overall, 9 data products are defined for VIRTIS-VEx: raw data, calibrated data, and derived geometry parameters, for each of the 3 channels.

All data products in the VIRTIS-VEx archive use the PDS Qube objects with 3 dimensions, and contain decompressed data in binary format. Data are located in the Qube core and housekeeping parameters are located in the Qube suffix (sideplane or backplane). In addition, all data files include an empty HISTORY object (PSA early requirement, maintained for consistency but unused). Finally, all files have an attached PDS label describing their content (e.g., timing information, operational mode, average instrument temperatures, viewing conditions, data dimensions, applied processing...). The labels are



padding with ascii character 32 (space) to an integer number of records, while the data objects are padded with character 0.

Measurements are stored in the Qube core in the order in which they are transmitted. In particular, successive frames in the Qube core correspond to data acquired at successive time steps. Associated to each frame of the Qube core, a frame in the suffix gathers the HK parameters acquired during the corresponding period.

Basic data access is performed through the LecturePDS software included in the DOCUMENT directory. The software documentation [AD 16] provides more specific information about data handling and visualization (e.g. dark frame identification in M cubes, suffix decoding...)

Although the data area is designed to preserve ISIS formatting requirements, the files cannot be directly ingested into ISIS. This however only requires modifications in the label, which are not supported by the team.

4.3.2 QUBE Core Structure

The following definitions and conventions are used for VIRTIS.

A QUBE core is a 3-dimension structure containing science measurements (Fig. 4.1). The axes of the QUBE are called BAND (spectral band defined by the wavelength), SAMPLE (spatial direction along the slit), and LINE (acquisitions in successive time steps).

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), spectra acquired through time at the same position along the slit.

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 atomic structure of the QUBE is called either pixel or spectel, depending whether it is considered a part of an image or a spectrum.

The storage order of the QUBE is always (Band, Sample, Line) (i.e., band interleaved by pixel, or BIP) to respect the order of the telemetry data flow and to minimize data handling operations.

FRAMES produced by VIRTIS-H are either (Fig. 4.2) sets of spectra acquired in sequence but transferred with a single SCET (formally similar to M data), or 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 successive spectral measurements at a given wavelength, or one of the detector dimensions, i.e. the second spectral axis.

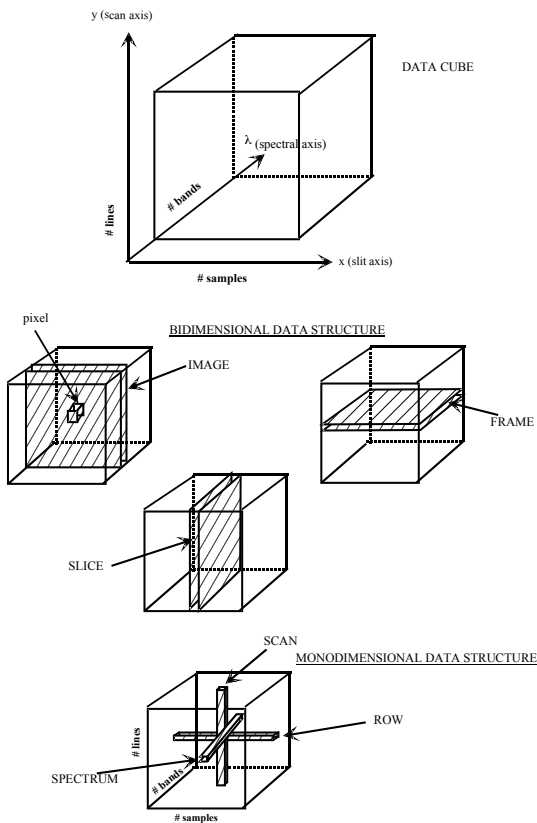


Fig. 4.1 – Structure of VIRTIS data cubes

4.3.3 Suffix Structure

The QUBE suffix is used to store complementary information related to the data (Fig. 4.2). For raw data QUBES, the sideplane is used to store a selection of housekeeping parameters that may affect the data calibration process. For calibrated data QUBES, the backplane is used to store the original acquisition time (SCET). Individual parameters are stored as 2-bytes integers, but always appear in even number (see appendix B). This preserves compatibility with ISIS formatting, which requires suffix elements to be encoded on 4 bytes, but can read the VIRTIS ones by groups of 2.

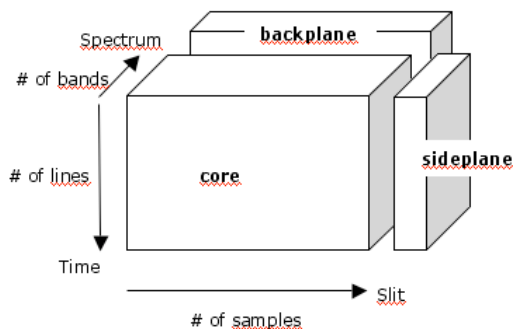


Fig. 4.2 — PDS Qube and suffix, as used for VIRTIS



4.3.4 Data Product A Design: VIRTIS-M raw data

Data from the M-visible and M-IR channels always consists of successive detector images. Each frame is compressed separately on board. Raw data from the Visible and the IR channel are stored in different files as Qube objects, so as to simplify data handling. For each channel, science data and dark frames are stored in the same file, interleaved in the Qube core, and appear in order of acquisition (Fig. 4.3).

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

The QUBE core contains the measurements in DN, encoded on 2-bytes integers (MSB storage). The last measured dark current is subtracted from the data on board, and is not re-added after decompression. Whenever temperature varies significantly during acquisition, an additional correction must be applied to optimize dark current subtraction.

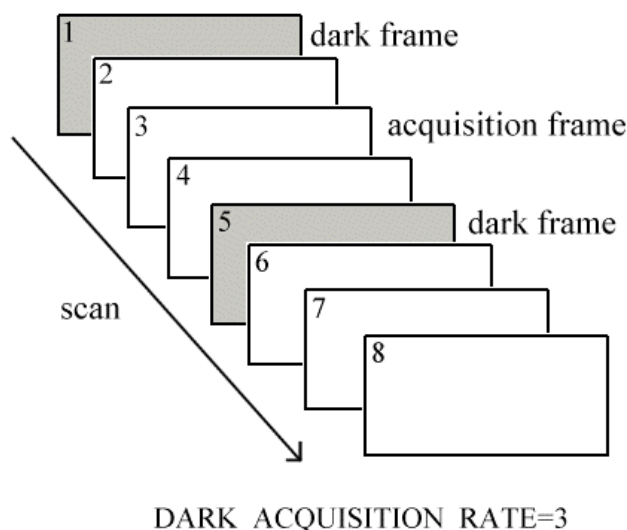


Fig. 4.3 – Dark frames acquisition for the M channels
(the “scan” direction is acquired through time)

The sideplane contains the HK parameters acquired between two successive frames, plus additional information from the science reporting TM header. A selection of 82 parameters is defined for M-visible and M-IR from the TM (versus 72 for H), which is detailed in Appendix B.

The sideplane information is stored according to the following rules:

- All parameters (HK and others) are stored on 2-bytes integers. Byte ordering is preserved from the TM (MSB). Parameters may be decompacted if they are stored on less than 16 bits in the TM, but no correction or conversion is applied at this level.
- To avoid considerable waste of space, the information is grouped in elemental structures (which are different for M and H, but identical for M-visible and M-IR), as detailed in Appendix B.
- An elemental structure is created each time an HK reporting TM is received. Missing parameters are replaced by the hexadecimal value FFFF (this value is not used by any HK parameter).
- 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 always contains 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 (see Fig. 4.4). A given parameter therefore has the same index number(s) in all rows.

- The number of sideplane rows actually used is identical for each frame. It is reported in the label with the SUFFIX_ITEM keyword.

