FM VIRTIS
EXPERIMENT USER MANUAL
(Delta Documentation)

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DOCUMENT CHANGE RECORD

ISSUE	DATE	TOTAL PAGES	AFFECTED PAGES	DESCRIPTION OF MODIFICATION
1	5/6/2004	49	All	First issue
2	23/12/2004	49		Most of the modifications are relevant for the action items arose during the review meetings. Among the others, in particular: Updated AD and RD, attachments, Software design, Budgets. Non ops heaters, Experiment operations, Interference tests, Alignment in flight. De-icing, Science cases, in particular case 3 pointing strategy Replaced OBCP operations with switch on and off procedure through DMS.

LIST OF VALID PAGES

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A. SCOPE

This document is a delta document and it updates or replaces part of the document "VIRTIS EXPERIMENT USER MANUAL ProtoFlight Model working copy", RO-VIR-UM-001, issue 3, for the VIRTIS experiment on the Rosetta mission. The RO-VIR-UM-001 is essential part of this document and the here given version is the latest at today.

B. APPLICABILITY

This document is applicable to VIRTIS for Venus Express FM.

C. DOCUMENTATION

C.1. APPLICABLE DOCUMENTS

AD 01 RO-VIR-UM-001, Issue 3 Working copy, July 2003, VIRTIS Experiment User Manual (for Rosetta)

AD 02 VVX-GAF-IC-002, Issue 1, December 2003, VIRTIS S/W Internal ICD

AD 03 VVX-GAF-UR-001, Issue 1, December 2003, VIRTIS S/W User Req.

AD 04 VVX-GAF-IC-003 Issue 4, 12/07/2004, VIRTIS OBDH ICD

AD 05 VVX-DLR-MA-001 Issue 3 rev 1, 06/07/2004, VIRTIS On Board Software User Manual for S/W PROM version 2.0.1 and EEPROM version 2.40

AD 06 VEX/CO/0027/T.ASTR, VIRTIS for Venus Express Partnership Agreement

AD 07 PID-A MEX-MMT-SP-0007 Issue : 02 Rev. : 0001 Payload Interface Document

AD 08 VEX-T.ASTR-TCN-00665 Issue 3, 12 December 2003 : Science cases definition and study assumptions

AD 09 VEX-T-ASTR-CR0008, Issue 4 rev 5, September 2003

AD 10 VEX-T.ASTR-UM-00882 Issue 1 Rev.0, 27 February 2004: Venus Express User Manual Volume 1 (Mission and Spacecraft Overview)

AD 11 VEX-T.ASTR-UM-01097 Issue 1 Rev.0, 27 February 2004: Venus Express User Manual Volume 2 (Spacecraft Functions Detailed Design)

AD 12 VEX-T.ASTR-UM-01098 Issue 1 Rev.0, 27 February 2004: Venus Express User Manual Volume 3 (Spacecraft Operations)

C.2. REFERENCE DOCUMENTS

RD 01 VVX-VIR-BD-001, issue 1, 10 October 2004, VIRTIS Performance Budget

RD 02 VVX-VIR-TN-001, issue 1, 25 October 2004, VIRTIS Performance Analysis

RD 03 VVX-GAF-TN-030, rev. 0, 14 September 2004, VIRTIS limited life items status & budget @ delivery

RD 04 VVX-GAF-MA-002, issue 4, 27 August 2004, VIRTIS for Venus Express FM AIT Manual

RD 05 VEX-ESC-IF-5005, issue 1 rev 2, 17 August 2004, Flight Dynamics Interface Control Document

RD 06 VEX-T.ASTR-ICD-00326, issue 1 rev 1, 06/06/03, Generic TM/TC ICD

C.3. NEW APPLICABLE ATTACHMENTS

ATTACHMENT 0 : AD 01, RO-VIR-UM-001, Issue 3 Working copy, July 2003, VIRTIS Experiment User Manual (for Rosetta)
ATTACHMENT 1 : VIRTIS Modules Mechanical ICDs And Assembly Drawings
ATTACHMENT 2 : AD 04, VVX-GAF-IC-003 Issue 4, 12/07/2004, VIRTIS OBDH ICD
ATTACHMENT 3 : AD 05, VVX-DLR-MA-001 Issue 3 rev 1, 06/07/2004, VIRTIS On Board Software User Manual for S/W PROM version 2.0.1 and EEPROM version 2.40
ATTACHMENT 4 : N/A
ATTACHMENT 5 : AD 03, VVX-GAF-UR-001, Issue 1, December 2003, VIRTIS S/W User Req.
ATTACHMENT 6 : AD 02, VVX-GAF-IC-002, Issue 1, December 2003, VIRTIS S/W Internal ICD

D. DEFINITIONS

D.1. LIST OF ACRONYMS

AD	Applicable Document
CCD	Charge Coupled Device, detector for the visible channel of VIRTIS-M
CCE	Cryo-Cooler Electronics
DMS	Data Management System
FOV	Field Of View
EIDP	End Item Data Package
EM	Engineering Model
FM	Flight Model
GA	Galileo Avionica
IFOV	Instantaneous Field Of View
NCR	Non Conformance Report
NEV	Near Earth Verification
PEM-H	The VIRTIS-H proximity electronics
PEM-M	The VIRTIS-M proximity electronics
PUS	Packet Utilization Standard
RD	Reference Document

RFW	Request For Waiver
SPC	Spacecraft
SWT	Science Working Team
TLC	Tele-Command
TRP	Temperature Reference Point
VIRTIS	Visible Infra Red Thermal Imaging Spectrometer
VOI	Venus Orbit Insertion
VVX	VIRTIS for Venus Express
-H	VIRTIS-H, the VIRTIS High Resolution Spectrometer channel
-M	VIRTIS-M, the VIRTIS Mapping channel
-ME	VIRTIS-ME, the VIRTIS Main Electronics
-OM	VIRTIS-OM, the VIRTIS Optical Module

1. GENERAL DESCRIPTION

1.1. SCIENTIFIC OBJECTIVES

VIRTIS is an imaging spectrometer which will allow 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 CO_2.

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 (0.25-1μm) and one infrared (1-5 μm) are committed to spectral mapping, and are housed in the Mapper (-M) optical subsytem. One channel is devoted solely to spectroscopy at high resolution, and is housed in the High resolution (-H) optical subsystem (2-5 μm). 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.

1.1.1. 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 unprecedent 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, SO_2, H_2O) from 1-2.5 μm 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 will also provide true colour high definition images of Venus of great value for public outreach programme.

1.1.2. 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 μm, 1.1, 1.18, 1.74 and 2.3 μm are sensitive to radiation coming from layers from the surface (in the shortest wavelength) to about 30 km (to be compared to the cloud level at about 60 km altitude), only in night side observations, sensitive to the thermal emission from the atmosphere. The solar reflection by the clouds on the day side contribute to more than 10000 flux than thermal emission, and completely overwhelm the thermal emission of the deeper layers.

VIRTIS-M: main purpose = spectral mapping visible and infrared at moderate spectral resolution
Night side
- Surface mapping (0.9, 1.1, 1.18 μm)
- O_2 emission (at 1.27 μm)
- Lower atmospheric sounding (H_2O)
- Lightning search

Day side
- UV cloud absorber signature / correlation with IR absorptions
- O_2 emission (at 1.27 μm), also observed at day
- CO_2 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 CO_2 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 will give a high signal to noise on the day side in a very short time; night side observations on the contrary will need longer integration (of the order of 1 sec 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.

1.1.3. OBSERVATION STRATEGY

The usual observation mode is for both channels working together, but each channel can be operated alone if needed (for limited resources for example).

The different orbital cases are related to different scientific objectives:

Case 1 (pericenter observations): these observations will usually be made as VIRTIS without scanning mirror motions (TBC), as image reconstruction will not be possible in this mode. Statistical coverage of different regions of Venus, on night as well as on day side will be possible. Occasionally the use of the scanning mirror (in fixed or scanning mode) will improve this statistical coverage

Case 2 (off-pericenter observations): these observations allow VIRTIS to perform spectral mapping (for -M), with image cube reconstruction obtained by internal mirror motion synchronized with orbital motion (an altitude higher than 12000 km is needed for this mode). This mode is considered as the main scientific observing mode for VIRTIS, as most of the scientific objectives, related to combined spectroscopic/mapping observations are obtained in this mode

Case 3 (apocenter observation): this mode is the extreme case of previous mode, and allow VIRTIS to observe the full disk of Venus (from South hemisphere point of view), through off-nadir pointing in 3x3 mosaics (or more). This mode will be used for global meteorology (with repetition during several orbits to get a full atmospheric rotation). It will also be of high interest for public outreach images.

Case 5 (stellar occultation/3 axis stabilized): used in parallel with SPICAV observations, VIRTIS will, as SPICAV, be able to retrieve upper atmospheric structure and composition by studying stellar flux spectral absorptions. In particular, minor constituents could be detected, and the upper atmosphere structure will be deciphered from CO_2 absorption

Cases 7 (limb sounding) VIRTIS unique capabilities of imaging in the 4.3 μm band of CO_2 will allow a powerful sounding of the mesospheric emissions. The only operational constraint in this mode is to avoid VIRTIS slit to be parallel to the limb, but no specific angle is required. Mars Express/OMEGA observations on the limb of Mars have provided interesting observations (Nice EGU meeting, April 2004), which VIRTIS on Venus could complement in a similar observing mode.

2.2. ELECTRICAL I/F

2.2.1. POWER INTERFACE CIRCUIT

The decontamination heaters (only) are not any more applicable, being not implemented on VIRTIS for Venus Express.

2.3.2. SOFTWARE DESIGN

The EEPROM software for the Venus Express version is the **2.40** while the PROM version is identical to the Rosetta one (2.0-1). The version **2.50** for the EEPROM has been issued but not yet uploaded into the main electronics

2.4. BUDGETS

2.4.1. MASS

The mass of the instrument can be retrieved from the single unit masses as reported in the PFM ADP, and listed hereafter in the Table 2.4.1.1.

Table 2.4.1.1 : The table reports the VIRTIS-VEX mass record measured during the acceptance campaign. Savers, shorting plugs, covers and red tagged items are not included in the measurements.

#	Unit	Mass (g)	#	Unit	Mass (g)
1	OM	19527	11	VIR 9H	211,6
2	External Sun Shields	905	12	VIR10H	95,3
3	Lateral MLI	470	13	VIR11H	159,4
4	PEM-M	2895,5	14	VIR12H	101,8
5	PEM-H	1216	15	VIR 13H	107,3
6	ME	5606	16	VIR 14H	90,9
7	VIR5H	436,1	17	VIR 15H	64,6
8	VIR 6H	352,6	18	VIR 16H	81,4
9	VIR 7H	275,1	19	VIR 17H	51,4
10	VIR 8H	381,8	20	VIR 18H	58,4
TOTAL	**VIRTIS-VenusX FM**				**33087.2**

2.4.2. OPERATING POWER

In Table 2.4.2.1 the power consumption of each subsystem under different operating conditions and different operative modes is given. These values has been retrieved during the thermal vacuum test of VIRTIS.
During -M cover operation which is possible in all modes, add 11W (30sec max peak). During –H cover operation which is also possible in all modes, add instead 6.5W (30sec max peak).

All modes with science acquisition are referred to cooler in steady state and then in full operative temperature for the IR detectors.

Table 2.4.2.1 : VIRTIS Subsystems power consumption.

	VIRTIS Power Consumption on Main Power Bus vs. Operating modes	ME	PEM-M	PEM-H	Power consumption (W)
1	Science M/H	Science	Science	Science	49.63
2	Calibration M	Science	Calibration	Idle	51.89
3	Calibration H	Science	Idle	Calibration	44.24
4	-ME IDLE	Idle	OFF	OFF	5.92
5	Cool-down -M	Idle	Cool-down	OFF	22.56
6	Cool-down -H	Idle	OFF	Cool-down	22.96
7	Cool-down -M + -H	Idle	Cool-down	Cool-down	43.43
8	PEM-M IDLE Steady State	Idle	Idle	Cool-down	47.66
9	PEM-H IDLE Steady State	Idle	Cool-down	Idle	45.23
10	PEM-M+-H IDLE Steady State	Idle	Idle	Idle	52.73
Δ	Cover – M				0.28
Δ	Cover – H				0.28
11	Annealing	Idle	Annealing	Annealing	31.92
12	PEM-M+-H ON	Idle	PEM-ON	PEM-ON	26.23
Δ	Emergency Cover actuation				33.84 (-H)

During the cool-down phase, a long peak of 70 W can be reached.
We remind that VIRTIS power consumption is strongly dependent on the cryocooler thermal load (essentially cold box temperature) and boundary conditions.

2.4.3. DATA RATES (H/K AND SCIENCE)

VIRTIS shall dump data and H/K on the DMS through two channels the 16 bit Serial Digital Telemetry (SDT), slow line, and the High Speed Link (HRD).
The SDT I/F is used for the following functions:

- to transfer in serial form the housekeeping data. Data rate for H/K transmission shall not exceed the 3 Kbit/s

- . to transfer a limited volume of science data in case of failure of HSDC I/F (degraded mode). Average data rate in degraded mode (H/K plus science data) will not exceed 60 Kbit/s.

VIRTIS shall use the HRD channel to download science data directly on the SSMM. Only in case of HRD line failure, the data shall be transferred using the 16bit serial TM line.
The average data rate on the HRD is highly dependent on the selected scientific mode (selected by e.g. pixel binning, repetition time, etc), on the data compression factor, whose exact value depends on the typical scene content, and on the number of channels used (either only –M, only –H or both). The details on the operative modes and the full list of the instrument data rates in the various operative modes are given in table 3, pag. 18 of AD 04. The maximum expected data rate shall not exceed the 700 Kbit/s over 2.5 sec periods.