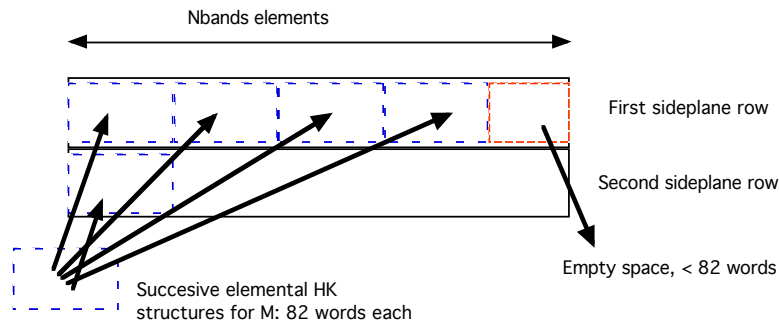


Fig. 4.4 – Organization of the sideplane for raw data

A raw data cube is therefore composed of a time-sequence of *frame* ($Nband \times Nsample$ values) + *suffix* ($Nband \times$ number of rows required to accommodate all the housekeeping structures).

4.3.5 Data Product B Design: VIRTIS-H raw data

VIRTIS-H raw data files are formally similar to VIRTIS-M ones but differ in details depending on acquisition mode.

Backup mode. Image transfer mode is used (the complete detector image is transferred at each time step). Dark current frames are interleaved with the dark-removed data. Only one file is written; it contains a cube, the core of which contains the measured image frames and dark frames ($432 \times 256 \times$ number of images acquired). This format is very similar to VIRTIS-M.

Nominal mode. Data measurements are grouped as sets of 64 spectra compressed together, interleaved with single dark spectra measurements. Data are transmitted using the “64-spectra frame” transfer mode, dark spectra use the “spectrum” transfer mode. Two files are written together:

The first file contains a cube, the core of which contains the measured spectra grouped in sets of 64 ($3456 \times 64 \times$ sequence length), as displayed in Fig. 4.5.

The second file contains a QUBE, the core of which contains the dark spectra ($3456 \times 1 \times$ number of dark spectra). Dark measurement rate depends on the telecommand received, and has no relationship with the 64-spectra structure. Practically, it is selected to be a divisor of 64 so as to optimize compression efficiency.

Calibration mode. A group of 7 images and a group of two spectra are acquired in sequence (see section 2.3.1.4). Two short files are written:

The first file contains a QUBE, the core of which contains the images of the detector ($432 \times 256 \times 7$).

The second file contains a QUBE, the core of which contains the spectrum and its associated dark current ($3456 \times 1 \times 2$).



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 QUBE core contains the measurements in DN, encoded on 2-bytes integers (MSB storage). The last measured dark current is subtracted from the data on board, and is not re-added after decompression. Whenever temperature varies significantly during acquisition, an additional correction must be applied to optimize dark current subtraction.

The QUBE sideplanes contain the corresponding housekeeping parameters stored in an elemental structure just like for VIRTIS-M. The VIRTIS-H elemental structure has 72 elements (versus 82 for VIRTIS-M), and is detailed in Appendix B. In nominal mode, one sideplane frame corresponds to all HK information received during the period of acquisition of the 64 spectra grouped in the frame. In this case, the only SCET available from the science TM is that of the last acquired spectrum (the 64th one).

Open issue: At the time of writing, the HK parameters are shifted by 64 spectra in nominal mode, because of a non conformity in the EGSE. See section 2.3.1.7.

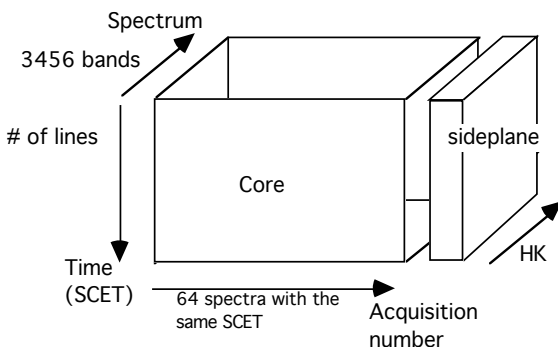


Fig. 4.5 — VIRTIS-H data cube in 64-spectra (nominal) mode.
Dark spectra are stored in a separated file.

4.3.6 Data Product C Design: VIRTIS-M calibrated data

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 contain one qube with a backplane and a bottomplane.

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 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 4-bytes integers of this row (with only two bytes used out of 4) (see section 3.2.2). This SCET is reconstructed at mid-exposure.

The bottomplane has 3 frames containing reference data for each spectel: wavelength and FWHM (in microns), then absolute uncertainty on the signal (1-sigma deviation). There is no sideplane associated to this QUBE.



4.3.7 *Data Product D Design: VIRTIS-H calibrated data*

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. The files contain a table and a qube.

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 spectral: 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.

Dark current files are also calibrated and are provided independently with the same formatting. This is intended to allow fine corrections of the dark current if needed, without running the whole calibration pipeline again. In particular, these dark currents may be interpolated through time using a different scheme, and the difference may be added to the calibrated signal.

4.3.8 *Data Product E Design: geometry data*

Geometry files are documented separately in [AD 13]. One geometry file is computed for each measurement file in flight, providing geographical coordinates on two reference layers at Venus, plus viewing angles and additional quantities. These parameters are stored in a QUBE core with no associated sideplane.

4.3.9 *VIRTIS VEx PDS labels*

PDS labels describing the content of data files are always attached (included in the files). The PDS labels for all VIRTIS files have the same structure. The keywords are grouped in functional sections.

- File information
- Data description
- Information on science operations, including geometry
- Instrument status description
- Data object (qube) description

Keywords belonging to the above groups are listed in the following sections. Examples of actual labels are provided in Appendix D. More details on the origin of the value can be found in Appendix C. In the following sections, the value field is filled with constant values, or with a dummy parameter whenever the value can vary.



Some of the keywords are introduced by the namespace "VEX:". Such keywords are defined in a mission-specific dictionary in agreement with the PSA, and are used to store information that standard PDS keywords cannot accommodate.

Some keywords refer to external documents containing more detailed explanation as stream text, but no retrievable data. Those are located in the DOCUMENT directory.

All spaces and tabulations in the labels are encoded with ASCII character 32 (space). No ASCII 0 (NULL) character is present, to preserve compatibility with most software languages (this character is often used as string delimiter). All label lines are less than 80 characters long, including the EOL marker encoded as ASCII 13-10 (CR-LF).

4.3.9.1 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, 30/09/2010"

/* File format and length */
PRODUCT_ID          = "filename.ext"
RECORD_TYPE         = FIXED_LENGTH
RECORD_BYTES        = 512
FILE_RECORDS        = nn
LABEL_RECORDS       = n
FILE_STATE           = CLEAN
```

The LABEL_REVISION_NOTE references the version of the label template used when writing the file.

The PRODUCT_ID data element provides the name of the data file, including extension, for further software processing.

The RECORD_TYPE data element identifies the record characteristics of the file. Physical records are always fixed-length. The RECORD_BYTES data element identifies the number of bytes in each physical record of the data product file. Records length is always equal to 512 bytes.

The FILE_RECORDS data element identifies the number of physical records in the file.

The LABEL_RECORDS data element identifies the number of physical records that make up the PDS product label.

The FILE_STATE data element is related to ISIS processing (not used).

4.3.9.2 Data Object Pointers

The type and location of data objects are provided through standard PDS syntax. Locations are always given as the first record number of the data object within the file, starting from 1.

```
/* Pointers to data objects */
^HISTORY      = n+1
OBJECT        = HISTORY
DESCRIPTION   = "Reserved area for ISIS compatibility"
END_OBJECT    = HISTORY
^QUBE        = n+2
```



The VIRTIS VEx files include the following data objects:

- 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.
- Raw data files are accommodated in a single QUBE object with sideplane.
- Calibrated data files are accommodated in a QUBE object with backplane. This QUBE is preceded by reference spectral data providing wavelength, FWHM and accuracy. This reference data is accommodated either in a first Qube with 3 frames (for both M channels), or in a TABLE object with 3 columns (for the H channel).
- Geometry files only use a single QUBE with no suffix, and no HISTORY object is present.

4.3.9.3 Data Production

The following keywords provide information as to the generation of the data product. Most of them is for team information only.