2.4.4. NON-OPS HEATERS

The decontamination heaters (only) are not any more applicable, being not implemented on VIRTIS for Venus Express. For the decontamination or de-icing of the radiator, see par. 4.3.1.7
For the CCD storage heaters, the heaters are both located inside the VIRTIS–M Cold Box at visible detector level. In Figure 2.4.4-1 is shown the location of the heaters and thermistors. They shall be both switched-on at the same time (total required power of 0.2W). From a thermal point of view, it is agreed to not consider this thermal dissipation during VIRTIS Safe mode, because it is negligible.

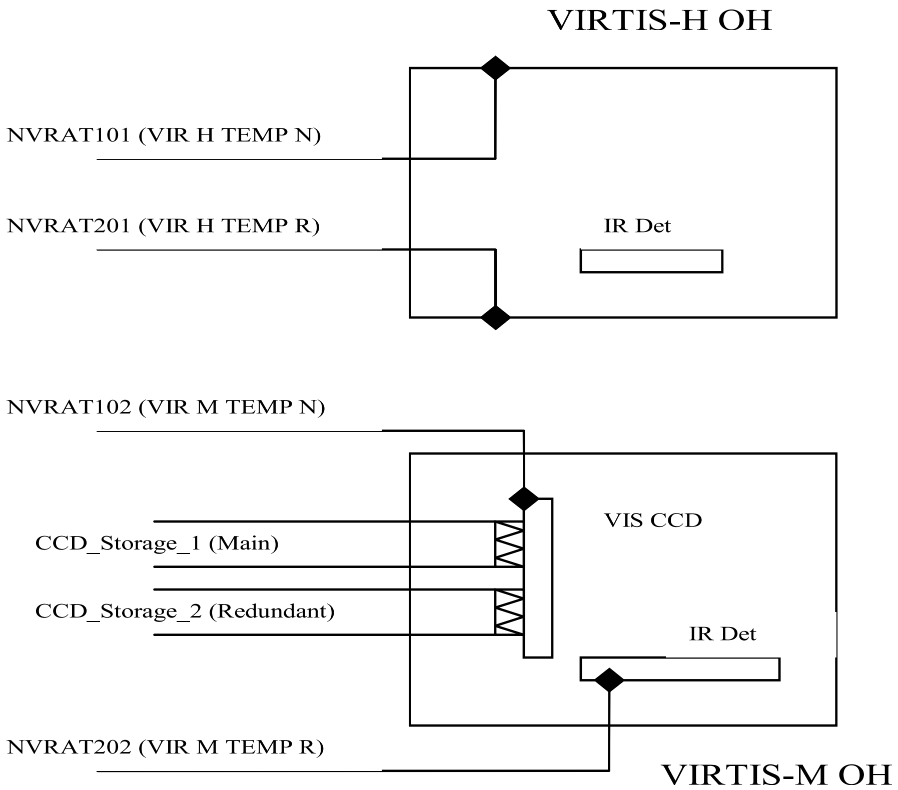

Figure 2.4.4-1 : VIRTIS CCD_storage heaters & S/C powered thermistors location

Differently from Rosetta mission, due to the more stringent thermal environment of Venus Express at Venus, the CCD storage heaters must be off when VIRTIS PEM-M is on and they should be conditioned to temperature when the PEM-M is off according to the following scheme:

```
--------------------------------------------------------------------------------
case NVRD0004=1 (PEM-M=ON) then HEATERS always OFF
case NVRD0004=0 (PEM-M=OFF) then
      HEATERS ON if NVRAT102 VIR M TEMP N) < -123°C
      HEATERS OFF if NVRAT102 (VIR M TEMP N) > -113°C
--------------------------------------------------------------------------------
In case of failure of the NVRAT102 (VIR M TEMP N), it has to be used as redundant
thermistor the NVRAT201 (VIR H TEMP R), inside VIRTIS-H cold box. Notice that in
this case (failure case), the heaters will be decoupled from the thermistor and
thus no effect will result from the temperature reading after the heaters are on.
```

The power consumption of the heaters is given in Table 2.4.4.1.

	Heater Function	Average (BOL) [W]	Long Peak [W]	Short Peak [W]
1	Decontamination Heater_1	N/A	N/A	N/A
2	Decontamination Heater_2	N/A	N/A	N/A
3	CCD_Storage_1	0.1	0.1	0.1
4	CCD_Storage_2	0.1	0.1	0.1

Table 2.4.4.1 : power consumption of the VIRTIS-VEX heaters

3. OPERATING MODES DESCRIPTION

3.1. INTRODUCTION

VIRTIS is an highly complex instrument, in fact inside a common structure (the Optics Module) it contains two scientifically complementary but operationally independent instruments: VIRTIS -H and VIRTIS -M. The difficult task of the ME on board software has been thus to manage two separate instruments with different timing and data processing requirements working most of the time in parallel. The Main Electronic Software shall allow full independent operations of VIRTIS -M and VIRTIS-H.
In producing this User Manual we have been trying to summarise the main characteristics of the instrument operations. However, to describe fully the operations of the instrument a large number of documents is required. Thus it has been considered most useful to have these documents being integral part of this User Manual as attachment rather than duplicating information. Thus the following documents have been attached and can be found at the end of the document:

AD 02, VVX-GAF-IC-002, Issue 1, December 2003, VIRTIS S/W Internal ICD
AD 03, VVX-GAF-UR-001, Issue 1, December 2003, VIRTIS S/W User Req.

AD 04, VVX-GAF-IC-003 Issue 4, 12/07/2004, VIRTIS OBDH ICD

AD 05, VVX-DLR-MA-001 Issue 3 rev 1, 06/07/2004, VIRTIS On Board Software User Manual for S/W PROM version 2.0.1 and EEPROM version 2.40

4. EXPERIMENT OPERATIONS

4.1. OPERATIONAL CONSTRAINTS

In this chapter we list the operational constraints (for both on ground and in-flight activities) and instrument usage tips arisen during testing and operation of the instrument.

4.1.1. THERMAL LIMITATION ON ME USAGE

It is not applicable to VIRTIS for Venus Express. There is no any thermal limitation for temperatures within the op and not op ranges. For more general thermal constraints see par. 4.1.9

4.1.2. HIGH SPEED LINK DISCONNECTION

This constraint was supposed applicable for on ground operations.
For in flight operations it is not applicable.

4.1.3. INCORRECT HOUSE KEEPING READING (NCR RO-VIR-NCR-0038)

It is not applicable to VIRTIS for Venus Express. Different hardware.

4.1.4. NO EVENT REPORT OF SUCCESSFUL PRIMARY BOOT

No change.

4.1.5. EVENT RUNS UNSYNCHRONISED

This event is issued only when an accept_time_update is NOT issued after 60s from Power on. After 60 sec from Power on the instrument start in Unsynchronised mode even if the time update is not done.

When the instrument start in Unsynchronised mode is not more possible to synchronise the time until:

1) VIRTIS is switched OFF and then ON again
2) VIRTIS is sent in IDLE mode using VTC_EnterIdle TC, but in this case the event ME_SCET_WRONG is issued when the new time update is received

4.1.6. OFFSET IN PS/DPU TEMPERATURE READINGS (RO-VIR-NCR-0049)

The RO-VIR-NCR-0049 is not applicable on Venus Express. Nevertheless, due to the VVX-GAF-NC-015 (ME_PS_TEMP HK changes in reference to the IFE status) , we still have an offset in the temperature readings under the following conditions.
A value from 3 to 4K (there is some variability) must be subtracted from the default housekeepings ME_PS_TEMP and ME_DPU_TEMP in case that the -ME redundant channel is ON and the –H CCE (inside the ME) is switched OFF. Differently if the –H CCE is ON the temperature housekeepings ME_PS_TEMP and ME_DPU_TEMP are correctly displayed.

4.1.7. SOFTWARE VERSIONS

At today the following S/W versions have been used in the FM:

- PROM version V2.0-1
- EEPROM version V2.40
- EGSE software version V2.2

We remind that inside the EEPROM of the main electronics, two software revisions can be stored at the same time even though only one (the latest) is used during routine operations. At the moment also the software revision 2.30 is stored inside the –ME.
Please, note that a new software revision for the main electronics has been issued (**V2.50**) along with the relevant documentation on September 30 2004 but not yet uploaded in the VIRTIS FM. We have to upload it as soon as a time slot during the spacecraft activity is available for this task. Once the new revision is loaded (**V2.50**) as latest release, also the software release V2.40 will be stored inside the –ME EEPROM according to the previous statement.

4.1.8. COVERS AND SUN CLEARANCE ANGLE

A general operational constraint is to avoid the direct Sunlight into the VIRTIS FOV which might be dangerous for the detectors when the detectors are working and which may affect the thermal behaviour of the instrument for the successive observations when the detectors are not working. The right use of the covers (both –M and –H) is very important to avoid these problems.
From this point of view, VIRTIS requires the closure of the –M and –H covers when the angle between the Sun line of sight and the FOV boresight is less than **15deg**. This action will prevent the incoming of the Sunlight directly into the instrument cold boxes. Notice that the geometry of this concurrence is particularly probable in specific phases of the mission.
In summary, the VIRTIS covers must be closed when VIRTIS is not operating or when the angle between the Sun line of sight and the FOV boresight is less than 15deg.
The Sun clearance angle given for degraded operations on Rosetta (40deg) is not applicable on VEX.

4.1.9. THERMAL CONSTRAINTS AND SCIENTIFIC PERFORMANCES

VIRTIS is a high sensitivity instrument having the optical module essentially working at cryogenic temperature in order to reduce the thermal background for the infrared channels (both –M and –H). Despite it has been designed for the colder environment experienced by the Rosetta mission, its high sensitivity makes it suitable also for Venus Express where we expect a more demanding thermal environment. On one hand the radiance from Venus day side will be so high that the integration time to be used will be of the order of 20ms for infrared, see par.8.2 of RD 02. On the other hand we expect a weak signal from the Venus night side which implies a longer integration time of the order of a few sec, depending on the thermal environment, see par.9.2 of RD 02. A summary of the temperature ranges for the subsystems of VIRTIS is given in the Table 4.1.9.1. In the table is also identified the cryocoolers temperature constraint in the –OM cryocoolers interface temperature range. For the cold boxes, both –M and –H, there is an upper thermal limitation (not operative conditions, flight and ground) of +40°C due to the infrared detector thermal constraint, see RD 03. Even though VIRTIS has been designed to work at a temperature of 135K for the cold boxes, both –M and –H, for Venus Express the thermal requirement has been relaxed to **150K**. On the other hand, because we expect a variable thermal environment and stringent thermal conditions at certain seasons, during the VIRTIS calibration campaign performed on ground we tested the instrument at 165K for the cold boxes. That's way in the Table 4.1.9.1 has been given this temperature as the maximum operative temperature for –OM cold boxes. As one can imagine, it has to be said that the scientific performances of the infrared channels are progressively degraded when the temperature of the cold boxes is more and more high, due to the increasing of the thermal background. The –M visible is not affected by the thermal background but the performance is anyway degraded when the visible detector temperature is higher.

Table 4.1.9.1 : temperatures range

	OPERATIVE		NOT OPERATIVE	
	Min	Max	Min	Max
VIRTIS-ME	-20°C	+50°C	-30°C	+60°C
PEM-M	-20°C	+50°C	-30°C	+60°C
PEM-H	-20°C	+50°C	-30°C	+60°C
-OM @ Cryo-Coolers interface	-20°C	+40°C	-30°C	+60°C (*)
-OM cold boxes (It is not a TRP)	-138°C (**)	-108°C (**)	-168°C (***)	+40°C

(*) only in flight conditions with radiator on the shadow (and thus –OM cold boxes at operative temperature) otherwise +40°C if the –OM cold boxes at +40°C. For cold boxes the upper limit is +40°C due to the detectors thermal limitation.
(**) the operative range here given is the minimum and maximum temperature tested during the VIRTIS calibration campaign. The functional temperature can cope with a wider range but the scientific performances are progressively degraded when the temperature is more and more high.
(***) CCD storage heaters should be already on.

It has to be noticed that the –OM cold boxes temperature is not a real TRP and the temperature readings to the SPC are placed in different regions for –M and –H. Only for –H the two readings are placed on the box while for –M they are on the detectors and are not representative of the cold box temperature. Thus, for a full and homogeneous treatment of the cold boxes, the temperatures have to be evaluated by using the VIRTIS thermal model.
When VIRTIS is operative the radiator must be oriented to the shadow, or the x component of the SPC-Sun vector in the SPC reference system must be positive (as from Figure 4.1.1, section 3 of AD 10). For a discussion about a different orientation of the radiator during the VIRTIS not operative conditions, see the de-icing procedure in par. 4.3.1.7 which defines also the upper boundaries when the radiator is exposed to the Sun.
It has to be mentioned that there is a thermal-mechanical constraint (as for Rosetta) due to the sophisticated blocking mechanism of the internal –M scanning mirror which is unblocked at a temperature lower than 200K (including margin, by design is 230K). It means that the internal –M scanning mirror must not be operated at a temperature higher than 200K, value on the other hand falling in the not operative range of VIRTIS.

4.1.10. CRYOCOOLERS AND INFRARED DETECTORS OPERATIONS

The two cryocoolers of VIRTIS along the two IR detectors are identified as limited life time items of the instrument. These items have also been used and operated during the ground testing and calibration activities. The budget at delivery for all the items is given in RD 03 at the time of the official DRB meeting. These items are internally operated by VIRTIS according to the operational procedures and observation strategy. In flight use of these components during the mission will be optimised phase by phase and case by case in order to limit the lifetime resources.
For this reason the number of switch on and the operating time of the cryocoolers plus the thermal profile and operating time of the IR detectors operations will be recorded and monitored during all the mission activity. This information can be then used for predictive lifetime limit of the items.
The cryocooler has been endurance tested on Rosetta by Galileo Avionica for 440 ON-OFF cycles and for an Operating Time of 3400 hours. However, as heritage of life demonstration test performed at Ricor on K508 cryocooler similar type, the estimated cryocooler lifetime is greater than 10700 hours with a number of On-Off cycles of 1300. Budget at delivery is 39 for the total switch-ON number for –M (equal for –H) and 321 hours for the accumulative operating time for –M (323 hours for –H).
The guarantee operating time for the IR detectors by the manufacturer dossier is 1 year under flight environment conditions.

4.1.11. INCORRECT EEPROM SWITCHING OFF

In PROM-S/W V2.0 (07/2000) the EEPROM power is not properly switched-off after a Memory Management (Mem id 143) action with access to the EEPROM device (e.g. software upload), see VVX-VIR-NC-021. The EEPROM voltage is still about 4,3V after switching off the device (EEPROM voltage provided by ME Default HK Report TM packet).
The problem is due to a wrong EEPROM switching OFF procedure implemented in the PROM SW and is present only when VIRTIS is in SAFE mode and only when Load/Dump/Check Memory ID 143 is performed.

In the EEPROM SW it is implemented the correct EEPROM switching OFF procedure, so after a VTC_ENTER_IDLE TC (SW secondary boot from EEPROM to RAM) the EEPROM is correctly switched OFF.

As work around procedure the following step have to be performed during Memory Management Mem ID 143:

- VIRTIS in SAFE mode (memory management is possible only in SAFE mode)
- PROM SW is running
- Perform Memory ID143 management activities (ZVR14302 or ZVR14305 or ZVR14309)
- Send ZVR00000 VTC_Enteridle (EEPROM will be switched OFF by EEPROM SW after its upload and start in RAM)
- EEPROM SW is running in RAM
- go back to SAFE mode using ZVR00037 VTC_EnterSafe if other Memory management activities are planned on other Memory IDs

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4.1.12. NON-OPS HEATERS

For the correct use of the non-operations heaters (CCD storage heaters), see par.2.4.4

4.1.13. PACKET UTILIZATION STANDARD (PUS) FOR SOLICITED TELEMETRY PACKETS

For solicited TM packet (telemetry packet in response to TC) the PUS follows the following rules:
0 : for science data TM service (20,3) and (20,13)
2 : for all the other TM reports.

VIRTIS follows the same described rule both for solicited and unsolicited TM packet. The rule is derived from Rosetta requirement and it is implemented in the –ME PROM on board software and it cannot be changed.

This rule is different with respect to the rule defined in par. 5.1.2 of RD 06

4.2. GROUND OPERATION PLAN

The detailed ground test plan along with the specific AIT procedures is given in RD 04.
Here we point out that VIRTIS is not intended for use under ambient conditions in its full configuration. In fact, VIRTIS is an infrared spectrometer which needs to be cold to operate properly. Moreover, the scan mirror in VIRTIS-M has a sophisticated blocking mechanisms which frees it only below 200K.
This means that full operation can be performed only with the instrument under vacuum and at low environmental temperatures (less than 200K). Usage in air will damage the cryocoolers, the IR detectors and the VIRTIS-M Scan Mirror. This means that the testing activities at S/C level shall be split:

- Tests performed in clean room but at ambient pressure/temperature conditions. This include Bench Test, I&T, IST and partially the SFT which shall be limited to all the operations that do not require usage of Cryocoolers and IR detectors. In practice all test performed at Alenia - Torino premises fall in this category. Full functionality of the instrument cannot be tested; nonetheless, all the S/C interface can be operated and exercised.
- Test carried out inside the TV chamber (Thermal Vacuum and Thermal Balance tests). Under proper environmental conditions also performance measurements can be executed.

4.3. FLIGHT OPERATION PLAN

4.3.1. COMMISSIONING PLAN

The commissioning phase activities related to instruments usage shall be devoted to the Functional Tests (including internal calibration), to the Interference Tests (susceptibility of VIRTIS to external electrical noise and vice-versa) and to the co-alignment of VIRTIS with the other remote sensing instruments (SPICAV, VMC and possibly PFS).
For the Near Earth Verification phase, according to the AD08 starting from Day 8 to Day 28 we consider high priority the observations of Earth and Moon since their observation will be used for in

flight check of the on ground calibration and thus very important for testing the performances and the health status of the VIRTIS instrument. The same observations performed on VIRTIS Rosetta indeed were very fruitful for checking the general instrument behavior.
On the other hand we highlight that these observations are very important also for public outreach purposes. From this point of view It is important to begin the observation of Earth and Moon as soon as possible at the very beginning of the payload commissioning for NEV in order to be as close as possible to the observed targets.
We must again point out that for proper usage of the instrument the environmental temperature must be below 200K. This condition must be verified during ground operations as well as during in flight operations, and particularly for the commissioning phase when for the first time the instrument shall be powered.

4.3.1.1. FUNCTIONAL TESTS

No change.

4.3.1.2. INTERFERENCE TESTS

Basically the same as for Rosetta for what EMC is concerned, where on the other hand, we do not expect problems.

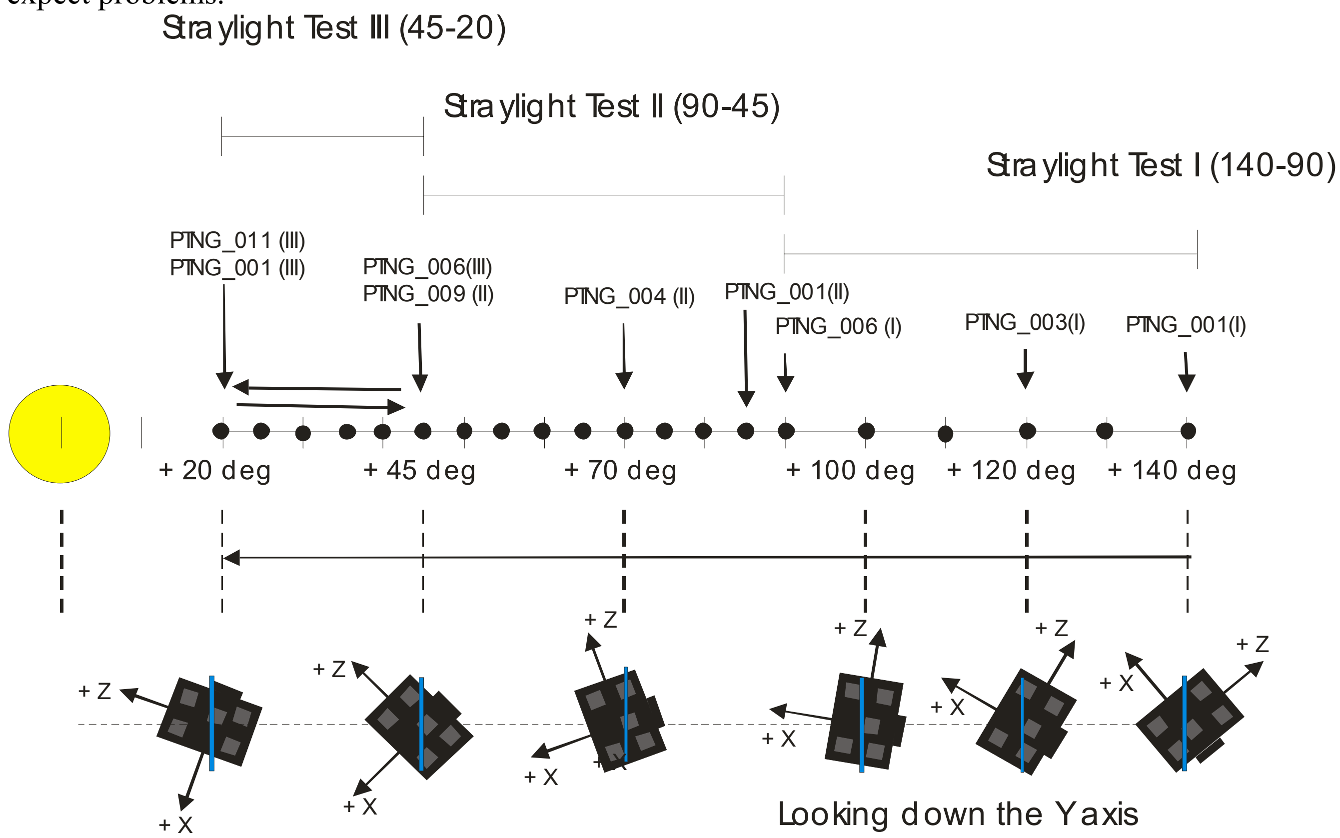

Figure 4.3.1.2-1 : possible starting point of a procedure for straylight measurements. We propose to apply the procedure also for different angles around X axis (detail TBD, still under discussion with VSOC)

Regarding the stray light check in flight we propose an extended campaign to fully test it in different conditions. Indeed at Venus we potentially have severe observation conditions due to the Sun close to the FOV in some season but also to the fact that we might have large radiance close to the instrument FOV from the Venus day side when observing at night side where the intensity is much weaker.We propose a test campaign strarting from that shown in Figure 4.3.1.2-1 but in addition to be performed also for different angles around X axis in order to explore lines of sight different with respect to VIRTIS boresight. It will help a lot if the campaign will be divided into several phases, as shown in the figure, in order to react and to refine the successive measurements according to the outcome from the previous tests.

4.3.1.3. INTERNAL CALIBRATION SEQUENCE

The VIRTIS-M calibration procedure is divided in 7 phases which are summarised in table 4.3.1.3-1 In each phase 5 repetition are performed. The data volume for the –M calibration shall then be given by: [(432x256) x 2 detectors (IR and CCD)] x 7 phases x 5 acquisitions x 16bit. The real Data volume must take into account also the packetisation for delivery to the S/C, thus producing a total of **128 Mbit (16 Mbytes).**

Calibration for –H (see table 4.3.1.3-2) consists of a spectral calibration with full detector reading and use of three different lamps. The calibration is partitioned in 4 phases each devoted to the use of a single lamp. For each lamp 7 H_Image_slice and 2 H_Spectrum shall be produced, giving a total data volume of **13.2 Mbit (1.65 Mbytes)**.

Phase #	Cover	Shutter	Lamp IR/VIS	Int. Time IR/VIS (s)	Mode
0	Close	Open	OFF/OFF	0.0 / 0.0	Read-Out Noise
1	Close	Open	OFF/OFF	0.5 / 1.0	Background VIS+IR
2	Close	Close	OFF/OFF	0.5 / 1.0	Dark VIS+IR
3	Close	Open	ON/OFF	0.5 / 20.0	IR acquisition +VIS
4	Close	Open	OFF/ON	0.02 / 1.0	VIS Acquisition + IR
5	Close	Close	OFF/OFF	0.5 / 1.0	Dark VIS+IR
6	Close	Open	OFF/OFF	0.5 / 0.5	Background VIS+IR

Table 4.3.1.3-1 VIRTIS-M calibration phases sequence

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 On
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) - Dark
	Closed	Open	OFF	OFF	ON	Radiometric Calibration (Spectrum) – Lamp ON

Table 4.3.1.3-2 VIRTIS-H calibration phases sequence

When a more extensive calibration and check out of the instrument will be executed, in addition to the internal calibration we shall also perform measurements of external dark opening the cover (TBC). For VIRTIS-M one 64x64 image acquisition (in the case of nominal mode) requires 18.9 Mbit uncompressed (including one dark every ten slices) while for high spatial resolution case it is 16 times larger. For VIRTIS-H the image mode correspond to 64 spectra (plus one dark every ten spectra) each of 55kbit. This make about 3.5 Mbit uncompressed. After the data compression with a compression factor of 2 (conservative) produces a data volume of 11.2 Mbit. Taking into account 10 repetitions of this cycle we get an overall data volume of **112.1Mbit**.

4.3.1.4. VIRTIS-M / SPACECRAFT ALIGNMENT

The VIRTIS-M spacecraft alignment measurement will be performed basically as for Rosetta. Nonetheless, due to the difficult accessibility of the VIRTIS reference cube during the on ground alignment measurements campaign on Venus Express, the outcome from this measurement is also important to confirm the offset to be used for the VIRTIS-H alignment and thus it has to be done well in advance with respect to the VIRTIS–H alignment measurements themselves. One month is considered sufficient for off line processing of the first step. For this reason and due to the limited recovery time in case of trouble for the short cruise to Venus, we ask to have the measurements soon after the first switch on of VIRTIS during the NEV activity. The proposed target is the Earth and Moon system which is also interesting from a scientific point of view and which give us an important comparison test with the data coming from the similar campaign performed on Rosetta. In this case we can also test VIRTIS-M from a calibration and performance point of view.
We proposed to point the spacecraft in order to have the target on the boresight of VIRTIS-M and to acquire a full image at high spectral and high spatial resolution for VIRTIS–M switched on only.
We need another SPC re-pointing with the same target for the image to fully define, without ambiguity, the orientation plane and not only the boresight axis.
Thus two SPC orientations that differ by an angle of 1deg (along track or across track, TBC) are needed.
The detailed procedure is still TBD and it has to be agreed and refined with VSOC and confirmed by VMOC.