```
/* Producer information */
PRODUCER_ID           = VEX_VIRTIS_TEAM
PRODUCER_FULL_NAME    = "DROSSART-PICCIONI"
PRODUCER_INSTITUTION_NAME = "ISTITUTO NAZIONALE ASTROFISICA"
PRODUCT_CREATION_TIME = yyyy-mm-ddThh:mm:ss.fff
TELEMETRY_SOURCE_ID  = "VIRTIS_EGSE3"
SOFTWARE_VERSION_ID  = {"VirtisVEX SW v.X.XX", "EGSE_SOFT_X.0",
                        "PDS_CONVERTER_X.0", "EGSE2PSA_CONVLABEL_X.X.X",
                        "GEOVIRTIS_X.0", "V_GEOLABEL_X", "V_CALIBM_VEX_X.X", "V_CONVLABEL_X.X"}
SOURCE_PRODUCT_ID     = "<Original EGSE file name>"
```

PRODUCER_INSTITUTION_NAME identifies the institute in which the data product was generated. The possible values are LESIA (Observatoire de Paris, Meudon) and ISTITUTO NAZIONALE ASTROFISICA (INAF, Rome).

PRODUCT_CREATION_TIME provides the UTC of file generation as a standard ISO time string.

TELEMETRY_SOURCE_ID identifies the EGSE hardware used to generate the file (this information is relevant only for ground calibrations; the flight value is constant).

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.

SOURCE_PRODUCT_ID provides reference to an intermediate data product for internal check (EGSE output generated from the TM). This keyword is only present in raw data files.

4.3.9.4 Data Description

This section identifies the data and its version number.

```
/* Data description parameters */
DATA_SET_NAME         = "VENUS EXPRESS VENUS VIRTIS 2/3 V1.0"
DATA_SET_ID           = "VEX-V-VIRTIS-2/3-V1.0"
RELEASE_ID            = 0001
REVISION_ID           = 0000
PRODUCT_TYPE          = EDR
PROCESSING_LEVEL_ID   = 2
```



```
STANDARD_DATA_PRODUCT_ID = "VIRTIS DATA"  
MISSION_NAME             = "VENUS EXPRESS"  
MISSION_ID               = VEX  
INSTRUMENT_HOST_NAME    = "VENUS EXPRESS"  
INSTRUMENT_HOST_ID      = VEX  
MISSION_PHASE_NAME      = "xxx"  
PI_PDS_USER_ID          = "DROSSART-PICCIONI"  
INSTRUMENT_NAME         = "VISIBLE AND INFRARED THERMAL IMAGING SPECTROMETER"  
INSTRUMENT_ID           = "VIRTIS"  
INSTRUMENT_TYPE         = "IMAGING SPECTROMETER"  
^INSTRUMENT_DESC        = "VIRTIS_EAICD.TXT"  
VEX:CHANNEL_ID          = "VIRTIS_M_VIS"  
DATA_QUALITY_ID         = 1  
DATA_QUALITY_DESC       = "0:INCOMPLETE ; 1:COMPLETE"
```

The Planetary Science Archive of ESA implements the "Release" concept: data is delivered as units (releases), which can be updated (revision). The RELEASE and REVISION_ID data elements are included to handle the release concept.

PRODUCT_TYPE identifies the product level. Possible values are EDR (raw data and geometry) or RDR (calibrated data). Derived products will use the value DDR.

PROCESSING_LEVEL_ID is accordingly 2 (raw data and geometry) or 3 (calibrated data).

STANDARD_DATA_PRODUCT_ID identifies data ("VIRTIS DATA") from geometry ("VIRTIS GEOMETRY") for use in further processing.

MISSION_PHASE_NAME indicates in which phase of the mission the data was acquired. It uses the values defined by the PSA (section 4.1 and Table 4.1).

CHANNEL_ID identifies the 3 channels of VIRTIS. Possible values are "VIRTIS_M_VIS", "VIRTIS_M_IR" and "VIRTIS_H". A namespace is used here because the values are longer than allowed in the official definition of the PDS for this keyword.

DATA_QUALITY_ID is an error flag set by the EGSE during low level processing (see section 3.3). A value of 0 indicates missing data paquets.

4.3.9.5 Science Operations

The keywords in this section contain information on the target, timing and so on. Geometric keywords are listed in this group: values for these keywords are generated from processing with SPICE routines.

```
/* Science operations information */  
TARGET_TYPE              = "PLANET"  
TARGET_NAME              = "VENUS"  
START_TIME               = yyyy-mm-ddThh:mm:ss.fff  
STOP_TIME                = yyyy-mm-ddThh:mm:ss.fff  
SPACECRAFT_CLOCK_START_COUNT = "n/sssssssssss.fffff"  
SPACECRAFT_CLOCK_STOP_COUNT = "n/sssssssssss.fffff"  
ORBIT_NUMBER             = xxxx  
VEX:SCIENCE_CASE_ID      = x  
VEX:SCIENCE_CASE_ID_DESC = "Please refer to VEX_SCIENCE_CASE_ID_DESC.TXT"  
OBSERVATION_TYPE         = "NULL"  
SPACECRAFT_ORIENTATION   = (xx,xx,xx)  
^SPACECRAFT_ORIENTATION_DESC = "VEX_ORIENTATION_DESC.TXT"  
SPACECRAFT_POINTING_MODE = "string"  
^SPACECRAFT_POINTING_MODE_DESC = "VEX_POINTING_MODE_DESC.TXT"  
DECLINATION              = xx  
RIGHT_ASCENSION          = xx
```




MAXIMUM_LATITUDE	= xx
MINIMUM_LATITUDE	= xx
EASTERNMOST_LONGITUDE	= xx
WESTERNMOST_LONGITUDE	= xx
SLANT_DISTANCE	= xx

The TARGET_TYPE and TARGET_NAME data elements identify the target of the observation. They are usually set to PLANET and VENUS.

START_TIME and STOP_TIME are the UTC of the first and last science data packets received for the current sub-session. They are computed through the SPICE system from the OBT.

SPACECRAFT_CLOCK_START_COUNT / STOP_COUNT are the corresponding OBT, from the TM. The format is described in section 3.2.2.

ORBIT_NUMBER is given at start time of the sub-session, from mission planning. The value to this keyword complies to the convention used at mission level, where orbit number changes at apocenter. This is different from the convention used to derive file names, and therefore this value may not match the directory and file names (see section 4.1). The value is encoded on 4 digits with initial zeros.

SCIENCE_CASE_ID refers to mission planning, and is retrieved from the ITL file. It is encoded as in Table 2.1, or set to 0 if value is missing/unknown (in particular for calibrated sessions, and whenever the target is not Venus).

OBSERVATION_TYPE was an early PSA requirement, but is not actually used.

SPACECRAFT_ORIENTATION and SPACECRAFT_POINTING_MODE refer to spacecraft attitude, and are defined in the documents mentioned, located in the DOCUMENT directory.

The next keywords provide average geometrical quantities, as derived from the SPICE system:

DECLINATION and RIGHT_ASCENSION provide the pointing direction in the J2000 reference frame (direction of the channel boresight). They are normally found in conjunction with the "INERT" value of the SPACECRAFT_POINTING_MODE keyword; in other situations they are set to -999.99.

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

The SLANT_DISTANCE element provides the average distance, in kilometers, from the spacecraft to the center of the observation along the line of sight. The center of observation is either the intercept with Venus surface, or the tangent point for limb observations.

Four extra keywords are present in the geometry file labels, which are related to the Sun position:

SOLAR_DISTANCE	= xx
SOLAR_LONGITUDE	= xx
SUB_SOLAR_LONGITUDE	= xx
SUB_SOLAR_LATITUDE	= xx

The SOLAR_DISTANCE element provides the value of the distance from the center of the observation to the apparent position of the Sun, in kilometers.

The SOLAR_LONGITUDE element provides the planetocentric longitude of the Sun in degrees, starting from Venus northern hemisphere spring equinox. This quantity is a measurement of season and location of Venus on its orbit.



The SUB_SOLAR_LONGITUDE and SUB_SOLAR_LATITUDE elements provide the coordinates of the sub-solar point at observing time.

4.3.9.6 Instrument Status

The instrument status description and the operating parameters are contained in the following keywords, which are different for the M and H channels.

The keywords for VIRTIS M-Vis are as follows:

```

/* Instrument status */
INSTRUMENT_MODE_ID = 14
^INSTRUMENT_MODE_DESC = "VIRTIS_EAICD.TXT"
INST_CMPRS_NAME      = "string"
INST_CMPRS_RATE      = xx
INST_CMPRS_RATIO     = xx

VEX:VIR_VIS_START_X_POSITION = x0
VEX:VIR_VIS_START_Y_POSITION = y0
VEX:SCAN_MODE_ID      = ns
SCAN_PARAMETER        = (x, x, x, x)
SCAN_PARAMETER_DESC   = ("SCAN_START_ANGLE", "SCAN_STOP_ANGLE",
    "SCAN_STEP_ANGLE", "SCAN_STEP_NUMBER")
SCAN_PARAMETER_UNIT   = ("DEGREE", "DEGREE", "DEGREE", "DIMENSIONLESS")
FRAME_PARAMETER       = (x, x, x, x)
FRAME_PARAMETER_DESC  = ("EXPOSURE_DURATION", "FRAME_SUMMING",
    "EXTERNAL_REPETITION_TIME", "DARK_ACQUISITION_RATE")
FRAME_PARAMETER_UNIT  = ("S", "DIMENSIONLESS", "S", "DIMENSIONLESS")
EXPOSURE_DURATION_DESC = "-1: many exposure times (calibration sessions)
    Values are available in sideplane. See EAICD.TXT"
MAXIMUM_INSTRUMENT_TEMPERATURE = (x, x, x, x)
INSTRUMENT_TEMPERATURE_POINT = ("FOCAL_PLANE", "TELESCOPE",
    "SPECTROMETER", "CRYOCOOLER")
INSTRUMENT_TEMPERATURE_UNIT = ("K", "K", "K", "K")

```

INSTRUMENT_MODE_ID provides the acquisition mode as defined in section 2.2.2. This mode determines in particular the QUBE dimensions.

INST_CMPRS_NAME indicates which of the 3 types of on-board compression was used for the data, while INST_CMPRS_RATE indicates the requested compression rate in bits per data word (see Table 4.3). Although data are decompressed before generation of the PDS files, the compression mode is described in the label to keep track of the data history, and to allow data quality check.

INST_CMPRS_RATIO stores the actual compression ratio reached on-board, as computed by the EGSE. This is mostly intended to study the impact of the compression on the TM rate.

Reversible compression by definition has a variable compression rate which depends upon data structure. Observed compression ratios commonly range from 2 to 3 in this mode.

INST_CMPRS_NAME	INST_CMPRS_RATE	Comments
NONE	16	No compression applied
REVERSIBLE	"N/A"	Lossless (ratio ~ 1.5-3.5)
WAVELET	2	Lossy with selected rate
	1.5	(ratio = 16/rate)
	1	



Table 4.3 – Possible on-board compression modes and related keywords

VIR_VIS_START_X_POSITION and VIR_VIS_START_Y_POSITION define the origin of the window used in the M-detector (section 2.3.1 and Fig. 2.2).

Notice that different keywords are used for the V-IR channel to store the equivalent quantities: VIR_IR_START_X_POSITION and VIR_IR_START_Y_POSITION (this is the only difference between M-vis and M-IR in this section of the labels). Similarly, the H channel uses the keywords VIR_H_START_X_POSITION and VIR_H_START_Y_POSITION.

SCAN_MODE_ID refers to the functioning mode of the M-channels scanning mirror; the possible values are 0=Pushbroom (fixed, non-rest position), 1=Scanning, 2=Off (rest position). The namespace is required by a slightly non-standard use of this keyword in the VIRTIS labels.

Scanning parameters are identified with the next 3 keywords: SCAN_PARAMETER lists the values as retrieved from the TM, SCAN_PARAMETER_DESC identifies them, and SCAN_PARAMETER_UNITS provides the units for these parameters.

The parameters are respectively the initial and final angles in the scanning cycle, the angular value of one step, and the number of steps performed between two consecutive acquisitions (usually set to 1). The first two values may be negative. The mirror angle used for each acquisition is available in the sideplane (encoded) and in the mirror spice kernels. Notice that the final angle is not necessarily reached, depending on session duration.

Encoding of the mirror angle value is detailed in document [AD14].

Acquisition parameters are introduced in a similar way by the FRAME_PARAMETER keywords. Exposure duration is the individual exposure time, frame summing is the number of individual exposures summed on board for each acquisition, external repetition time is the minimum time lapse between two acquisitions, and dark acquisition rate gives the number of acquisitions between two dark frame measurements (see Fig 4.3).

Both exposure duration and external repetition time are encoded as -1 whenever they can take various successive values in the same file (in practice, this occurs only with calibration sequences). In this case, the actual values can be retrieved from the sideplane for every time step.

Detailed acquisition schemes for H and M are provided in document [AD 9].

The same keyword system is used with MAXIMUM_INSTRUMENT_TEMPERATURE to provide the maximum temperatures measured during the sub-session in specific points inside the instrument.

The equivalent section for the H channel reads:

```
/* Instrument status */
INSTRUMENT_MODE_ID      = 7
^INSTRUMENT_MODE_DESC  = "VIRTIS_EAICD.TXT"
INST_CMPRS_NAME        = "string"
INST_CMPRS_RATE        = xx

VEX:VIR_H_START_X_POSITION = x0
VEX:VIR_H_START_Y_POSITION = y0
FRAME_PARAMETER         = (400, 2, 1, 766.7, 3)
FRAME_PARAMETER_DESC    = ("EXPOSURE_DURATION", "FRAME_SUMMING",
    "FRAME_ACQUISITION_RATE", "INTERNAL_REPETITION_TIME",
    "DARK_ACQUISITION_RATE")
FRAME_PARAMETER_UNIT    = ("MS", "DIMENSIONLESS", "DIMENSIONLESS",
    "MS", "DIMENSIONLESS")
EXPOSURE_DURATION_DESC = "-1: many exposure times (calibration sessions)
    Values are available in sideplane. See EAICD.TXT"
MAXIMUM_INSTRUMENT_TEMPERATURE = (273.0, 283.0, 293.0, 303.0)
```