4.3.1.5. VIRTIS-H / SPACECRAFT ALIGNMENT

A dedicated campaign will be performed for the VIRTIS-H SPC alignment measurement. The proposed scheme is like the Rosetta one.
We propose a raster scan by the SPC of at least 11x11 points with a delta angle of 0.03deg (TBC) around the VIRTIS-H boresight which results centered in the matrix. VIRTIS-M will perform a full image in high spatial and high spectral resolution only for two points that are at the extreme positions on the diagonal line of the matrix.
The target will be the same star used also for Rosetta (TBC). The continuation time for each point will be essentially defined by the integration time used for the selected target and thus of the order of a few sec unless limited by another payload involved in the same campaign.
The detailed procedure is still TBD and it has to be agreed and refined with VSOC and confirmed by VMOC.

4.3.1.6. VIRTIS / OTHER REMOTE SENSING INSTRUMENTS CO-ALIGNMENT

Since the combined VIRTIS IFOVs are the smallest of all the instruments, when aligning VIRTIS Vs S/C with a known star, the same star will fall inside the FOV of the other instruments (SPICAV, VMC); thus, VIRTIS -H and -M will be simultaneously co-aligned with the other imaging instruments.

4.3.1.7. DECONTAMINATION OR DE-ICING OF THE RADIATOR

Differently with respect to Rosetta, VIRTIS for Venus Express does not have the deicing heaters for the radiator. The reason is that we do not really expect problems of icing on the radiator surface because on one hand the cruise of the mission is very short (there is no any hibernation phase as for Rosetta) and moreover the expected thermal environment is hot at Venus.

Nonetheless, if really needed, we described here a procedure to execute the deicing of the radiator through its pointing toward the Sun. The procedure and configuration here described **must not be considered as a routine operation for the scientific observation plan**. It has to be applied only when necessary upon **specific request by VIRTIS PI**.

We do not consider here the cumulative degradation of the optical properties of the radiator painting due to solar flux with consequent degradation of VIRTIS scientific performances in time. At the moment we are not able to quantify and to evaluate it but certainly we consider it of minor importance due to the total exposure time of the procedure, as we see hereafter.

Also it is not considered here yet the effect of possible hot spots due to the solar radiance passing between the radiators borders and impinging internal parts or subsystems, generally speaking as "non light tightening of the radiator".

The procedure consists to point the radiator to the Sun for **0.5h** by a TBD angle for the line of sight of Sun with respect to the normal to the radiator. The angle is not relevant for the deicing procedure itself but it can be important to overpass possible issues related to the hot spots. Indeed it can be found out an angle sufficiently safe to avoid critical hot spots inside the –OM and this is currently under investigation.

For the thermal results here presented we have used the line of sight of Sun normal to the radiator.

A thermal analysis has been done for the "sizing case" (case 1, 12h phase) by pointing the radiator during the normal orbit one hour after the pericenter for a total exposure duration of 0.5h which is, according to the results, sufficient for the deicing.

In Figure 4.3.1.7-1 is shown the average temperature versus time during the deicing on the three pieces of the VIRTIS radiator, main radiator, -M and –H. The configuration is for sizing case (case 1, 12h) and exposure time is 30' starting 1 hour after pericenter. It is possible to see that a temperature of the order of 250-280K is reached (for Rosetta was 250K using the deicing heaters) and this is considered sufficient for the deicing of radiator.

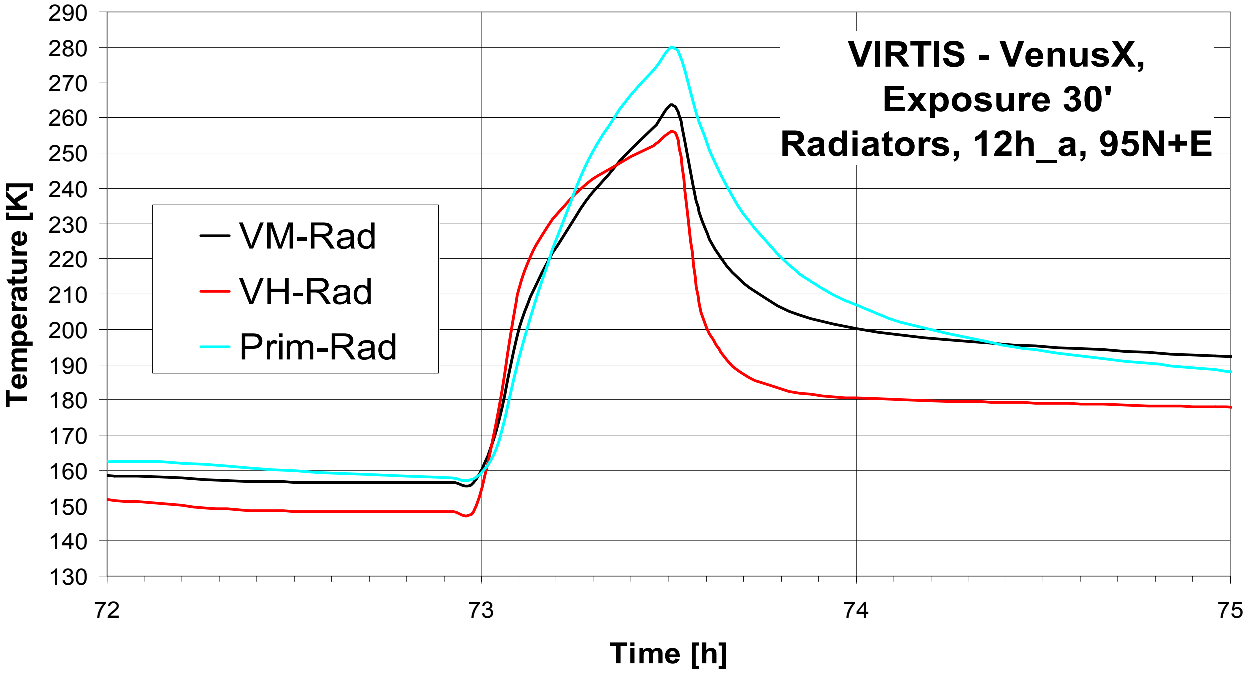

Figure 4.3.1.7-1 : Average temperature vs time on the three pieces of the VIRTIS radiator. The configuration is for sizing case (case 1, 12h) and exposure time is 30' starting 1 hour after pericenter. A temperature of the order of 250K as for Rosetta is considered sufficient for deicing of radiator.

In Figure 4.3.1.7-2 is shown the average temperature of the radiators for several orbits, again for sizing case at 12h. The exposure of radiator starts at 73h time. From a recovery time point of view, it can be seen that in the successive orbit after the deicing procedure the thermal regime is again close to be restablished. Thus a case 3 observation, for example, would be again possible when the deicing is performed.

From a safety point of view, the cold boxes are the most critical parts from a thermal point of view. In Figure 4.3.1.7-3 is possible to observe that the temperature of the cold boxes is reasonably safe and well within the non-operational range to support safely the deicing procedure. The overall temperature is below 210K and then there is a sufficient margin to support the deicing when needed.

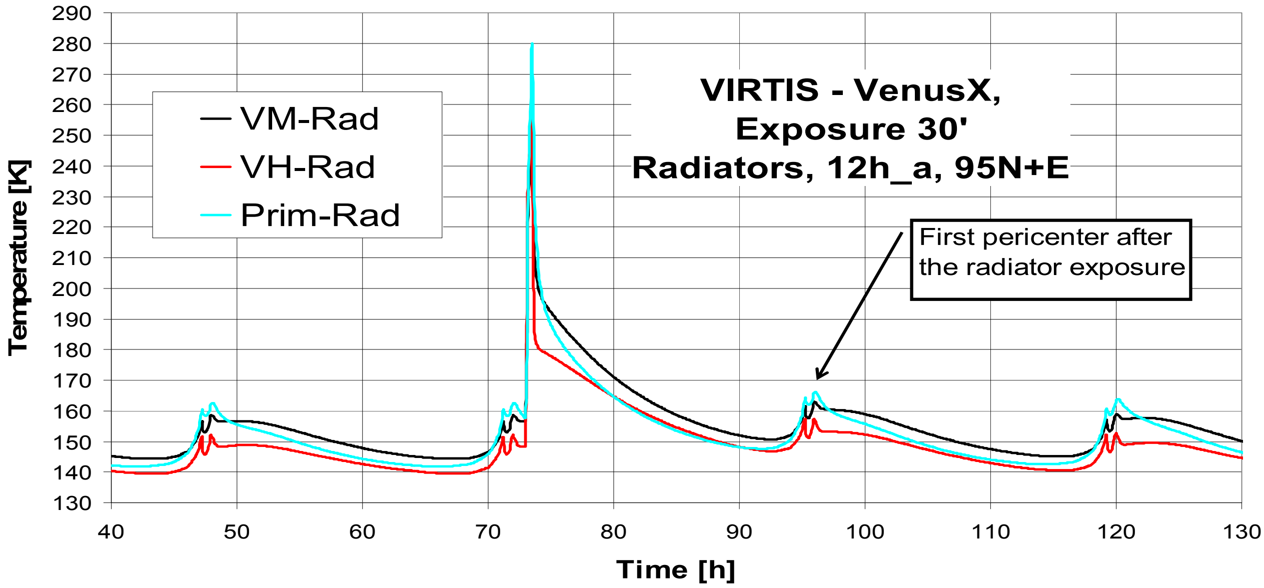

Figure 4.3.1.7-2 : Average temperature of the radiators for several orbits, sizing case at 12h. The exposure of radiator starts at 73h time. In the successive orbit after the deicing, the thermal regime is close to be restablished. A case 3 observation, for example, would be possible.

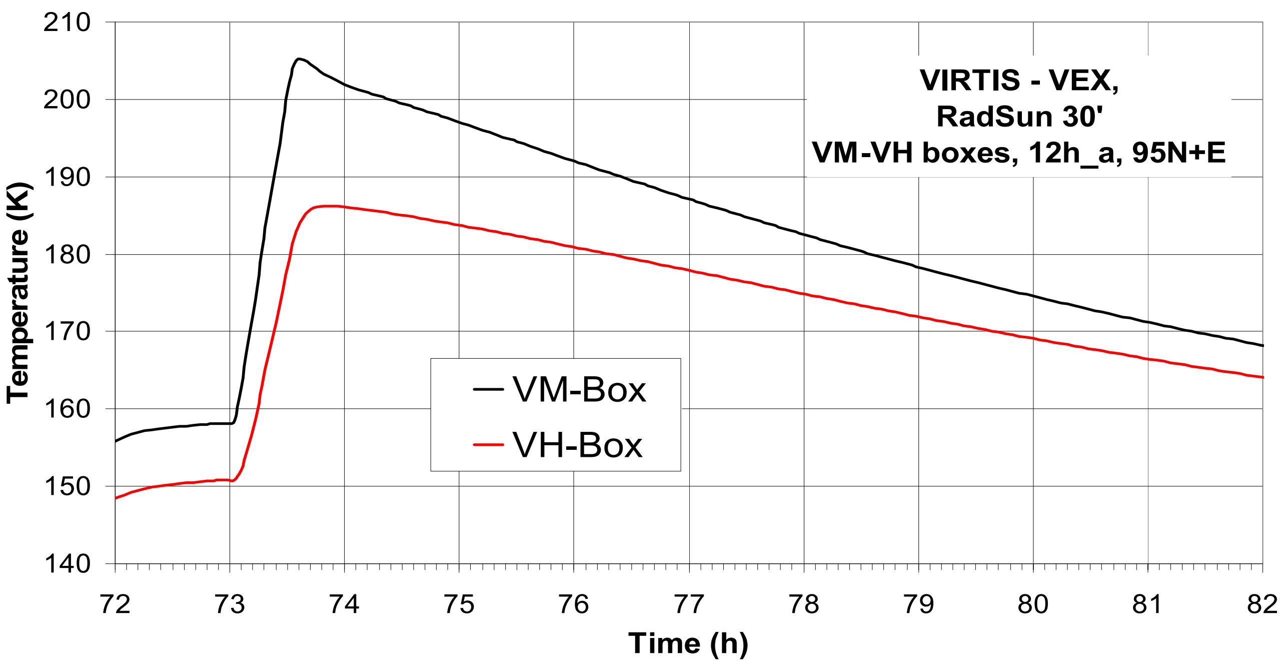

Figure 4.3.1.7-3 : Average temperature of the cold boxes during deicing (sizing case at 12h). The exposure of radiator starts at 73h time. The temperature of the cold boxes is reasonably safe and well within the non-operational range to support safely the deicing procedure.

4.3.2. CRUISE PHASES

During the cruise phase VIRTIS is generally switched off, as other experiments, with the exclusion of periodical testing of VIRTIS which include the calibration sessions.
When activated during the Cruise Phases check-outs VIRTIS shall perform the full calibration sequence.
The possibility to look at Venus from time to time whenever is possible would be a good opportunity to check the performances of VIRTIS in advance, before the official start of the commissioning, and to retrieve good science of the Planet when it is well within the VIRTIS FOV. Just as an example, Venus at a distance of about 50 Mkm fills 1 full pixel of VIRTIS in high spatial resolution mode.
When the spacecraft will be closer to Venus, the Venus disc at a distance of more than 200000km will fill the entire FOV of VIRTIS and it would give us, whether is possible (TBC), one image qube of the full disc in one single shot without spacecraft repointing, important for science and public outreach as well. **From this point of view we highlight the importance, if feasible, to observe during the apocenter lowering right after the VOI. In this case we are at a distance of about 200000km such that we have the full Venus disk within the VIRTIS-M FOV and thus unique to achieve important results from a scientific point of view. We can for example to study in this way the dynamics of the Southern emisphere in a ideal observation configuration.**

4.3.3. MARS GRAVITY ASSIST

N/A.

4.3.4. EARTH GRAVITY ASSISTS

N/A.

4.3.5. ASTEROIDS FLYBYS

N/A.

4.3.6. COMET FAR APPROACH PHASE

N/A.

4.3.7. COMET CLOSE-APPROACH & TRANSITION TO GLOBAL MAPPING PHASES

N/A.

4.3.8. COMET NUCLEUS MAPPING AND CLOSE-ENCOUNTER

N/A.

4.3.9. COMA OBSERVATION

N/A.

4.3.10. MISSION TIMELINE

The mission timeline is still TBD and it will be developed with the science observations master plan.

4.3.11. SCIENCE CASES

In this chapter we will explore the different science cases described in the AD06 from a VIRTIS point of view. The VIRTIS FOV is placed in the SPC axis (+Z) which is normally pointed to the center of Venus in nadir configuration. Nevertheless in some case the VIRTIS FOV axis will be pointed off-nadir, limb or stellar occultation in combination with other instruments.

The cases applicable to the VIRTIS observations are the case 1 (Sizing case, observations at pericenter), case 2 (Off-pericenter observations by the +Z looking instruments), case 3 (global spectro-imaging by VIRTIS from apocenter), case 5 (stellar occultation by SPICAV) and case 7 (limb observations).

In the other cases VIRTIS will be kept switched off and covers closed except when the given case is considered a combination with another case applicable to the VIRTIS observations.

Notice that the VIRTIS instrument is basically a data volume limited instrument rather than a data bus speed/arbitration limited and thus the total data volume of VIRTIS for each orbit will be agreed according to the science observations master plan only. For this reason the typical mode of VIRTIS given to ASTRIUM for the analysis of the science cases and described in the AD06 is for reference only and other modes can be used for the real observations, depending on the optimization of the data volume with respect to the observation duration. For example if there will be a specific constraint on the maximum allowed data volume for VIRTIS (during the definition of the science observations master plan), VIRTIS team can decide to use a less demanding mode in terms of data volume (or use higher compression factor as well) and extending the observations for a longer time, if feasible from a power/thermal SPC point of view.

A full calibration sequence will be repeated every TBD orbits before the observation phase.

In fig. 4.3.11-1 is represented a general view of the orbital geometry for the nominal orbit. The origin of the polar plot is placed in the center of Venus and the distance of the spacecraft along the orbit are given in respect to the center of the planet. The blue vertical line represents the Venus rotation axis. The red circle is the altitude of 10000 Km. The colored parts of the orbit show where the 3 limb observation cases are considered (respectively magenta, green and orange)

For the limb observations, the optical axis of the slit is set tangent to the sphere which defines the top of the atmosphere (here assumed at 210 Km above the surface). During all limb observations the optical axis of the slit moves inertially (TBC) and thus its direction does not change on the orbit plane.

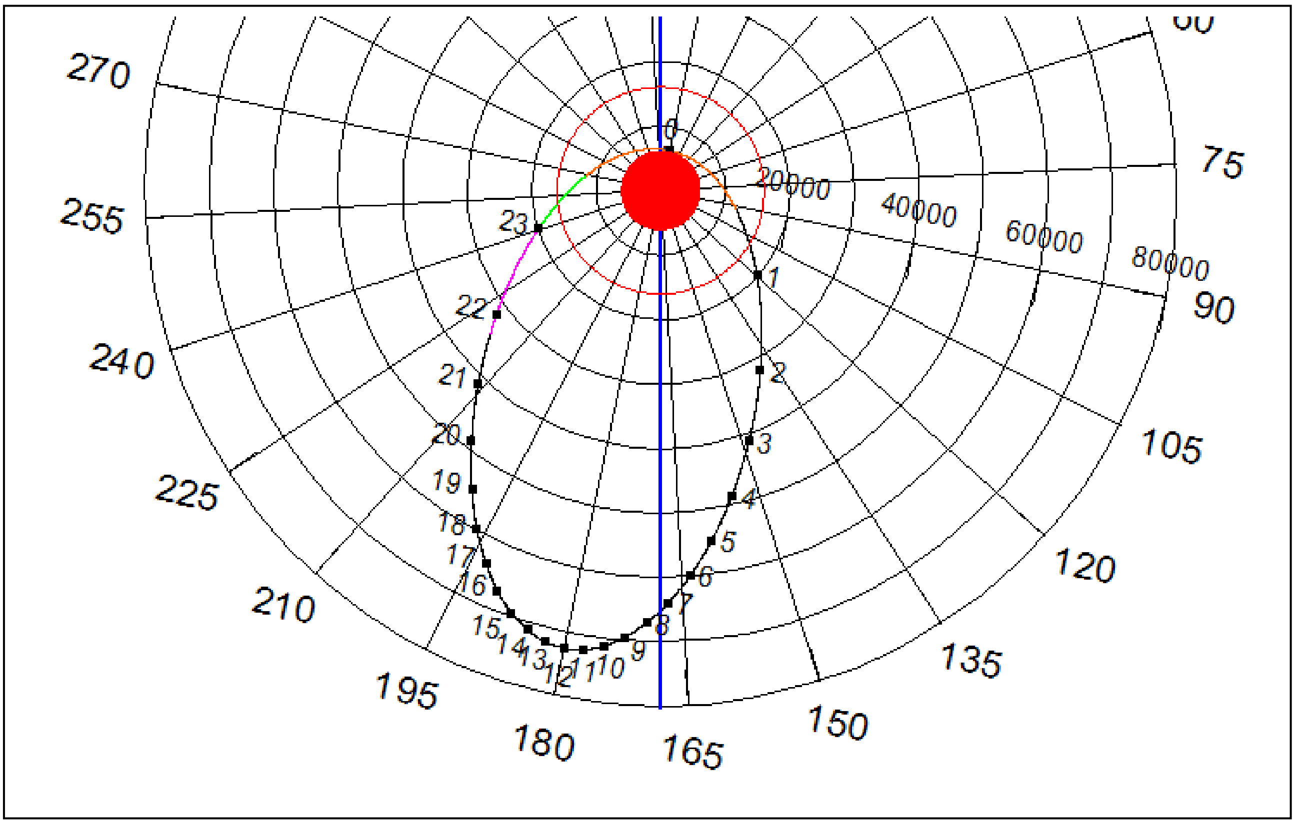

Fig. 4.3.11-1: Geometry for the science cases and the nominal orbit

4.3.11.1. CASE 1 PERICENTER OBSERVATIONS

Case 1 (pericenter observations): these observations will usually be made as VIRTIS without scanning mirror motions (TBC), as image reconstruction will not be possible in this mode. Statistical coverage of different regions of Venus, on night as well as on day side will be possible. Occasionally the use of the scanning mirror (in fixed or scanning mode) will improve this statistical coverage.

In Fig. 4.3.11.1-1, it is possible to see the main observations parameters for the pericenter observations. The color of each curve and the axis to which it refers are the same. The abscissa is the time along the orbit in hours and time 0 is the pericenter pass of the spacecraft.

The plotted parameters are the absolute speed of the spacecraft and its components: along the direction of the observation (component parallel to the optical axis of VIRTIS) and orthogonal to the direction of the observation (perpendicular to the optical axis of VIRTIS).

The pixel size is here defined as the linear dimension of the –M hi-res spatial pixel (250urad in angle) on the surface of Venus at the center of the slit.

There are also reported: the dwell time in orange color, the spacecraft relative speed at the surface (groundspeed) in dark green color, the “pace of the measurement” which is given by the size of the pixel on the ground (calculated from the IFOV) summed to the displacement which occurs during the 2.5 s which is the shortest time between 2 consecutive observations (minimum repetition time).

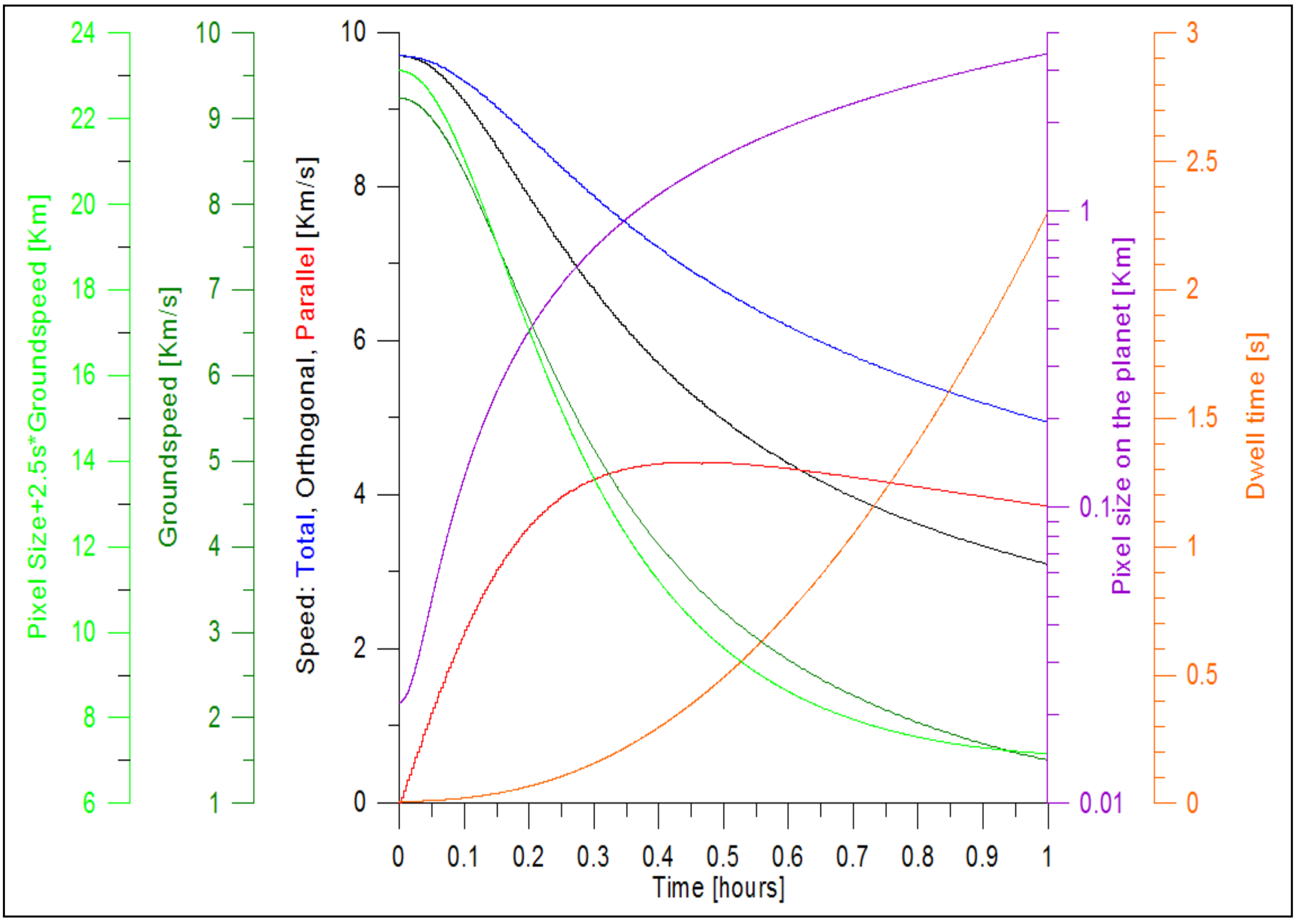

Fig. 4.3.11.1-1: Main observation parameters for VIRTIS in the science case 1

As it is possible to see in the plot, the dwell time is typically less that the VIRTIS minimum repetition time in the case 1, which means that the image reconstruction is not possible or that the images present the pixel elongated in the motion direction of the SPC or that there are “holes” when the scanning mirror of –M is used. On the other hand the dwell time is typically greater than the typical integration time to be used for Venus on the night side (0.2-0.4sec, TBC), if we exclude a small part around exactly at the pericenter (about 20’), which means that the single frame is not affected at all by the high speed of the SPC motion. In the other case we will have a spot size slightly elongated also for the single frame which is any way not a problem in the framework of a “statistical coverage”.
For this reason in this mode we can give the priority to the spectral performances of –M and –H, using the high spectral resolution mode rather than the high spatial resolution mode, whether there are problems of data volume. On the other hand the altitude of the SPC is very low in this case and thus the typical spot size is very small even in the nominal case (as low as 25m).
The typical data rate considering the -H nominal, -M high spectral is about 352 kbits/s on the high speed bus for the minimum repetition time of 2.5sec.
As a consequence, the data volume will be the data rate times the duration of the observation (ex. 1900 Mbits not compressed for 90’ of observation).

4.3.11.2. CASE 2 OFF-PERICENTER OBSERVATION

Case 2 (off-pericenter observations): these observations will usually be made as VIRTIS with scanning mirror motions (TBC) and this mode is from a scientific point of view one of the most important. As in the previous case, case 1, in Fig. 4.3.11.2-1 it is possible to see the main observations parameters for the off-pericenter observations. Again, the color of each curve and the axis to which it refers are the same. The abscissa is the time along the orbit in hours and time 0 is the pericenter pass of the spacecraft, here outside the graph on left side.