```
INSTRUMENT_TEMPERATURE_POINT = ("FOCAL_PLANE", "GRATING", "PRISM", "CRYOCOOLER")
INSTRUMENT_TEMPERATURE_UNIT = ("K", "K", "K", "K")
VEX:VIR_DEAD_PIXEL_MAP_FILE_NAME = "filename"
VEX:VIR_H_PIXEL_MAP_COEF =
( ( 4.749950E+1, 1.247300E-1, 9.890690E-5 ),
  ( 9.938600E+1, 9.844940E-2, 7.085630E-5 ),
  ( 1.341680E+2, 8.166750E-2, 4.918400E-5 ),
  ( 1.591860E+2, 6.661960E-2, 4.094150E-5 ),
  ( 1.773400E+2, 5.713190E-2, 2.702870E-5 ),
  ( 1.904680E+2, 5.634040E-2, 5.267310E-6 ),
  ( 2.012000E+2, 4.654330E-2, 1.068770E-5 ),
  ( 2.093140E+2, 4.806390E-2, -8.723980E-6 ) )
VEX: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") )
```

The differences with M are related to FRAME_PARAMETER (where frame acquisition rate gives the number of frames skipped during the summation, and INTERNAL_REPETITION_TIME is used) and MAXIMUM_INSTRUMENT_TEMPERATURE (which are measured at different locations). No scanner keyword is present for H, which has fixed pointing direction.

VIR_H_START_Y_POSITION and VIR_H_START_Y_POSITION provide the origin of the part of the detector actually used (see Figure 2.3).

VIR_DEAD_PIXEL_MAP_FILE_NAME refers to a file contained in the CALIB directory, providing the list of pixels not included in the summation performed on board (see section 2.3.1.6).

VIR_H_PIXEL_MAP_COEF provides the coefficient of the polynomials to reconstruct the channels wavelengths (see section 2.3.1.7).

Similarly to VIRTIS-M, both exposure duration and internal repetition time are encoded as -1 whenever they can take various successive values in the file (in practice, this occurs only with calibration sequences). In this case, the actual values can be retrieved from the sideplane for every time step.

In the M calibrated files, the MAXIMUM_INSTRUMENT_TEMPERATURE vector includes an extra field storing the maximum temperature of the other M detector encountered during the same sub-session (i.e., M-visible labels contain a 5th field IR_FOCAL_PLANE, and M-IR labels contain a field VIS_FOCAL_PLANE).

In the geometry files, this section is limited to instrument mode and M scanning mode.

4.3.9.7 Reference to Geometry Files

The following keyword introduces a string vector listing the SPICE kernels used to compute the geometry values included in the present label, and in the corresponding geometry file. All the spacecraft-related kernels are included in the Venus-Express SPICE dataset whose DATA_SET_ID is VEX-E/V-SPICE-6-V1.0. In addition, specific VIRTIS kernels are produced to describe the M scanning mirror orientation, and are included in the GEOMETRY directory.

```
/* Pointer to navigation data file */
SPICE_FILE_NAME = {"string", "string"...}
```



4.3.9.8 Data Objects Definition

In raw data files, the only data object present is a QUBE. The binary data are stored in the core, housekeeping parameters are stored in the sideplane. Qube dimensions vary depending on channel, acquisition mode, and session duration.

```
/* Cube keywords */
OBJECT = QUBE
AXES = 3
AXIS_NAME = (BAND, SAMPLE, LINE)
CORE_ITEMS = (x, y, z)
CORE_ITEM_BYTES = 2
CORE_ITEM_TYPE = MSB_INTEGER
CORE_BASE = 0.0
CORE_MULTIPLIER = 1.0
CORE_VALID_MINIMUM = -32768
CORE_NULL = -32768
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, N, 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 = "VIRTIS_EAICD.TXT"
END_OBJECT = QUBE
```

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) (see sections 4.3.6 and 4.3.7). 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 4.4. 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 4.4 – Special values used in calibrated data files

All labels end with the standard PDS delimiter, and are completed to a round number of records with ASCII 32 characters:

END

5 Appendix A: Available Software to Read PDS Files

The VIRTIS team maintains an IDL software library to read VIRTIS PDS files, including data files and related files such as transfer functions... This "LecturePDS" library is included in the PSA archive, with extensive documentation.

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.

Other software such as the SBNPDS library 4.1 may be able to read PDS cubes, although this is unlikely (specially for calibrated files).

6 Appendix B: Housekeeping Structures

The following tables list the housekeeping parameters present in the sideplanes of the VIRTIS cubes. For each word in the sideplane (first column) are listed: the type of telemetry packet from which it is extracted, the field and the word ordinal number in this packet, and the data field/HK name. The word is copied from the telemetry and deposited in the sideplane as it is, without any change. Fields identified as "SPARE" are empty (reserved for possible updates during development).

The original TM data fields are described in more details in documents [AD 9] and [AD 11]. Most of these parameters are intended for instrument monitoring during operations, and have little interest for the archive user.

Word number	Origin TM	Field in this TM	Word # in this TM *	Data Field
1	First Science reporting TM for this frame	Data Field Header	4	SCET data, 1 st word
2	–	–	5	SCET data, 2 nd word



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3	--	--	6	SCET data, 3 rd word
4	--	Science Data Header	9	Acquisition ID
5	--	--	10	Number of sub-slices + first serial number
6	--	--	12	Data Type
7	0	0		SPARE
8	VTM_ME_Default_HK_Report (SID1)	Data Field Header	4	SCET periodic HK, 1 st word
9	--	--	5	SCET periodic HK, 2 nd word
10	--	--	6	SCET periodic HK, 3 rd 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		SPARE
20	MTM_ME_General_HK_Report (SID2)	Data Field Header	4	SCET periodic HK, 1 st word
21	--	--	5	SCET periodic HK, 2 nd word
22	--	--	6	SCET periodic HK, 3 rd 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_CCE_SEC_VOLT
29	0	0		SPARE
30	MTM_VIS_HK_Report (SID4)	Data Field Header	4	SCET HK, 1 st word
31	--	--	5	SCET HK, 2 nd word
32	--	--	6	SCET HK, 3 rd word
33	--	Source Data	10	M_CCD_VDR_HK
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	--	--	30	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		SPARE
59	MTM_IR_HK_Report (SID5)	Data Field Header	4	SCET HK, 1 st word
60	--	--	5	SCET HK, 2 nd word
61	--	--	6	SCET HK, 3 rd 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		SPARE

* According to document [AD 11]

Table B.1 – Elemental HK structure for M files sideplane

Word number	Origin TM	Field in this TM	Word # in this TM *	Data Field
1	First Science reporting TM for this frame	Data Field Header	4	SCET data, 1 st word
2	--	--	5	SCET data, 2 nd word
3	--	--	6	SCET data, 3 rd word
4	--	Science Data Header	9	Acquisition ID
5	--	--	10	Number of sub-slices + first serial number
6	--	--	12	Data Type
7	0	0		SPARE
8	VTM_ME_Default_HK_Report (SID1)	Data Field Header	4	SCET periodic HK, 1 st word
9	--	--	5	SCET periodic HK, 2 nd word
10	--	--	6	SCET periodic HK, 3 rd 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



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19	0	0		SPARE
20	HTM_ME_General_HK_Report (SID3)	Data Field Header	4	SCET periodic HK, 1 st word
21	--	--	5	SCET periodic HK, 2 nd word
22	--	--	6	SCET periodic HK, 3 rd 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
27	--	--	14	H_COOL_MOT_CURR
28	--	--	15	H_CCE_SEC_VOLT
29	0	0		SPARE
30	HTM_HK_Report (SID6)	Data Field Header	4	SCET HK, 1 st word
31	--	--	5	SCET HK, 2 nd word
32	--	--	6	SCET HK, 3 rd 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
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_Objective
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		SPARE
72	0	0		SPARE



* According to document [AD 11]

Table B.2 – Elemental HK structure for H files sideplane

7 Appendix C: Derivation of Operational Parameters

The parameters present in the labels are derived as follows from housekeeping parameters present in the sideplane. This may be used e.g., to derive integration times used during the calibration sessions, or to follow temperatures through time. Handling of sideplane values is detailed in the software documentation [AD 16]

Keyword	Channel	Origin TM	Data field
INSTRUMENT_MODE_ID	All	ME_default HK	V_MODE (extracted)
INST_CMPRS_NAME	M IR & visible	M_DUMP_OPERATIONAL_PARAMETERS	M_COMPR
_	H	H_DUMP_OPERATIONAL_PARAMETERS	H_COMPR
VIR_VIS_START_X_POSITION	M visible	M_DUMP_FUNCTIONAL_PARAMETERS	M_CCD_WIN_X1
VIR_VIS_START_Y_POSITION	M visible	M_DUMP_FUNCTIONAL_PARAMETERS	M_CCD_WIN_Y1
VIR_IR_START_X_POSITION	M IR	M_DUMP_FUNCTIONAL_PARAMETERS	M_IR_WIN_X1
VIR_IR_START_Y_POSITION	M IR	M_DUMP_FUNCTIONAL_PARAMETERS	M_IR_WIN_Y1
VIR_H_START_X_POSITION	H	H_DUMP_FUNCTIONAL_PARAMETERS	H_XWIN
VIR_H_START_Y_POSITION	H	H_DUMP_FUNCTIONAL_PARAMETERS	H_YWIN
FRAME_PARAMETER			
EXPOSURE_DURATION	M-visible	M_VIS HK	M_CCD_EXPO * 50 <s>
EXPOSURE_DURATION	M-IR	M_IR HK	M_IR_EXPO * 50 <s>
FRAME_SUMMING	M	M_DUMP_OPERATIONAL_PARAMETERS	M_SS
EXTERNAL_REPETITION_TIME	M	M_DUMP_OPERATIONAL_PARAMETERS	M_ERT (decoded, in s)
DARK_ACQUISITION_RATE	M	M_DUMP_OPERATIONAL_PARAMETERS	M_D/BCK_RATE
	H	see below	
MAXIMUM INSTRUMENT TEMPERATURE			
FOCAL_PLANE	M-visible	M_VIS HK	M_CCD_TEMP
FOCAL_PLANE	M-IR	M_IR HK	M_IR_TEMP
TELESCOPE	M, visible & IR	M_IR HK	M_TELE_TEMP
SPECTROMETER	M, visible & IR	M_IR HK	M_SPECT_TEMP
CRYOCOOLER	M, visible & IR	ME/M general HK	M_COOL_TIP_TEMP
FOCAL_PLANE	H	H HK	HKMs_Temp_FPA
GRATING	H	H HK	HKMs_Temp_Grating
PRISM	H	H HK	HKMs_Temp_Prism
CRYOCOOLER	H	ME/M general HK	H_COOL_TIP_TEMP

Table C.1 – Origin of operational parameters in the labels

For H, the FRAME_PARAMETER elements are derived from event reporting paquet H_DUMP_OPERATIONAL_PARAMETERS as follows:

EXPOSURE_DURATION (in ms):



$$= [(H_INT_SCIENCE_NUM2*1024) + H_INT_SCIENCE_NUM1] * 512/1000$$

FRAME_SUMMING (number of summed frames) :

$$\begin{aligned} &= 1 && \text{if } H_SUM = 0 \\ &= H_N_Sum_Frame && \text{if } H_SUM = 1 \end{aligned}$$

FRAME_ACQUISITION_RATE (acquisition rate):

$$\begin{aligned} &= H_N_FRAME && \text{if } H_SUM = 0 \\ &= 1 && \text{if } H_SUM = 1 \end{aligned}$$

INTERNAL_REPETITION_TIME (in ms):

if $H_SUM = 0$:

$$= \{ [(H_INT_SCIENCE_NUM2*1024) + H_INT_SCIENCE_NUM1] * 512/1000 + Ttrf \} * H_N_FRAME$$

if $H_SUM = 1$:

$$= \{ [(H_INT_SCIENCE_NUM2*1024) + H_INT_SCIENCE_NUM1] * 512/1000 + Ttrf \}$$

where $Ttrf = \text{data readout} + \text{hk_readout} + \text{idle time}$:

$Ttrf = 377.556$ (ms) in spectrum or 64-spectral slice transfer mode

$Ttrf = 1275.576$ (ms) in image transfer mode

DARK_ACQUISITION_RATE is from H_DARK_RATE

8 Appendix D: Examples of Actual Labels

8.1.1.1 VIRTIS M-IR raw data files labels