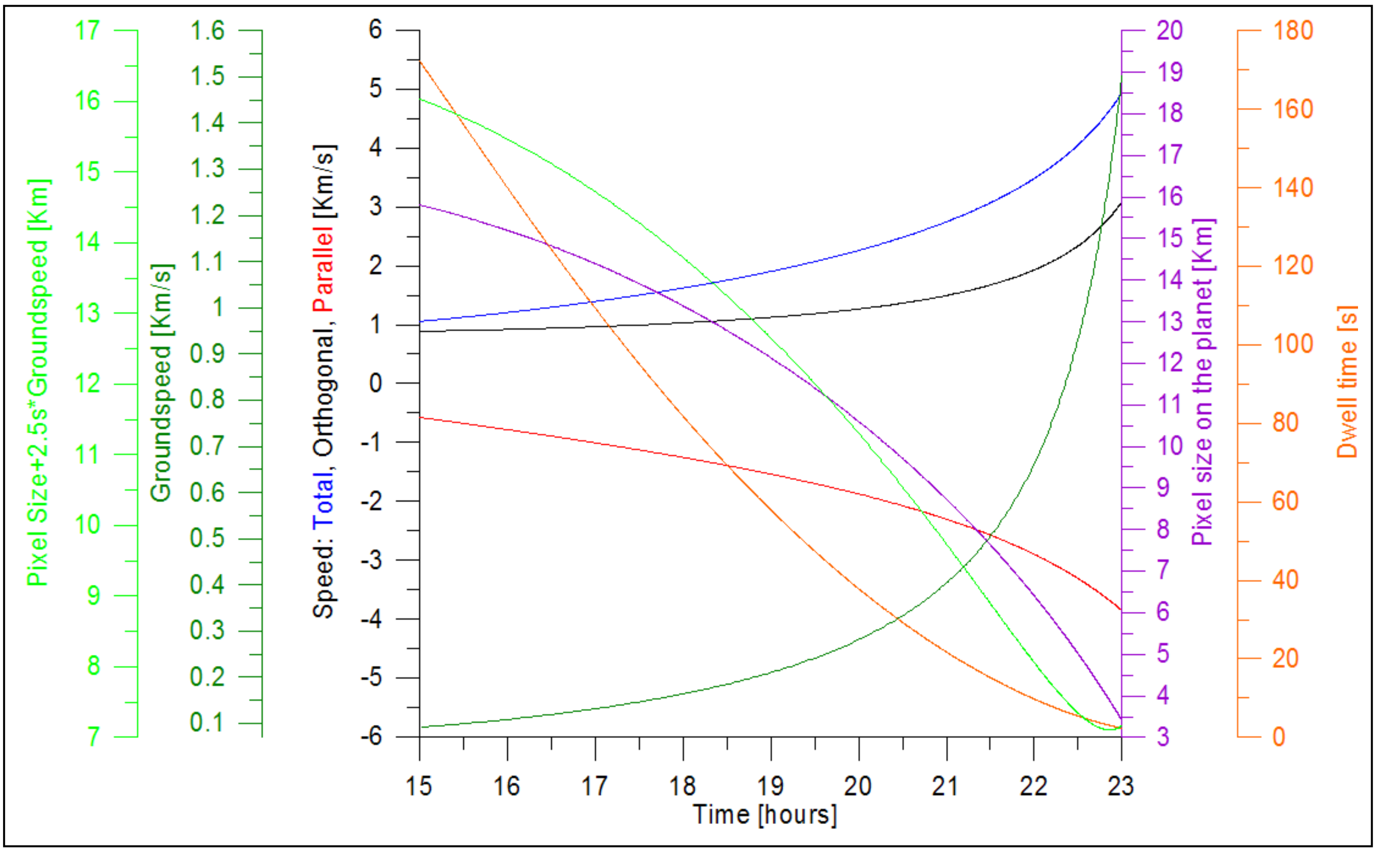

Fig. 4.3.11.2-1: Main observation parameters for VIRTIS in the science case 2

The plotted parameters are the absolute speed of the spacecraft and its components: along the direction of the observation (component parallel to the optical axis of VIRTIS) and orthogonal to the direction of the observation (perpendicular to the optical axis of VIRTIS).

The pixel size is here defined as the linear dimension of the –M hi-res spatial pixel (250urad in angle) on the surface of Venus at the center of the slit.

There are also reported: the dwell time in orange color, the spacecraft relative speed at the surface (groundspeed) in dark green color, the "pace of the measurement" which is given by the size of the pixel on the ground (calculated from the IFOV) summed to the displacement which occurs during the 2.5 s which is the shortest time between 2 consecutive observations (minimum repetition time).

From the previous plot we can see that differently from the case 1, in this case the dwell time is always greater than the minimum repetition time (and obviously the integration time) and thus the image reconstruction is now possible without problems.
The typical use of this case will be the tracking of special features on Venus surface or atmosphere and to follow the evolution in time of the phenomena.
In this case the spatial resolution may be important and then also the high spatial and high spectral resolution for –M will be used, depending on the maximum available data volume and downlink capability of the SPC.
In the case of tracking features mode (off-nadir pointing of the SPC) and especially for the high spatial and high spectral mode of VIRTIS, it can be chosen a longer repetition time, eventually associated to data compression, in order to reduce the total data volume when necessary. On the other hand the timescale associated with the typical Venus phenomena is fully compatible also with the higher repetition time of VIRTIS (see attachment 2) and it might be limited by the orbit period only.

4.3.11.3. CASE 3 GLOBAL SPECTRO IMAGING OF VIRTIS AT APOCENTER

Case 3 (global spectro imaging of VIRTIS at apocenter): these observations will usually be made as VIRTIS with scanning mirror motions . As in the previous cases, in Figure 4.3.11.3-1 it is possible to see the main observations parameters for the off-pericenter observations. Again, the color of each curve and the axis to which it refers are the same. The abscissa is the time along the orbit in hours and time 0 is the pericenter pass of the spacecraft while at 12hours we are at the apocenter position (center of axis).
The plotted parameters are the absolute speed of the spacecraft and its components: along the direction of the observation (component parallel to the optical axis of VIRTIS) and orthogonal to the direction of the observation (perpendicular to the optical axis of VIRTIS).
The pixel size is here defined as the linear dimension of the –M hi-res spatial pixel (250urad in angle) on the surface of Venus at the center of the slit.
There are also reported: the dwell time in orange color, the spacecraft relative speed at the surface (groundspeed) in dark green color, the “pace of the measurement” which is given by the size of the pixel on the ground (calculated from the IFOV) summed to the displacement which occurs during the 2.5 s which is the shortest time between 2 consecutive observations (minimum repetition time).
Due to the 90deg of orbit inclination, the global view is possible only for the Southern emisphere of Venus. Nevertheless the orbital parameters of Venus are such that the planet is thought to be symmetric with respect to the equatorial plane.
We want to highlight that the southern emisphere of Venus as seen from VIRTIS will be half dark and half illuminated by the Sun. This would imply that the integration time should be changed accordingly depending on the side being seen by VIRTIS (essentially two different integration time) in order to avoid the saturation.
If we want to exclude the saturation within a single qube (and frame) for this case but also in general fro the other cases, VIRTIS requires to have the Venus terminator parallel to the VIRTIS slit.

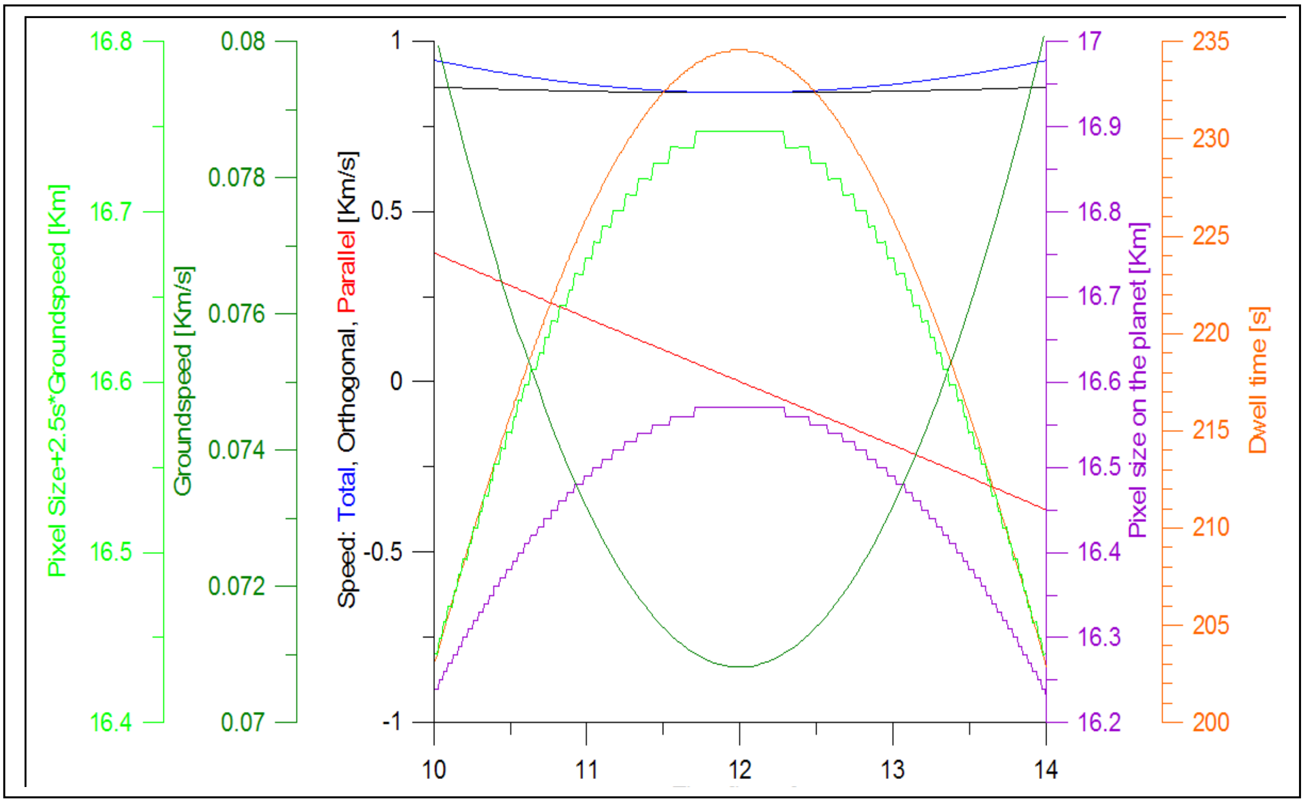

Figure 4.3.11.3-1 : Main observation parameters for VIRTIS in the science case 3

Since the VIRTIS slit is parallel to the solar panel axis (Y axis), we would expect that this requirement is achieved in general because the solar panel must be directed to the Sun for powering the SPC, especially at the apocenter.

These measurements, combined with a proper spacecraft repointing, as shown in Figure 4.3.11.3-2, will be a unique opportunity to observe the full disc of the Southern emisphere of Venus and to study the global meteorological phenomena. It is to say that these observations are important also for public outreach purposes. The ellipse about the center is due to the fact that the ground track at the apocenter is at about 80°S and not at 90°S, where in this case the terminator would be exactly in the center. The South pole (90°S) will be on the terminator and moving around the center of the disk in the figure, along with the deformation of the ellipse, depending on the season.

The Venus night side in the figure is on top. The qubes on the day side (1,2,3) will use the integration time optimised for the high flux expected. The qubes on the night side (7,8,9) will use a longer integration time optimised for the much weaker radiance expected in the Venus dark side. The intermediate qubes (4,5,6) will be acquired using both integration times, as for day and night side, at each SPC position. Thus the total number of VIRTIS qubes will be 12 for the 9 SPC repointings. The expected repetition is 2.5sec, still compatible with the exposure time also for night side.

The total cumulative duration of a full global image for a set of 12 qubes in the minimum repetition time of 2.5sec for VIRTIS will be 144' (12' multiplied by 12). This time includes the VIRTIS TLC handling time but it does not include the SPC repointing, estimated of the order of 2' per each

orientation. For the positions 4,5 and 6 the SPC will point for a duration doubled respect to the other points due to the double qubes for each position with two different integration time.
In the Table 4.3.11.3.1 is shown the sequence of the SPC repointing strategy for the VIRTIS case 3 global mosaicking. The sign of the rotation angle along X(Y) axis is positive when the nadir Z axis will go toward the Y(X) axis. The sequence has to be done according to the fact that the dark side of Venus is on top. When the dark side is on the bottom of the figure, the Y axis of SPC will be on the right side and the X axis will be on top. Notice that the definition here given for the rotation angle along X axis coincides with the definition "along track" given in par.2.1.4.1 of RD 05 while the rotation angle along Y axis coincides with the definition "across track" in par.2.1.4.2 of RD 05 but the sign which might be different depending on the season. We propose to ESOC the pointing here given in respect of the dark/day side as in the figure so that we can maintain the same timeline with the same sequence about the exposure time for VIRTIS (TBC by ESOC). The 62mrad of rotation (with respect to the total 64 mrad of VIRTIS) takes into account a small overlap between two next qubes.
In terms of data volume, one single image qube not compressed for the nominal mode is 19.5 Mbits for –M plus 4.2 Mbits for –H and thus 23.7 Mbits in total.
For high spectral mode case we have 58.4 Mbits (-M) + 4.2 Mbits (-H) = 62.6 Mbits.
For high spatial mode we have : 311 Mbits (-M) + 24 Mbits (-H) = 335 Mbits.
For high spatial and high spectral mode : 934 Mbits (-M) + 24 Mbits (-H) = 958 Mbits.
For the set of the 12 qubes (global image) we have for the nominal mode : 284 Mbits (from 14 to 142 Mbits compressed, depending on the compression type and scenario).

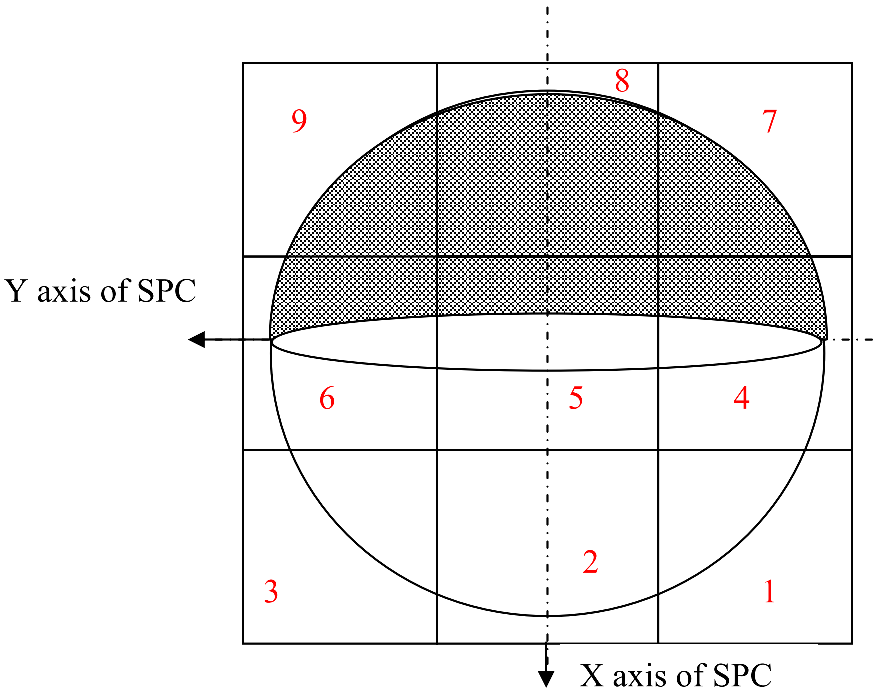

Figure 4.3.11.3-2 : SPC repointing strategy with numbered sequence for VIRTIS in the science case 3. The dark side of Venus is on top and the radiator (-X) is pointed to the shadow. The ellipse about the center is due to the fact that the ground track at the apocenter is at about 80°S and not at 90°S.

For high spectral mode : 751 Mbits (from 37.5 to 375.5 Mbits compressed).
For high spatial mode : 4020 Mbits (from 201 to 2010 Mbits compressed).

Table 4.3.11.3.1 : SPC repointing sequence for case 3. The sign of the rotation angle along X(Y) axis is positive when the nadir Z axis will go toward the Y(X) axis.

Pos.	Rotation angle along X axis [mrad]	Rotation angle along Y axis [mrad]	Duration [min]
1	-62	+62	12
2	0	+62	12
3	+62	+62	12
4	-62	0	24
5	0	0	24
6	+62	0	24
7	-62	-62	12
8	0	-62	12
9	+62	-62	12

Finally for high spatial and high spectral : 11496 Mbits (from 574.8 to 5748 Mbits compressed).
We want to highlight that the SPC repointing for case 3 to perform the VIRTIS global mosaicking of the Venus Southern emisphere is just a particular case for an “extended” time of case 2. Indeed, depending on the scientific objectives to cover in a specific orbit, we might use a simple off-nadir pointing in a tracking mode of specific zone of Venus (as for case 2), without spacecraft repointing, in order to observe for a long time (of a few hours timescale) specific features of the Venus atmosphere. For example this is applicable when we want to study the cold polar collar and the polar vortexes. In this case VIRTIS can provide 4-D image qubes and to perform a kind of a tomographic map vs time of the lower Venus atmosphere especially devoted to specific phenomena.
In this case the total data volume will be the data volume of a single qube times the number of qubes which is given by the total duration divided by the repetition time for each qube, or in other words the datarate times the duration of the observation period.

4.3.11.4. CASE 4 VERA BI-STATIC SOUNDING

In this science case VIRTIS will be kept switched off and covers closed except when the case 4 is considered in combination with another case applicable to the VIRTIS observations.
We want to notice anyway that the thermal environment experienced by VIRTIS even though switched off during this phase of observation (for other payloads), especially the radiator and the cold boxes of –M and -H, will be affecting the further observation sequences of VIRTIS due to the thermal inertia of the instrument.

4.3.11.5. CASE 5 STELLAR OCCULTATION BY SPICAV

From a VIRTIS point of view, we consider this case as a special case of the Limb observations, case 7, hereafter discussed. The only difference is that the inertial pointing of the SPC is such that the FOV of the instrument (really it should be the SPICAV FOV, as said in the title of the science case) is pointed to a selected Star. To notice that if the co-alignment between VIRTIS and SPICAV is not achieved within the minimum IFOV among VIRTIS-H and SPICAV, the simultaneous observation of the Star by VIRTIS-H and SPICAV is not possible, while for VIRTIS-M we can still recover the disalignment by using the motion of the scan mirror (and thus not using the fixed angle mode).
On the other hand this science mode is really a combined mode with the Limb science case but the constraint on the specific pointing to the Star. For this reason what we'll describe hereafter for the case 7 (limb observations) is valid also for this case.

4.3.11.6. CASE 6 SOLAR OCCULTATIONS BY SPICAV / SOIR

In this science case VIRTIS will be kept switched off and covers closed except when the case 6 is considered in combination with another case applicable to the VIRTIS observations.
We want to notice anyway that the thermal environment experienced by VIRTIS even though switched off during this phase of observation (for other payloads), especially the radiator and the cold boxes of –M and -H, will be affecting the further observation sequences of VIRTIS due to the thermal inertia of the instrument.

4.3.11.7. CASE 7 LIMB OBSERVATIONS

In the limb observations, we want to study the profile of the atmosphere at different altitudes, especially for the higher atmosphere. Using –M VIRTIS can make a picture of the spectra at different altitude in one shot, depending on the distance. Through –H instead it is possible to have a high spectral resolution profile during the SPC motion.

In Fig. 4.3.11.7-1 it is possible to see the main observations parameters for the limb observations. Again, the color of each curve and the axis to which it refers are the same. The abscissa is the time along the orbit in hours and in this case time 24 is the pericenter pass of the spacecraft (equivalent to 0). A time larger than 24 hours means that we are exploring the following orbit.

The plotted parameters are the absolute speed of the spacecraft and its components: along the direction of the observation (component parallel to the optical axis of VIRTIS) and orthogonal to the direction of the observation (perpendicular to the optical axis of VIRTIS).

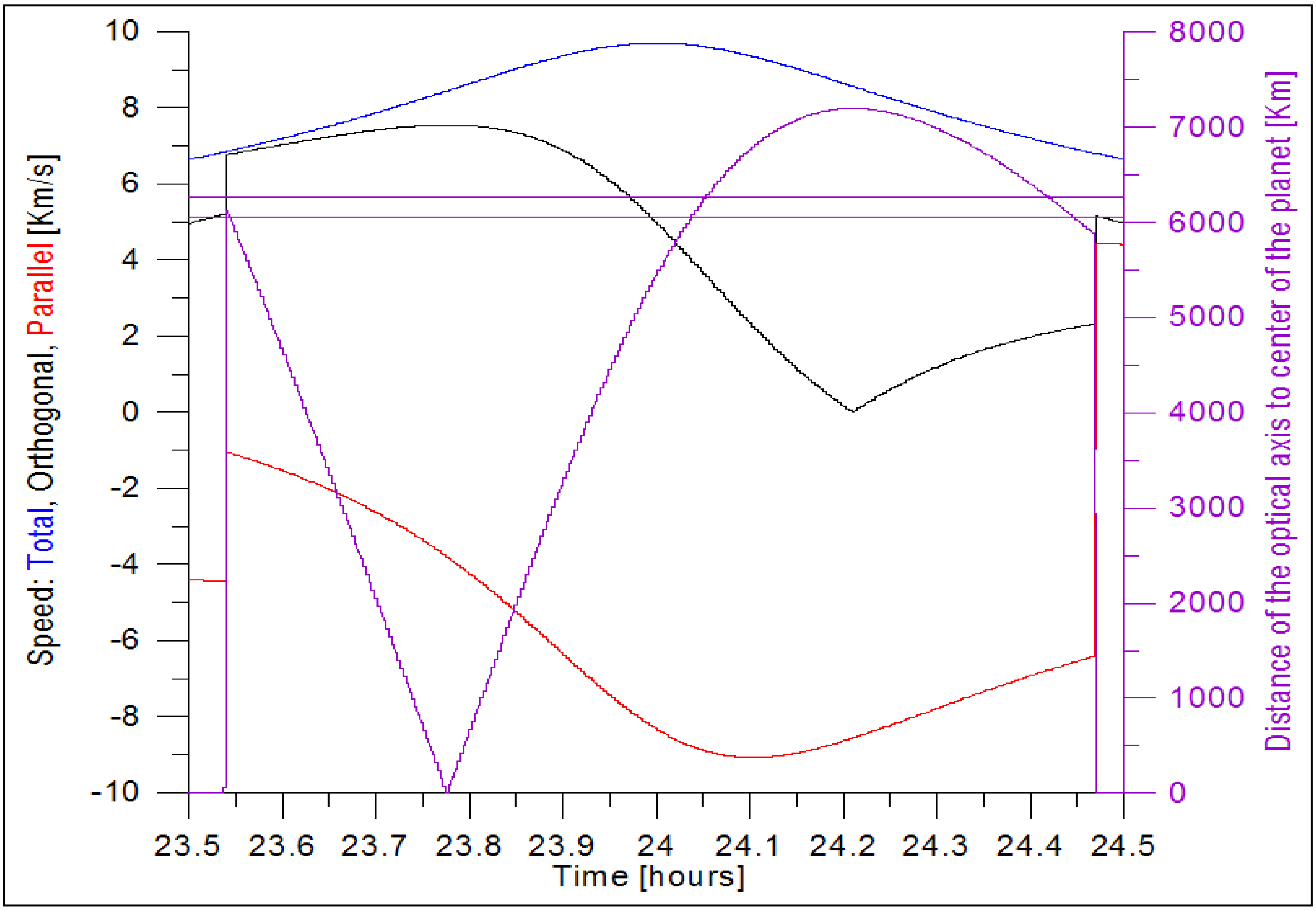

Fig. 4.3.11.7-1: Main observation parameters for VIRTIS in the general science case 7, limb @ +-90°

In Fig. 4.3.11.7-2 and Fig. 4.3.11.7-3 it is possible to see the main observations parameters for the limb observations for the Latitude of the limb at +-90deg and +-50deg cases. Indeed a new parameter is added in the orbital parameters for the limb calculations. When the limb simulation starts, the point where the optical axis of the slit touches the sphere defining the top of the atmosphere gives the "latitude of the limb", reported on top of the plots. Such a point and the centre of the planet define a straight line which remains orthogonal to the slit optical during the inertial pointing of the spacecraft. The "distance of the optical axis to the center of the planet" is the length of the linear segment which connect the intersection of the optical axis with the straight line and the centre of the planet. During the limb setting of the spacecraft there will be a time when VIRTIS is pointing Nadir. The red dots are the position in which the calculation have been made. The x-axis itself represents the surface of Venus. The red horizontal lines give the top of the atmosphere. The useful limb measurements are those ones (red dots) which are taken between the top of the atmosphere and the surface. The "speed of the limb" is the component of the velocity orthogonal to the line of sight of VIRTIS and the "pace" of the measurements is computed adding the size of the pixel to the speed of the limb multiplied by 2.5s. The pixel size is the cross-section of the IFOV at the "latitude of the limb".

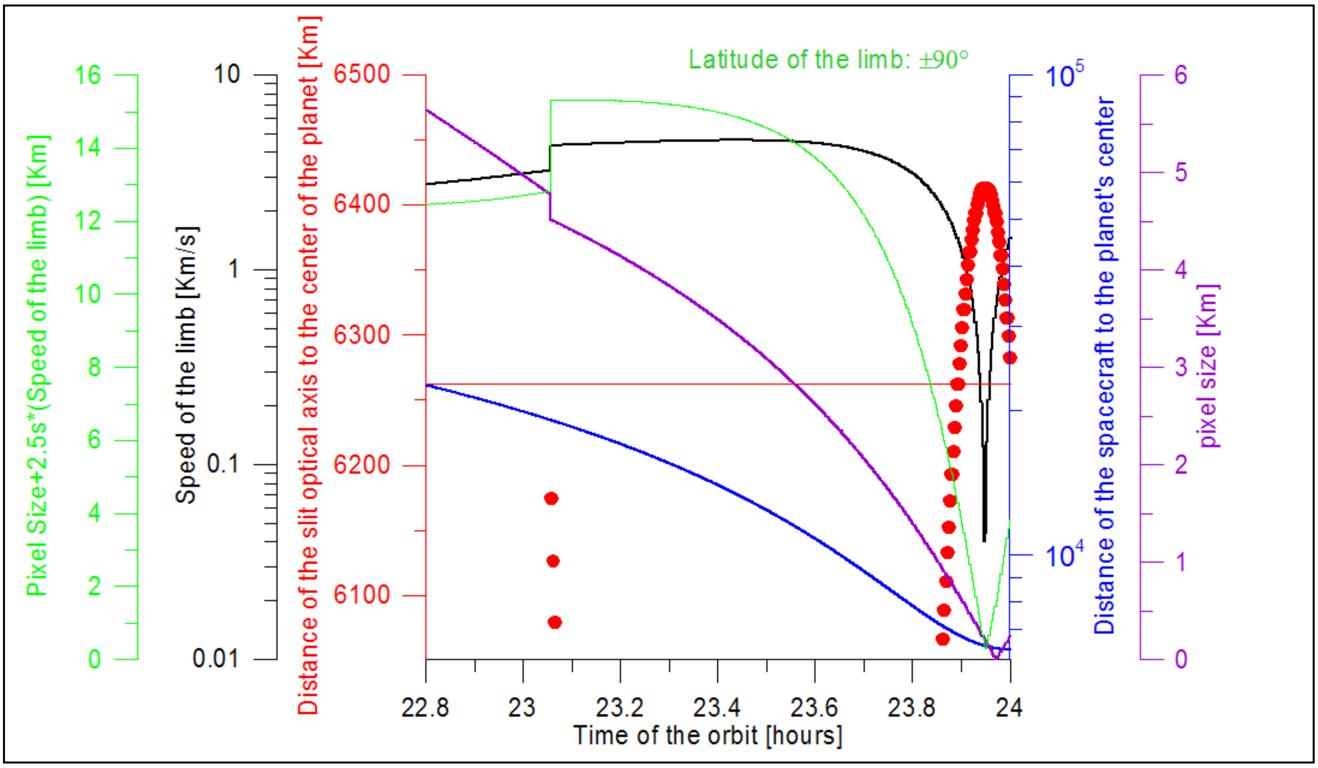

Fig. 4.3.11.7-2: Main observation parameters for VIRTIS in the general science case 7, limb @ +-90°