```
PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE     = "SE-MTC, 18/06/2007"

/* File format and length */
PRODUCT_ID              = "VI0005_14.QUB"
RECORD_TYPE             = FIXED_LENGTH
RECORD_BYTES           = 512
FILE_RECORDS            = 957
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             = VEX_VIRTIS_TEAM
PRODUCER_FULL_NAME      = "DROSSART-PICCIONI"
PRODUCER_INSTITUTION_NAME = "ISTITUTO NAZIONALE ASTROFISICA"
PRODUCT_CREATION_TIME   = 2007-05-11T18:43:28.00
TELEMETRY_SOURCE_ID     = "VIRTIS_EGSE_3"
SOFTWARE_VERSION_ID     = {"EGSE_SOFT_7.0", "PDS_CONVERTER_7.0",
"EGSE2PSA_CONVLABEL_1.2.1", "GEOVIRTIS_1.7", "V_GEOLABEL_1"}
SOURCE_PRODUCT_ID       = "PI64PM51.QUB"
```



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```
/* Data description parameters */
DATA_SET_NAME      = "VENUS EXPRESS VENUS VIRTIS 2 V1.0"
DATA_SET_ID       = "VEX-V-VIRTIS-2-V1.0"
RELEASE_ID        = 0001
REVISION_ID       = 0000
PRODUCT_TYPE      = EDR
PROCESSING_LEVEL_ID = 2
STANDARD_DATA_PRODUCT_ID = "VIRTIS DATA"
MISSION_NAME      = "VENUS EXPRESS"
MISSION_ID        = VEX
INSTRUMENT_HOST_NAME = "VENUS EXPRESS"
INSTRUMENT_HOST_ID   = VEX
MISSION_PHASE_NAME = "VOI"
PI_PDS_USER_ID    = "DROSSART-PICCIONI"
INSTRUMENT_NAME    = "VISIBLE AND INFRARED THERMAL IMAGING SPECTROMETER"
INSTRUMENT_ID      = "VIRTIS"
INSTRUMENT_TYPE    = "IMAGING SPECTROMETER"
^INSTRUMENT_DESC   = "VIRTIS_EAICD.TXT"
VEX:CHANNEL_ID     = "VIRTIS_M_IR"
DATA_QUALITY_ID    = 1
DATA_QUALITY_DESC  = "0:INCOMPLETE ; 1:COMPLETE"

/* Science operations information */
TARGET_TYPE        = "PLANET"
TARGET_NAME        = "VENUS"
START_TIME         = 2006-04-25T22:52:21.381
STOP_TIME          = 2006-04-25T22:55:44.033
SPACECRAFT_CLOCK_START_COUNT = "1/00036370341.65319"
SPACECRAFT_CLOCK_STOP_COUNT  = "1/00036370544.30556"
ORBIT_NUMBER       = 0005
VEX:SCIENCE_CASE_ID = 0
VEX:SCIENCE_CASE_ID_DESC = "Please refer to VEX_SCIENCE_CASE_ID_DESC.TXT"
OBSERVATION_TYPE   = "NULL"
SPACECRAFT_ORIENTATION = ( 0.0012, 0.0004, -1.0000)
^SPACECRAFT_ORIENTATION_DESC = "VEX_ORIENTATION_DESC.TXT"
SPACECRAFT_POINTING_MODE = "NADIR"
^SPACECRAFT_POINTING_MODE_DESC = "VEX_POINTING_MODE_DESC.TXT"
DECLINATION         = 0.00000
RIGHT_ASCENSION     = 0.00000
MAXIMUM_LATITUDE    = -64.7892
MINIMUM_LATITUDE    = -74.9709
EASTERNMOST_LONGITUDE = 336.651
WESTERNMOST_LONGITUDE = 276.433
SLANT_DISTANCE      = 31156.1

/* Instrument status */
INSTRUMENT_MODE_ID = 19
^INSTRUMENT_MODE_DESC = "VIRTIS_EAICD.TXT"
INST_CMPRS_NAME     = "REVERSIBLE"
INST_CMPRS_RATE     = "N/A"
INST_CMPRS_RATIO    = 3.394

VEX:VIR_IR_START_X_POSITION = 1
VEX:VIR_IR_START_Y_POSITION = 7
VEX:SCAN_MODE_ID          = 1
SCAN_PARAMETER            = (-30.2126, 35.621, 0.2582, 1)
SCAN_PARAMETER_DESC      = ("SCAN_START_ANGLE", "SCAN_STOP_ANGLE",
"SCAN_STEP_ANGLE", "SCAN_STEP_NUMBER")
SCAN_PARAMETER_UNIT       = ("DEGREE", "DEGREE", "DEGREE", "DIMENSIONLESS")
FRAME_PARAMETER           = (0.8, 4, 10, 20)
FRAME_PARAMETER_DESC      = ("EXPOSURE_DURATION", "FRAME_SUMMING",
"EXTERNAL_REPETITION_TIME", "DARK_ACQUISITION_RATE")
FRAME_PARAMETER_UNIT      = ("S", "DIMENSIONLESS", "S", "DIMENSIONLESS")
EXPOSURE_DURATION_DESC    = "-1: many exposure times (calibration sessions)
```



```
Values are available in sideplane. See EAICD.TXT"
MAXIMUM_INSTRUMENT_TEMPERATURE = (93.0969, 172.6110, 171.1640, 75.4139)
INSTRUMENT_TEMPERATURE_POINT = ("FOCAL_PLANE", "TELESCOPE",
 "SPECTROMETER", "CRYOCOOLER")
INSTRUMENT_TEMPERATURE_UNIT = ("K", "K", "K", "K")
```

```
/* Pointer to navigation data files*/
SPICE_FILE_NAME = {"NAIF0008.TLS", "PCK00008.TPC", "DE405S.bsp",
 "CLOUD-VENUS.ker", "venus_cloud.bsp", "VEX_060504_STEP.TSC", "VEX_V06.TF",
 "VEX_VIRTIS_V03.TI", "ORHV_____00030.bsp",
 "ORVV_060409211524_00039.bsp", "ATNV_P051109051109_00040.bc",
 "VIRTIS_ck2_0000.bc"}
```

```
/* Cube keywords */
OBJECT = QUBE
AXES = 3
AXIS_NAME = (BAND, SAMPLE, LINE)
CORE_ITEMS = (144,64,24)
CORE_ITEM_BYTES = 2
CORE_ITEM_TYPE = MSB_INTEGER
CORE_BASE = 0.0
CORE_MULTIPLIER = 1.0
CORE_VALID_MINIMUM = -32768
CORE_NULL = -32768
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 = (0,6,0)
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 = 0
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 = "VIRTIS_EAICD.TXT"
END_OBJECT = QUBE

END
```