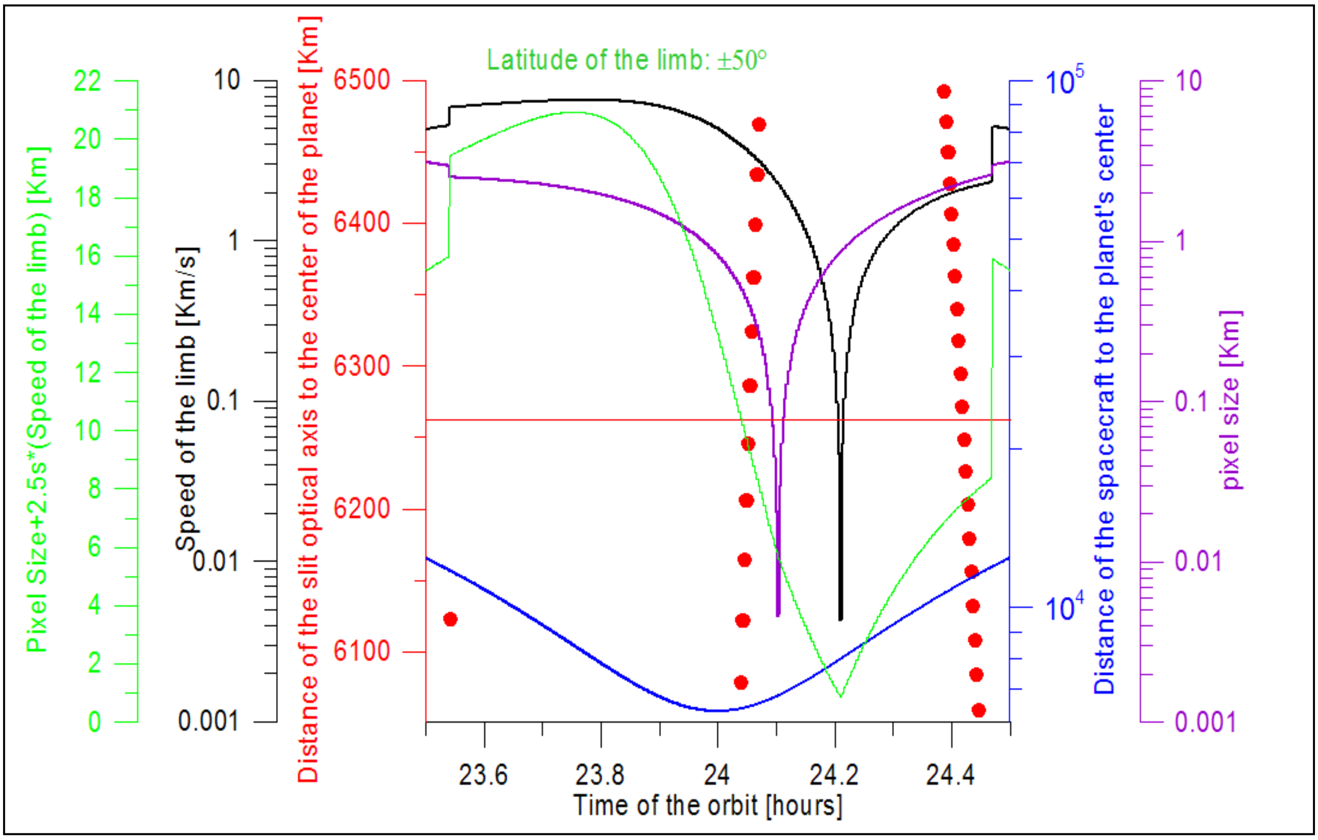

Fig. 4.3.11.7-3: Main observation parameters for VIRTIS in the general science case 7, limb @ +-50°

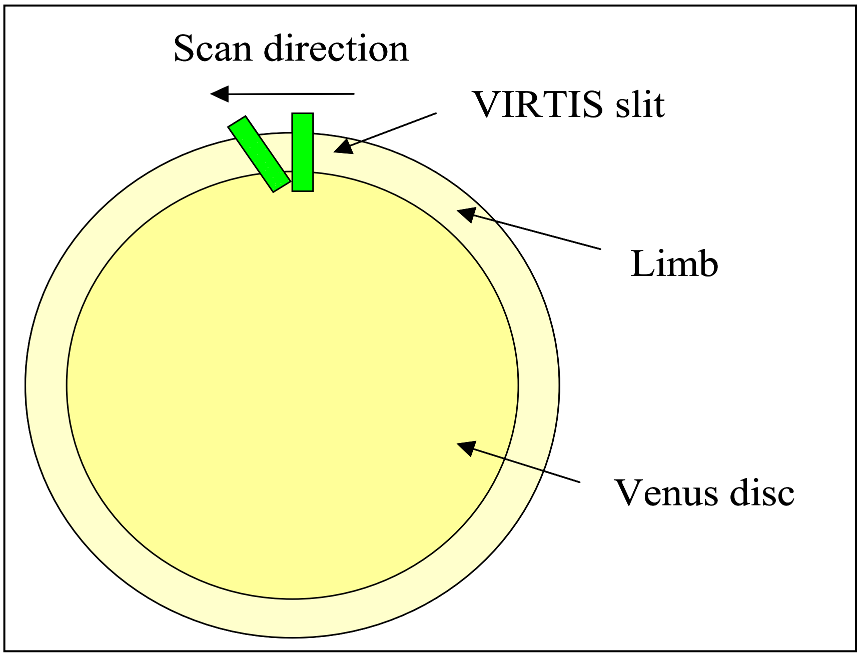

Fig. 4.3.11.7-4: Geometry of the VIRTIS slit wrt Venus limb and disc

In Fig. 4.3.11.7-4 it is possible to see how the slit of VIRTIS can be placed from a geometrical point of view to perform the limb observations. The slit not necessarily must be exactly perpendicular to the surface of Venus in order to have a picture of the limb in one shot but it is desirable to have it not exactly parallel to the surface. An angle smaller than 45deg between the perpendicular to the surface and the VIRTIS slit is enough. In any case we can consider also to use the scanning mirror of –M for a better coverage.

In terms of data volume, one single image qube not compressed for the nominal mode is 18.9 Mbits for –M plus 3.5 Mbits for –H and thus 22.4 Mbits in total. The number of image qubes to acquire depends on the distance of the limb from the SPC (if the slit does not cover the full limb) but also on the number of IFOV of –H to cover the full limb, to be studied in more detail in future on the science master plan.

4.3.11.8. CASE 8 EARTH RADIO OCCULTATIONS BY VERA

In this science case VIRTIS will be kept switched off and covers closed except when the case 8 is considered in combination with another case applicable to the VIRTIS observations.
We want to notice anyway that the thermal environment experienced by VIRTIS even though switched off during this phase of observation (for other payloads), especially the radiator and the cold boxes of –M and -H, will be affecting the further observation sequences of VIRTIS due to the thermal inertia of the instrument.

4.3.11.9. CASE 9 VERA SOUNDING OF SOLAR CORONA IN CONJUNCTIONS

In this science case VIRTIS will be kept switched off and covers closed except when the case 9 is considered in combination with another case applicable to the VIRTIS observations.
We want to notice anyway that the thermal environment experienced by VIRTIS even though switched off during this phase of observation (for other payloads), especially the radiator and the cold boxes of –M and -H, will be affecting the further observation sequences of VIRTIS due to the thermal inertia of the instrument.

4.3.11.10. CASE 10 STUDY OF THE VENUS GRAVITY FIELD ANOMALIES BY VERA

In this science case VIRTIS will be kept switched off and covers closed except when the case 10 is considered in combination with another case applicable to the VIRTIS observations.
We want to notice anyway that the thermal environment experienced by VIRTIS even though switched off during this phase of observation (for other payloads), especially the radiator and the cold boxes of –M and -H, will be affecting the further observation sequences of VIRTIS due to the thermal inertia of the instrument

5. OPERATIONAL PROCEDURES AND TELECOMMAND SEQUENCES

5.1. GROUND TEST SEQUENCES

The ground test plan along with the specific procedures is given in RD 04.

5.2. ON-BOARD CONTROL PROCEDURES (OBCPS)

VIRTIS on Rosetta uses two OBCP procedures for power on and power off. On Venus Express the OBCP is not used and thus not applicable. The two procedures for power on and power off must be defined through the SPC DMS. Wherever the OBCP procedure here is mentioned or is referred in the Rosetta UM, it is intended that the DMS procedure is used instead.
Hereafter the sequence for power on and power off.

VIRTIS POWER-ON		
Time	**Step**	**Check**
00.00.00	Switch ON Main or Redundant LCL of VIRTIS	
	Verify LCL power consumption	150 – 250 mA (TBC)
00.00.30	Start send time update to VIRTIS	
00.01.10	Verify reception of HK report "Default HK"	YVR00001 ME Def HK
	Verify SAFE mode is active	NVRD0001 ME Mode ME_SAFE; NVRD0002 H Mode=H_off NVRD0003 M Mode=M_off
Connection test		
00.02.10	ZVR0041 Connection Test Request	
00.02.20	Verify reception of connection test report	YVR00011 Connection Test Report

VIRTIS POWER-OFF		
Time	**Step**	**Check**
00.00.00	ZVR00037 VTC_EnterSafe	
00.00.30	Stop send time update to VIRTIS	
00.00.35	Switch OFF Main or Redundant LCL of VIRTIS	

5.3. FLIGHT OPERATIONS SEQUENCES

Basically no change. Nevertheless it has to be reviewed and reiterated specifically for Venus Express in some part.

6. DATA OPERATIONS HANDBOOK

See attachment 2.

7. ATTACHMENTS

7.0. ATTACHMENT 0

AD 01, RO-VIR-UM-001, Issue 3 Working copy, July 2003, VIRTIS Experiment User Manual (for Rosetta)

7.1. ATTACHMENT 1

Mechanical Interface Control Drawings

ASSEMBLY DRAWINGS

a.	OPTICS MODULE Assembly Drawing	AD 28030C17958A	Issue 2	5 sheets
b.	ME Assembly Drawing	VVX-KAY-DR-001	Issue 1	2 sheets
c.	PEM-M Assembly Drawing	AD 12030C17959B	Issue 0	1 sheet
d.	PEM-H Assembly Drawing	512.2-0001	Issue D	1 sheet

INTERFACE CONTROL DRAWINGS

e.	OPTICS MODULE ICD	DF000004160003	Issue 0	3 sheets
b.	VIRTIS ME ICD	VVX-KAY-DR-001	Issue 1	1 sheets
f.	VIRTIS PEM-M ICD	DF 12079C17959B	Issue 0	1 sheet
d.	PEM-H Assembly Drawing	512.2-0001	Issue D	1 sheet

7.2. ATTACHMENT 2

AD 04, VVX-GAF-IC-003 Issue 4, 12/07/2004, VIRTIS OBDH ICD

7.3. ATTACHMENT 3

AD 05, VVX-DLR-MA-001 Issue 3 rev 1, 06/07/2004, VIRTIS On Board Software User Manual for S/W PROM version 2.0.1 and EEPROM version 2.40

7.4. ATTACHMENT 4

None, N/A for Venus Express

7.5. ATTACHMENT 5

AD 03, VVX-GAF-UR-001, Issue 1, December 2003, VIRTIS S/W User Req.

7.6. ATTACHMENT 6

AD 02, VVX-GAF-IC-002, Issue 1, December 2003, VIRTIS S/W Internal ICD

ATTACHMENT 0

AD 01, RO-VIR-UM-001, Issue 3 Working copy, July 2003, VIRTIS Experiment User Manual (for Rosetta)

(it is also within the FM ADP)

ATTACHMENT 1

Mechanical Interface Control Drawings

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(ICD is also within the FM ADP)

ATTACHMENT 2

AD 04, VVX-GAF-IC-003 Issue 4, 12/07/2004, VIRTIS OBDH ICD

(it is also within the FM ADP)

ATTACHMENT 3

AD 05, VVX-DLR-MA-001 Issue 3 rev 1, 06/07/2004, VIRTIS On Board Software User Manual for S/W PROM version 2.0.1 and EEPROM version 2.40

(it is also within the FM ADP)

ATTACHMENT 4

None, N/A for Venus Express

ATTACHMENT 5

AD 03, VVX-GAF-UR-001, Issue 1, December 2003, VIRTIS S/W User Req.

(it is also within the FM ADP)

ATTACHMENT 6

AD 02, VVX-GAF-IC-002, Issue 1, December 2003, VIRTIS S/W Internal ICD

(it is also within the FM ADP)