8.1.1.2 VIRTIS geometry files labels

Examples can be found in [AD 13]

8.1.1.3 VIRTIS H calibrated data labels



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```
PDS_VERSION_ID      = PDS3
LABEL_REVISION_NOTE = "SE, 18/06/2007"

/* File format and length */
PRODUCT_ID      = "NULL"
RECORD_TYPE     = FIXED_LENGTH
RECORD_BYTES    = 512
FILE_RECORDS    = 610
LABEL_RECORDS   = 11
FILE_STATE      = CLEAN

/* Pointers to data objects */
^HISTORY        = 12
OBJECT          = HISTORY
DESCRIPTION     = "Reserved area for ISIS compatibility"
END_OBJECT      = HISTORY
^TABLE          = 13
^QUBE           = 94

/* Producer information */
PRODUCER_ID     = VEX_VIRTIS_TEAM
PRODUCER_FULL_NAME = "DROSSART-PICCIONI"
PRODUCER_INSTITUTION_NAME = "OBSERVATOIRE DE PARIS-LESIA"
PRODUCT_CREATION_TIME = yyyy-mm-ddThh:mm:ss.fff
TELEMETRY_SOURCE_ID = "VIRTIS_EGSE<n>"
SOFTWARE_VERSION_ID = {"EGSE_SOFT_<n>", "PDS_CONVERTER_<p>", "V_HCAL_<q>"}

/* Data description parameters */
DATA_SET_NAME    = "NULL"
DATA_SET_ID      = "NULL"
RELEASE_ID       = 0001
REVISION_ID      = 0000
PRODUCT_TYPE     = RDR
PROCESSING_LEVEL_ID = 3
STANDARD_DATA_PRODUCT_ID = "VIRTIS DATA"
MISSION_NAME     = "VENUS EXPRESS"
MISSION_ID       = VEX
INSTRUMENT_HOST_NAME = "VENUS EXPRESS"
INSTRUMENT_HOST_ID = VEX
MISSION_PHASE_NAME = "NULL"
PI_PDS_USER_ID   = "DROSSART-PICCIONI"
INSTRUMENT_NAME  = "VISIBLE AND INFRARED THERMAL IMAGING SPECTROMETER"
INSTRUMENT_ID    = "VIRTIS"
INSTRUMENT_TYPE  = "IMAGING SPECTROMETER"
^INSTRUMENT_DESC = "VIRTIS_EAICD.TXT"
VEX:CHANNEL_ID   = "VIRTIS_H"
PHOTOMETRIC_CORRECTION_TYPE = NONE
DATA_QUALITY_ID  = 1
DATA_QUALITY_DESC = "0:INCOMPLETE ; 1:COMPLETE"

/* Science operations information */
TARGET_TYPE      = "NULL"
TARGET_NAME      = "NULL"
START_TIME       = yyyy-mm-ddThh:mm:ss.fff
STOP_TIME        = yyyy-mm-ddThh:mm:ss.fff
SPACECRAFT_CLOCK_START_COUNT = "n/ssssssssss.fffff"
SPACECRAFT_CLOCK_STOP_COUNT  = "n/ssssssssss.fffff"
ORBIT_NUMBER     = "NULL"
VEX:SCIENCE_CASE_ID = "NULL"
VEX:SCIENCE_CASE_ID_DESC = "Please refer to VEX_SCIENCE_CASE_ID_DESC.TXT"
OBSERVATION_TYPE = "NULL"
SPACECRAFT_ORIENTATION = "NULL"
^SPACECRAFT_ORIENTATION_DESC = "VEX_ORIENTATION_DESC.TXT"
```



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```
SPACECRAFT_POINTING_MODE      = "NULL"
^SPACECRAFT_POINTING_MODE_DESC = "VEX_POINTING_MODE_DESC.TXT"
DECLINATION                    = "NULL"
RIGHT_ASCENSION                = "NULL"
MAXIMUM_LATITUDE               = "NULL"
MINIMUM_LATITUDE               = "NULL"
EASTERNMOST_LONGITUDE          = "NULL"
WESTERNMOST_LONGITUDE          = "NULL"
SLANT_DISTANCE                 = "NULL"

/* Instrument status */
INSTRUMENT_MODE_ID            = 7
^INSTRUMENT_MODE_DESC          = "VIRTIS_EAICD.TXT"
INST_CMPRS_NAME                = "NULL"
INST_CMPRS_RATE                = "NULL"
INST_CMPRS_RATIO               = "NULL"

VEX:VIR_H_START_X_POSITION     = "NULL"
VEX:VIR_H_START_Y_POSITION     = "NULL"
FRAME_PARAMETER                = (400, 2, 1, 766.7, 3)
FRAME_PARAMETER_DESC           = ("EXPOSURE_DURATION", "FRAME_SUMMING",
    "FRAME_ACQUISITION_RATE", "INTERNAL_REPETITION_TIME",
    "DARK_ACQUISITION_RATE")
FRAME_PARAMETER_UNIT           = ("MS", "DIMENSIONLESS", "DIMENSIONLESS",
    "MS", "DIMENSIONLESS")
EXPOSURE_DURATION_DESC         = "-1: many exposure times (calibration sessions)
Values are available in sideplane. See EAICD.TXT"
MAXIMUM_INSTRUMENT_TEMPERATURE = (273.0, 283.0, 293.0, 303.0)
INSTRUMENT_TEMPERATURE_POINT   = ("FOCAL_PLANE", "GRATING", "PRISM", "CRYOCOOLER")
INSTRUMENT_TEMPERATURE_UNIT    = ("K", "K", "K", "K")
VEX:VIR_PIXEL_MAP_FILE_NAME    = "PIXELMAP.DAT"
VEX:VIR_DEAD_PIXEL_MAP_FILE_NAME = "DEADPIXELMAP.DAT"
VEX:VIR_H_PIXEL_MAP_COEF       =
(( 4.749950E+1, 1.247300E-1, 9.890690E-5 ),
 ( 9.938600E+1, 9.844940E-2, 7.085630E-5 ),
 ( 1.341680E+2, 8.166750E-2, 4.918400E-5 ),
 ( 1.591860E+2, 6.661960E-2, 4.094150E-5 ),
 ( 1.773400E+2, 5.713190E-2, 2.702870E-5 ),
 ( 1.904680E+2, 5.634040E-2, 5.267310E-6 ),
 ( 2.012000E+2, 4.654330E-2, 1.068770E-5 ),
 ( 2.093140E+2, 4.806390E-2, -8.723980E-6 ))
VEX: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 = "NULL"

/* Spectral table */
OBJECT = TABLE
INTERCHANGE_FORMAT = BINARY
ROWS      = 3456
COLUMNS  = 3
ROW_BYTES = 12
OBJECT = COLUMN
NAME      = "WAVELENGTH"
UNIT      = "MICRON"
DATA_TYPE = "REAL"
```



```
START_BYTE = 1
BYTES      = 4
MISSING_CONSTANT = 0.0
DESCRIPTION = "Wavelengths list for this file"
END_OBJECT = COLUMN
OBJECT = COLUMN
NAME       = "FWHM"
UNIT       = "MICRON"
DATA_TYPE  = "REAL"
START_BYTE = 5
BYTES      = 4
MISSING_CONSTANT = 0.0
DESCRIPTION = "Estimated channel widths for this file"
END_OBJECT = COLUMN
OBJECT = COLUMN
NAME       = "UNCERTAINTY"
UNIT       = "W/m**2/sr/micron"
DATA_TYPE  = "REAL"
START_BYTE = 9
BYTES      = 4
MISSING_CONSTANT = 0.0
DESCRIPTION = "Estimated uncertainties for this file, 1 sigma"
END_OBJECT = COLUMN
END_OBJECT = TABLE

/* Cube keywords */
OBJECT = QUBE
AXES           = 3
AXIS_NAME      = (BAND,SAMPLE,LINE)
CORE_ITEMS     = (x,y,z)
CORE_ITEM_BYTES = 4
CORE_ITEM_TYPE = "REAL"
CORE_BASE      = 0.0
CORE_MULTIPLIER = 1.0
CORE_VALID_MINIMUM = -999
CORE_NULL      = -1004
CORE_LOW_REPR_SATURATION = -1003
CORE_LOW_INSTR_SATURATION = -1002
CORE_HIGH_REPR_SATURATION = -1001
CORE_HIGH_INSTR_SATURATION = -1000
CORE_NAME      = RADIANCE
CORE_UNIT      = "W/m**2/sr/micron"

SUFFIX_BYTES   = 2
SUFFIX_ITEMS   = (N, 0, 0)
BAND_SUFFIX_NAME = "SCET"
BAND_SUFFIX_UNIT = DIMENSIONLESS
BAND_SUFFIX_ITEM_BYTES = 2
BAND_SUFFIX_ITEM_TYPE = MSB_UNSIGNED_INTEGER
BAND_SUFFIX_BASE = 0.0
BAND_SUFFIX_MULTIPLIER = 1.0
BAND_SUFFIX_VALID_MINIMUM = 0
BAND_SUFFIX_NULL = 65535
BAND_SUFFIX_LOW_REPR_SAT = 0
BAND_SUFFIX_LOW_INSTR_SAT = 0
BAND_SUFFIX_HIGH_REPR_SAT = 65535
BAND_SUFFIX_HIGH_INSTR_SAT = 65535
END_OBJECT = QUBE

END
```




9 Appendix E: Software versions

The value of the keyword `SOFTWARE_VERSION_ID` includes references to the software used in sequence to handle the data. It is therefore a history of the processing applied to each individual file.

The VIRTIS VEx on-board software was implemented before launch in version 2.50

An update was performed on June 13th, 2007 to version 2.60 (including tuning of H shutter synchronization to solve the corrupted dark issue, plus limitation of HK generation to avoid saturation of the spacecraft DHU).

A major update of the EGSE was performed in March 2007. All files in the archive are processed with (at least) this version. Among other things, the EGSE generates the first version of the PDS raw data files.

The geometry and calibration software has evolved regularly. The minimum versions used in the archive are listed in table F-1. This information is mainly relevant to the team, to insure the data are processed consistently.

Software	Comment	Values in <code>SOFTWARE_VERSION_ID</code>
On board software	Updated on June 13th, 2007	"VirtisVEX SW v.2.50" "VirtisVEX SW v.2.60"
EGSE	Updated March 2007	"EGSE_SOFT_7.0" "PDS_CONVERTER_7.0" "EGSE2PSA_CONVLABEL_1.2.2"
Geometry computation		"GEOVIRTIS_4.0"
Geometry formatting + update of raw data labels		"V_GEOLABEL_5"
H-calibration scheme		"CALVIRTIS_1"
M-calibration scheme		"V_CALIBM_VEX_2.1"
Label updates (for minor fixes between releases)		"UPDATECALLABEL_2.0" "UPDATEGEOLABEL_2.0"
Calibrated files formatting		"V_CONVLABEL_2.0"

Table F.1 – reference to software used to generate the archive

10 Appendix F: Numeric codes

In some instances, numeric codes are used both in the labels and in the data fields to indicate special situations. These codes are listed here:

In file labels:

-999.99 is used to flag an unknown / non-defined value where a digital value is expected. The standard PDS use of alphabetical codes (UNK...) would result in reading errors.
Ex: DECLINATION when the spacecraft is not in inertial mode.

-1 for integration time. It is used to flag non-constant integration time during a sub-session. This normally occurs only during calibration sessions. In this case, the actual values can be retrieved from the sideplane for every time step (see [AD 9]).



Used in the first and third fields of FRAME_PARAMETER (resp. EXPOSURE_DURATION and EXTERNAL_REPETITION_TIME).

- 1 for ORBIT_NUMBER. It is used to identify pre-orbital observations with VIRTIS. The orbit number is encoded as 9999 in the corresponding file names. Orbit 0 corresponds to the Venus Orbital Insertion phase.
- 0 for SCIENCE_CASE_ID. This extra Science Case code is used to flag data acquired when Venus is not observed. This includes calibration sessions and observations of targets different from Venus.

In raw data qube cores:

Data are stored in DN but may be negative, because a dark current estimate is already subtracted on board. The following codes are introduced through the standard PDS keywords for the Qube object:

- 32768 Default value for NULL, and minimum valid value
- 32767 Maximum valid value, including saturation

In raw data qube suffix:

- 65535 (= 'FFFF' hexa) Flags missing HK measurement (this value is not normally used by any HK parameter)

In calibrated data qube cores:

Data are stored in physical units but may be negative, because of fluctuations on the dark current. The following codes are introduced through the standard PDS keywords for the Qube object:

- 999 Minimum valid radiance value
- 1004 No available data (including dead pixels)
- 1003 Low representation saturation
- 1002 Low instrumental saturation
- 1001 High representation saturation
- 1000 High instrumental saturation (physical saturation of the FPA)

In geometry files:

Different quantities are stored in the same qube core, in various physical units. The file structure is described in detail in document [AD 13]. Special codes used in this context are:

- 20000 Missing value for elevation (missing in the GTDR)
- 100000 This offset value is added to surface elevation for limb observations (line of sight not intercepting the planet ellipsoid). It must be subtracted from the written value to retrieve the tangent altitude.
- 2147483648 (= '80000000' hexa) Quantity cannot be computed due to missing HK parameter.